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Editors

The Vision Zero Handbook

Theory, Technology and Management for a Zero Casualty Policy

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Theory, Technology and Management for a Zero Casualty Policy

With 219 Figures and 62 Tables

Springer

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Preface

Globally, about 1.3 million people die every year in road traffic crashes and about 50 million are injured. For long, the death toll on roads was considered to be a necessary price that we have to pay for our mobility and development. But beginning in the late 1990s, an alternative approach to road safety has become more and more influential. The Vision Zero movement declares that every severe crash in road traffic is an avoidable failure and that no other goal is satisfactory than zero fatalities and serious injuries. This is by no means a new idea. Similar views have been expressed in many other areas of safety management. Safety work based on the idea that every accident is one too much can be found in workplace safety, fire safety, aviation, suicide prevention, patient safety, infection control, and many other areas. Zero goals are also gaining traction in environmental protection and sustainable development work. Terms such as zero waste, zero emissions, zero carbon, and zero poverty have become increasingly important in climate and environmental policies.

Detractors claim that Vision Zero is too stringent and therefore also unrealistic. But practical experience has shown again and again that the Vision Zero approach can efficiently reduce the number of deaths and serious injuries. Of course, it is not enough to set up Vision Zero as a goal. Its effects materialize when it is systematically applied, and every serious accident is treated as a failure that must not be repeated.

This handbook is the first comprehensive collection of knowledge and experience of Vision Zero. Its contributing authors are experts from all around the world, representing a wide range of academic disciplines and an equally wide range of specializations in practical safety management. The handbook is divided into five main parts. The *first part* discusses Vision Zero from several theoretical perspectives, relating it to other road safety targets, to other principles of safety management, to other forms of policy-making, and to ethical issues such as responsibility and paternalism. It also contains a chapter that scrutinizes the most common arguments against Vision Zero. The *second part* provides a broad overview of the worldwide adoption of Vision Zero in road traffic. It contains chapters on Vision Zero in Sweden, Norway, the Netherlands, Germany, Poland, Lithuania, Australia, Canada, the United States, and India, as well as chapters on its impact in international cooperation. The *third part* discusses Vision Zero from a managerial point of view, providing perspectives from road managers, vehicle manufacturers, and consumers. The *fourth part* introduces tools and technologies for Vision Zero in road traffic. It includes chapters on road safety analysis, road design, speed control, driver distraction, and automated vehicles. Finally, the *fifth part* puts focus on the application of Vision Zero in other areas than road traffic. It contains chapters devoted to Vision Zero in workplace safety, fire safety, suicide prevention, disease eradication, and waste management.

We hope that this handbook will inspire further developments, innovations, and decisions that contribute to eliminating human suffering. Safety is achievable, but it requires commitment, knowledge, and careful planning.

Stockholm, Sweden — Karin Edvardsson Björnberg
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Geneva, Switzerland — Matts-Åke Belin
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November 2022

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He is a leading researcher in the philosophy of risk and safety. He is also active in other areas of philosophy, in particular the philosophy of science and technology, decision theory, logic, and moral and political philosophy. He is editor-in-chief of *Theoria* and of the two book series *Outstanding Contributions to Logic* and *Philosophy, Technology, and Society*. He is a member of the Royal Swedish Academy of Engineering Sciences and past president of the Society for Philosophy and Technology. Hansson has published 17 books and about 400 papers in refereed international journals and books. His books include *The Ethics of Risk* (2013), *The Ethics of Technology: Methods and Approaches* (edited, 2017), and *Responsibility for Health* (2022).

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Part I

Ideas and Principles

Vision Zero and Other Road Safety Targets

1

Karin Edvardsson Björnberg

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Abstract

Every year, around 1.3 million people are killed on the road and another 20–50 million are severely injured. This makes road safety one of the most critical global public health issues. To address the negative trend, the international community has responded with the adoption of road safety targets. Sustainable Development Goals 3.6 and 11.2 are two examples. Also at the national level, goals and targets are increasingly used to steer work towards improved road safety. The frequent use of goals and targets in road safety policy makes it interesting to investigate

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under what conditions the adopted goals can be expected to be achieved. This chapter summarizes the main themes and conclusions of research that have been conducted on goal-setting in road safety policy and management to date. Drawing on previous research, it outlines and discusses a set of criteria that road safety goals should meet in order to be achievement-inducing, that is, have the capacity to guide and induce efforts towards the vision of zero fatalities and serious injuries on the road.

Keywords

Vision Zero · Goal-Setting · Management by Objectives · Rationality · Precision · Evaluability · Approachability · Motivity

Introduction

Every year, around 1.3 million people are killed on the road, and another 20–50 million are severely injured (WHO 2018). Data from the World Health Organization (WHO) show that around 90% of the fatalities occur in middle- and low-income countries. Approximately half of those killed are vulnerable road users, including pedestrians, cyclists and motorcyclists, children, and elderly people. At present, road traffic accidents are the dominant cause of death among people aged 5–29 years, and they are expected to be the seventh leading cause of death in 2030. Thus, road safety is one of the most critical global public health issues to date. In order to stabilize and then reverse the negative trend, the international community has responded with the adoption of road safety targets aimed at reducing the number of killed and seriously injured people on the road. In March 2010, the United Nations (UN) General Assembly proclaimed the period 2011–2020 as the "Decade of Action for Road Safety" (United Nations 2010). Since 2015, the UN member states have been bound by the Sustainable Development Goals (SDGs), which include the goal to halve the number of global deaths and injuries from road traffic accidents by 2020 (SDG 3.6; see also SDG 11.2). In November 2017, the UN agreed on a subset of global road safety targets designed to advance current efforts toward the 2020 goal (https://etsc.eu/un-agrees-on-road-safety-sub-targets-to-aid-progress-on-2020-sustainable-development-goals/. Accessed 20.01.2020). As noted by the Organization for Economic Co-operation and Development (OECD) and the International Transport Forum (ITF), this is the "strongest ever mandate for action on road safety" (ITF 2016, p. 17). Road safety targets have also been adopted at the national and city/state levels in Sweden (Tingvall and Haworth 1999; Johansson 2009; Belin et al. 2012; McAndrews 2013), Norway (Elvik 2008), the Netherlands (Wesemann et al. 2010), Australia (Corben et al. 2010), the United States (Cushing et al. 2016; Evenson et al. 2018; NYC 2018), the European Union (EU) (European Commission 2011; Tolón-Becerra et al. 2014), and many other countries (see Part 2 of this handbook).

The frequent use of goals and targets in road safety policy and management makes it interesting to investigate under what conditions the adopted goals and targets can be expected to be achieved. The preconditions for successful management by objectives (MBO) in the public sector have been studied extensively. As a result, an array of factors leading to inadequate goal fulfilment have been identified, including insufficiently operational goals and targets (Elvik 1993; Edvardsson and Hansson 2005) and insufficiently calibrated goal evaluation methodologies (Larsson and Hanberger 2016), gaming behavior (Smith 1995; Propper and Wilson 2003; Bevan and Hood 2006), and lack of adequate communication channels between different governance or administrative levels responsible for implementing such goals (Wibeck et al. 2006). Much of this literature has addressed other policy areas apart from transportation and road safety, such as environmental and climate policy (Lundqvist 2004; Edvardsson Björnberg 2009, 2013) or public health in a broader sense (Lager et al. 2007; Smith and Busse 2010). However, exceptions exist. As early as 1993, Elvik addressed the question of what criteria road safety targets must satisfy in order to better guide the rational choice of means (1993). A decade later, Rosencrantz et al. (2007) used a set of criteria, which resembled the politically more established SMART criteria, to analyze the rationality of the Swedish Vision Zero for traffic safety. Drawing on the literature in the field, Elvik (2008) identified seven conditions for successful road safety MBO, some of which concerned the goals themselves ("challenging, yet in principle achievable," "there should not be too many targets in view of the available policy instruments designed to realize them," etc.) while others concerned the policy context in which the goals were to be implemented ("responsible agencies should be supplied with sufficient funding to implement all cost-effective road safety measures," "incentives should exist to ensure commitment to targets from all agencies responsible for realizing them," etc.) (Elvik 2008, p. 1116). Sobis and Okouma (2017) analyzed the use of MBO in transportation service for the disabled in the municipality of Gothenburg (Sweden). They identified two factors that contributed to its successful outcomes: that MBO was used in combination with other steering practices and the establishment of a new organizational culture that emphasized the importance of information exchange between politicians and civil servants regarding goal evaluation and achievement.

This chapter summarizes the main themes and conclusions of research that have been conducted on goal-setting in road safety policy and management to date. The primary focus of the chapter is on the rationality of the goals and targets themselves, rather than on the policy context in which the goals are to be implemented. Drawing on previously published research on rational goal-setting (Edvardsson and Hansson 2005; Rosencrantz et al. 2007; Edvardsson Björnberg 2016), the chapter aims to address the following research questions:

- What are the potential benefits of using goal-setting in road safety management?
- When is a road safety goal or target rational (functional), that is, what criteria must the goal fulfil in order to be operative?
- What is the ideal number of road safety goals within a system of goals?
- How should road safety goals and sub-goals be aligned?
- Why does a road safety goal have to be stable over time?
- Who should be involved in the road safety goal-setting process?

Before proceeding to the research questions, the next section presents a brief history of the development of road safety policy and the use of road safety goals and targets in the United Kingdom and the United States. In the following, the terms "goal," "target," and "objective"' will be used interchangeably.

A Brief History of Goal-Setting in Road Safety Management

The invention of the modern car is commonly attributed to the German engineer and designer Karl Benz. His *Benz Patent-Motorwagen*, for which he received a patent in 1886, is considered by many to be the first power vehicle using an internal combustion engine. In the early days of motorcar invention, only limited numbers of cars for each brand were produced and used on the roads, which meant the number of car accidents and fatalities was low (Accidents involving coaches and pedestrians were obviously a cause of concern even before the motorcar was invented, thus leading to the implementation of safety measures, such as prohibiting minors from being cart drivers (Gregersen 2016). In one tragic instance, Pierre Curie, husband of Marie Curie, was killed when he fell under a horse-drawn cart in Paris in 1906.). It was not until large-scale manufacturing was introduced in the early twentieth century that road traffic situations remotely similar to the present one arose. Among the early organizations that noticed the problem of road safety were the National Safety Council (NSC) in the United States and the London Safety First Council (known today as the Royal Society for the Prevention of Accidents, RoSPA) in the United Kingdom. The NSC was established in 1913 with the aim of promoting health and safety initially in the workplace until the organization eventually expanded its efforts to include road safety, among other things. The London Safety First Council was established in 1916 in connection with a meeting convened by the operating manager of the London General Omnibus to address the "alarming increase in traffic accidents, and the direct connection therewith of the restricted street lighting which had been necessitated by the War conditions" (www.rospa.com; Jackson 1995).

Much of the work carried out by the early road safety organizations targeted the behaviors of individual road users, to whom accidents were causally attributed. In line with this, it was agreed that the behavior of individual road users, particularly children and drivers, had to be modified to fit the current road transport system. Among the early road safety measures initiated by the RoSPA were educational campaigns and road safety competitions targeting school children and professional drivers, respectively (www.rospa.com). The "traditional" behaviorally oriented approach to road safety management became very influential in the early twentieth century and is still the predominant approach to road safety management in many countries (Johansson 2009; Belin et al. 2012). However, other types of road safety measures have also been implemented, including improvements in road infrastructure and vehicle design (Oster Jr and Strong 2013). For instance, electric red-green traffic lights were introduced in the United States in 1912–1914 (https://en.wikipedia.org/wiki/Traffic_light#History. Accessed 09 Jan 2020). In 1922, the London Safety First Council suggested improvements in street lighting and argued for the marking of road crossings frequently in use (www.rospa.com). The first seat belt patent in the United States was secured by Edward J. Claghorn in 1885, but it would take another 65 years before seat belts were made available in American-made cars. In Britain, vehicle braking requirements were introduced by the Motor Car Act 1903, and further requirements concerning the construction, weight, and equipment of cars were introduced by the Road Traffic Act 1930.

Therefore, the early road safety work was, to a significant degree, advocated for and implemented by voluntary organizations. Although national and federal state governments were involved in establishing laws on speed limits, vehicle registration, and driver licensing—notable examples were the British Locomotive Acts (1861–1878) and the New York drunk driving laws (1910)—it was not until much later, around 1930, that national and federal state governments started to organize their work with the pronounced aim to increase road safety (For more details on the specifics of these regulations, see The Locomotives on Highways Act 1861, The Locomotive Act 1865, and the Highways and Locomotives (Amendment) Act 1878. See also Motor Car Act 1903 and Road Traffic Act 1930.) A first step in this direction was taken in 1933 when the British Government decided to start investigating the causes of road accidents. In fact, the RoSPA had already put forward calls for accident causation analysis to the British Minister of Transport in as early as 1928.

In the decades that followed the Second World War, road safety work became increasingly systematic and institutionalized. Road safety policies and plans were developed, coordinated, and implemented by governmental agencies given a parliamentary or congressional mandate to improve road safety. In the United States, the Department of Transportation was created by the Congress in 1966 with the mission to "serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future." Four years later, in 1970, the NHTSA was established by the Highway Safety Act and was given the responsibility to reduce deaths, injuries, and economic losses resulting from motor vehicle accidents.

A crucial feature of the systematic and institutionalized approach to road safety policy was the introduction of quantified road safety targets. The idea of MBO had been developed by Peter F. Drucker in the 1950s as a way of managing business corporations (Drucker 1954) (In the academic literature, especially in the Nordic countries, the term "management by objectives and results" (MBOR) is frequently used (e.g., Lundqvist 2004; Steineke and Hedin 2008; Kristiansen 2015). "Performance management" is a related management philosophy (Ammons and Roenigk 2015).). The basic idea of MBO is that business corporations can be effectively and efficiently managed if work departures from and is evaluated against a set of objectives set by senior managers and then implemented by the employees. In the 1980s, MBO was gradually implemented in the public sector, where it subsequently became a central feature of the so-called new public management (NPM) (Hood 1991) (Kristiansen (2015) argues that the origins of MBO in the Nordic countries can be traced back to the 1960s, 1970s, or 1980s, depending on which aspect of MBO is accentuated. In Sweden, for example, MBO-related ideas were already discussed in the 1960s in relation to budget reforms, although a comprehensive MBO reform was not launched until the 1980s (Sundström 2006).). In a public sector context, MBO typically encompasses a mixture of political control and administrative autonomy and discretion (Christensen and Laegreid 2001; Lundqvist 2004; Sundström 2006):

- Policy goals are adopted by politicians, while the responsibility for implementing them lies with the subordinate bodies. The implementing agencies enjoy a considerable degree of discretion in deciding on which measures to take to achieve the goals.
- Progress toward goal achievement is monitored, measured, and reported back to the politicians on a regular basis.
- The politicians are responsible for making policy adjustments and strategic decisions based on the reported results, for instance, on resource allocation (MBO systems typically reward agencies whose results are satisfactory and, conversely, punish agencies with insufficient goal achievement; however, this is not a pronounced feature of MBO in, for example, the Swedish public sector, where failure to achieve a policy goal is often regarded as a reason for adding funds (Steineke and Hedin 2008).

Thus, translated into a road safety policy context, MBO essentially means that road safety goals are formulated by the politicians, while the responsibility for implementation, evaluation, and feedback is delegated to another government body, in many cases the national or state road transport administration. The underlying rationale for governing by objectives rather than by rules or direct instructions is efficiency, both in economic terms and based on the belief that the administration knows how to best effectuate the intentions of the politicians.

It is obviously difficult to locate the exact point in time when a national government first quantified road safety targets. Nevertheless, the Lalonde Report, published by the Canadian Minister of National Health and Welfare in 1974, is sometimes identified as a milestone in this development (Belin et al. 2010). In the Lalonde Report, setting quantitative public health targets was introduced as a means of stimulating and coordinating governmental efforts toward reduced mortality and morbidity. The goal-setting strategy set out in the report was later taken up by the World Health Organization (WHO) and put to use by national public health authorities, which began to adopt quantified road safety targets (OECD/ITF 2016). Sweden was one of the early adopters, with quantified road safety targets being discussed as early as 1972 and eventually decided by the Parliament in 1982 (Belin et al. 2010).

Why Use Quantified Goals in Road Safety Management?

As noted above, early road safety work was not policy-driven but largely uncoordinated and implemented by different actors in an ad hoc fashion. Measures were certainly introduced with a clear goal in mind, namely, to reduce the number of deaths and injuries caused by road accidents. However, these measures were typically not part of a strategy or plan adopted with the aim of coordinating actions across time or among agents. Nevertheless, in many respects, the road safety measures introduced in the early days of widespread automobile use were successful in saving lives and averting harm. This brings forward the question of why road safety goals and targets had to be introduced at all. More generally, what are the potential benefits of introducing goal-setting as a management tool in road safety work?

Goals are typically set because the individual or organization (henceforth "agent") who sets the goal wants to achieve the state of affair referred to in the goal and because they believe that it becomes easier to achieve the desired states of affairs by setting the goal. Edvardsson and Hansson (2005) use the term "achievement-inducing" to denote those goals that contribute to their own achievement, i.e., goals that are rational (functional, or operative). There are two ways by which goals can be achievement-inducing. First, an adopted goal can be used to plan and coordinate action toward goal achievement over time and between agents. With the help of a goal, a road safety organization can plan and allocate work tasks to different departments or administrative units while ensuring that everyone knows what to do, when to do it, and how what is being done fits into what other departments or units are doing. For instance, a goal such as Vision Zero for road safety can be used to guide the selection of strategies or the adoption of goals and targets further down in the administrative chain (Tingvall and Haworth 1999). Moreover, an adopted goal can be used to induce and sustain action among the organization's employees. It may invigorate the commitment of the organization and its employees to road safety. Thus, Wong et al. (2006) argue that the role of road safety targets is "to provide a basis for motivating and monitoring actions to reduce death and injury in road traffic crashes" (p. 997).

Past studies have provided considerable empirical evidence to support the idea that goal-setting can have a positive effect on an individual's performance and, hence, be conducive to goal achievement (Locke and Latham 1990, 2002). Goals that are specific and challenging have, for instance, been shown to affect an individual employee's choices, efforts, and persistence in such a way that goal achievement is furthered (Latham et al. 2008). Although significantly less empirical evidence exists on public policy goals and how they affect organizational output (Jung 2014), studies suggest that the positive relationship between goal-setting and goal achievement may also hold true in this case. Elvik (1993) analyzed how road safety performance differed among Norwegian counties during the years 1982–1985 and 1986–1989 based on whether quantitative or qualitative road safety targets had been adopted. He showed that quantified road safety targets were more successful than qualitative targets in reducing the accident rate per kilometer; moreover, "the best performance was achieved by counties with highly ambitious quantified targets" (p. 569). Wong et al. (2006) investigated the association between goal-setting and road safety improvement during the period 1981–1999. In their study, they investigated 14 countries that had adopted road safety management targets and examined the road fatalities before and after the setting of the target in each country. The results showed that there was a significant overall reduction in road fatalities after quantified road safety targets had been adopted. On the basis of these findings, the authors argued that road safety goal-setting "helps to raise concern about road safety in societies, encourages decision-makers to formulate effective road safety strategies, and ensures that sufficient resources are allocated to road safety programs" (p. 1004) (The results were later updated by Allsop, Sze, and Wong (2011), who made some changes in the numerical estimates used. However, to the author's understanding and as pointed out by the authors of the 2011 publication, the changes did not alter the main argument of the previous paper.). In line with these studies, the ITF (2008) concluded that countries that have adopted quantitative road safety targets do better than countries with no such targets.

However, governance based on goals and targets also has some potential drawbacks. Bevan and Hood (2006) identified several ways in which public MBO systems (in their case, public health service targets) can be vulnerable to gaming. Among other things, they discussed the practice, common among public agencies, to adopt goals based on what has been achieved recently. However, this practice has an unfortunate consequence: managers and politicians who expect to gain a renewed term of office tend not to exceed adopted goals even if they could, as that would put greater expectations on their future performance. It remains unclear to what extent Bevan and Hood's (2006) findings can be translated into a road safety management context. Their analysis focused on the English public health service, which at the time of writing was managed through a system combining goals and targets with awards and punishments for (in)sufficient goal achievement. Such awards and punishments are not used in Swedish road safety work, to take one example; hence, the risk of gaming is arguably smaller. However, it is important to keep in mind that gaming could potentially occur in any MBO system depending on how it is set up, specifically on whether it grants awards and dispenses punishments based on performance outcomes.

When Is a Road Safety Target Rational?

Goals, therefore, have an important role in directing and motivating action, over time and among agents. However, to fulfil this action-guiding and action-motivating role, the goals must satisfy certain criteria. In the management and psychology literature, those criteria are often referred to as the "SMART criteria," according to which goals should be specific, measurable, attainable, relevant, and time-bound. (See Rubin (2002) for an elaboration of what the SMART acronym stands for.) Edvardsson and Hansson (2005) proposed a set of rationality criteria that are similar to the SMART criteria. They argued that goals should be precise, evaluable, approachable, and motivational. Other criteria are also conceivable. Edvardsson Björnberg (2016) examined the extent to which it is considered rationally justified for goals to be stable over time. Rosencrantz (2008) and Edvardsson Björnberg (2009) suggested that additional criteria, such as consistency, comprehensiveness, and non-redundancy, may apply to systems of goals. Elvik (1993) identified two sets of requirements that a target must satisfy to serve as a basis for the rational choice of means. The first concerns the relationship between the target and the values or preferences that the target expresses. The target should be "operational," which means that the underlying preferences should satisfy the requirements of transitivity and completeness. The second set of requirements concerns the relationship between the target and the state of affairs to which the target refers. Elvik (1993) identified three such requirements: (1) the targets should not be self-contradictory, by which he means that they should not be "formulated in a way that makes their fulfillment logically impossible" (cf. Hansson et al. (2016) on self-defeating goals); (2) they should not be tautologically fulfilled, i.e., "formulated in a way that will make any outcome fulfill the target"; and (3) they should refer to "targetable" outcomes, i.e., "not to outcomes that are essentially by-products" (p. 570).

Whether or not a goal will have the capacity to guide and motivate action does not only depend on the characteristics of the goal itself, such as precision or measurability. The context in which the goal is set and the process of setting such a goal could also determine how effective it will be in regulating action. This appears to be the case not the least in a road safety management context. Elvik (2008) identified seven conditions for successful road safety MBO, some of which concern the goals and targets themselves, while others relate to the policy context in which they are to be implemented. Among the contextual factors identified by Elvik are endorsement of the goals by the top management (e.g., politicians, ministries of transport, road safety authorities), availability of funding sufficient for implementing the goals, and the establishment of a system for monitoring progress and providing feedback to the responsible agencies, among others.

Below, the two categories of rationality criteria—for individual goals and systems of goals—will be discussed separately before proceeding to the contextual conditions.

Precision

A goal can guide action only when the implementing agent knows what the state of affairs referred to by the goal is and to what extent the actions undertaken bring him/her closer to those state of affairs. This requires that the goal is both precise and possible to evaluate. Edvardsson and Hansson (2005) argued that, of these two criteria, precision is more fundamental, because evaluability presupposes that the desired state of affairs referred to by the goals is reasonably clear. The criterion of precision can be divided into at least three subcategories. Edvardsson and Hansson (2005) distinguished between directional, completive, and temporal precision, where directional and completive precision correspond to the SMART criterion of specificity and temporal precision to the criterion that a goal should be "time-bound." Directional precision means that the goal specifies in what direction the implementing agent should go in order to reach the goal. Consider the following example:

1. There should be a decrease in the number of people killed on the road.
   Assuming that the number of fatalities can be determined in a reasonably authoritative way from 1 year to another, the goal can be said to have directional precision. However, the goal does not tell the agent to what degree the goal should be achieved. Thus, it lacks completive precision. Consider instead the following goal:
2. Nobody should be killed in the road traffic system.
   This goal has both directional precision (decrease in the number of fatalities) and completive precision (nobody). However, it lacks temporal precision, because it does not tell the agent within what time period the goal should be achieved. The following goal has directional, completive, and temporal precision:
3. The number of people killed on the roads should be decreased by 5% annually between 2020 and 2030.

Similar distinctions between different forms of goal precision have been made by other authors.

Elvik (1993) distinguished between "open targets," "semi-open targets," and "closed targets." Open targets are qualitative and are not specified to any degree or time. They correspond to Edvardsson and Hansson's (2005) directionally precise targets. Semi-closed targets are either quantified in time or have a quantified level component. They correspond to Edvardsson and Hansson's (2005) temporally and completely precise targets. Finally, closed targets have both temporal and completive precision.

Imprecise goals, or "goal ambiguity," refer to a fairly common phenomenon in public organizations (Chun and Rainey 2005; Rainey 2014). (See Chun and Rainey (2005, p. 2) for a definition of "organizational goal ambiguity.") Carrigan (2018) identified a number of reasons behind the relative proliferation of ambiguous goals in public policy. Public policy goals are typically the result of political compromise. In political contexts, keeping a goal vague is advantageous, because one may more easily gain broad support for it than if it is specified in greater detail. From a political point of view, it may be more expedient to propose a vague goal on the basis of which political unity can be sought and then work out the details at a later point when a reasonable degree of consensus surrounding the importance of the issue has been achieved. Thus, Chun and Rainey (2005) concluded that "goal clarification is often considered 'managerially sound' but 'politically irrational' in the public sector" (p. 23). Moreover, goals can be specified as part of the implementation process. Sometimes, adopting a goal and working out the details are more efficient, especially after accumulating knowledge about the policy issue and how it can be addressed. Many implementation issues can be difficult to foresee; therefore, it may be more efficient to allow the implementing agencies to specify precisely what to achieve (cf. Lindblom 1959). Finally, politicians may find it helpful to keep goals imprecise, as policy pronouncements in the form of clearly stated goals are often used as benchmarks against which performance is measured and votes are driven.

Organizational goal ambiguity has been considered problematic in the goal-setting literature. Imprecise goals are obviously more difficult to follow up and evaluate, and it may be more difficult for a group of agents working together toward the goals to organize their activities if the goals are imprecise and the agents lack the necessary background knowledge to coordinate their efforts efficiently. Imprecise goals may also decrease organizational commitment. Thus, Jung and Ritz (2014) argue that an ambiguous goal could “make it difficult for public employees clearly and effectively to determine how much and what kinds of effort they should make for the organization and the attainment of organizational goals, or in which direction to give effort and how to make task plans” (p. 467). (See Jung and Rainey (2011) for a discussion of the relationship between goal precision and government employee motivation.)

How precise a goal needs to be in order to have the capacity to guide action typically varies depending on the social context and the implementing agents’ background knowledge. Psychological studies have shown that for individuals, precise goals are typically more conducive to goal achievement than “do-your-best” goals; however, there are exceptions (Locke and Latham 2002). When the implementing agent is in a learning process and does not yet have sufficient knowledge to work toward an outcome-oriented goal, it may be better to set “do-your-best” outcome goals and then supplement them with specific learning goals. In those situations, specific high-performance outcome goals can be detrimental to goal achievement, as they can detract the agent from the search for an appropriate strategy. Consequently, Latham et al. (2008) concluded that “when effective behavioral routines have yet to be developed, a specific high learning goal rather than a performance one should be set” (p. 390). These findings may have some bearing on the issue of goal-setting in road safety management. Arguably, in countries and organizations with little previous knowledge about road safety management and where those responsible for implementing the targets are in a learning process, it could be more effective to adopt specific high learning goals (related to road safety management) rather than some specific performance outcome goal.

Evaluability

While precision concerns the goal (desired end-state) itself, evaluability concerns the agent’s actions and their effects on goal achievement. In this sense, precision is a more fundamental criterion, because evaluability depends on it. Goal-setting theory assumes that goals regulate performance more reliably when work is evaluated and information about how far one has come in relation to the goal is fed back to the goal-setter and/or implementer. Feedback and feedback mechanisms operate on different levels (Edvardsson and Hansson 2005). First, an agent or group of agents who are given information about where they stand in relation to the goal can more easily adjust their actions so as to further goal achievement more effectively. Second, such information can also be used to revise the goal itself. In many situations, it is difficult to know in advance whether or not a certain goal, for example, a road safety management target, is reasonably ambitious (see below). In such cases, information from evaluations may be necessary to adjust the level of goal difficulty. Third, adopting goals that are both precise and possible to evaluate is a prerequisite for establishing accountability for insufficient goal achievement. (Hence, for the incentive for political decision-makers to adopt vague goals that are difficult to evaluate, see above.) Finally, goals that are evaluable and evaluated could have a motivating function; see below.

Successful goal evaluation presupposes both that the goal itself (the desired end state) is clear and that it is possible to assess the degrees of goal achievement. In some situations, one and the same goal can be evaluated on the basis of more than one parameter. This is, for instance, the case with the Swedish Vision Zero for road traffic safety. The Swedish Vision Zero states that nobody should be killed or seriously injured on the road. One could imagine a situation wherein there is a decrease in the number of killed people while the number of seriously injured people is increasing at the same time, or vice versa. It is not entirely clear how such a mixed result should be interpreted in terms of actual goal achievement (Rosencrantz et al. 2007).

Approachability

In goal-setting theory, it is commonly argued that goals ought to be realistic in the sense that it should be possible to at least approach them to a meaningful degree (Edvardsson and Hansson 2005). Locke and Latham (1990, 2002), for instance, provide empirical support for the so-called high performance cycle, that is, the idea that better goal achievement can be reached when the goals are precise and challenging yet not excessively difficult to achieve (see also Latham and Locke 2007). Elvik (1993) followed this line of argument when he stated that road safety management targets should be “challenging, yet in principle achievable” (p. 1116) and that “any quantified target is a compromise between idealism and realism” (p. 579).

Formulating challenging but sufficiently realistic goals is not an easy task, especially not in the public sector wherein goal achievement is dependent on many different factors. This is also the case for road safety management targets. Setting “optimally challenging” road safety targets presupposes that the goal-setter has some knowledge about what social developments affecting transportation and traffic safety can be envisaged during the period between goal-setting and projected goal achievement, what (if any) road safety management measures will likely be introduced during the indicated time period (what measures are politically and economically feasible), and how effective the introduced measures will be in furthering goal achievement (Wesemann et al. 2010; see also Corben et al. 2010).

A common argument against Vision Zero for road traffic safety is that it is an unrealistic goal, because we will never be able to achieve zero fatalities and serious injuries in road traffic (e.g., Long 2012). This argument is analyzed by Abebe et al. 2021, Edvardsson Björnberg, and Hansson (▶ Chap. 3, “Arguments Against Vision Zero: A Literature Review” of this handbook). As noted there, several counter-arguments could be made against this way of reasoning. It could be argued that, when it comes to saving lives and avoiding serious injuries, no goal above zero should be considered ethically permissible. The Swedish Vision Zero for road safety policy is premised on the ethical assumption that it is unacceptable for people to be killed or seriously injured in the road transport system (Elvebakk 2007). Thus, Belin et al. (2012) argued that, “politically and humanly speaking, it was difficult to stipulate any other long-term goal” (p. 173). Trying to figure out what constitutes an optimal target level in terms of the number of killed and seriously injured people simply does not seem like a morally acceptable approach. Rosencrantz et al. (2007) drew parallels on how goals are set in workplace health and safety. Although few would deny that compromises between costs and workplace safety are unavoidable, government agencies are seldom (if ever) instructed to find out what constitutes an economically optimal level of fatal workplace accidents. Instead, it is assumed that a serious workplace accident should always be regarded as a failure.

Moreover, it is worth noting that many important political goals, such as liberty, social justice, or sustainable development, are highly idealistic in the sense that they concern end states that cannot be achieved once and for all but will have to be fought for indefinitely (Rosencrantz et al. 2007). This has not prevented political leaders and movements from formulating and using them as goals. Tingvall and Haworth (1999) appear to follow this line of reasoning when they write that zero (as in Vision Zero) is not a target to be achieved by a certain date. As noted by Kerr and LePelley (2013), highly ambitious goals, sometimes referred to as “stretch goals,” have also been adopted in business organizations in order to stimulate creativity and “out-of-the-box thinking” among the organization’s employees (see also Sitkin et al. 2011).

Motivity

A goal can be achievement-inducing not only by virtue of its action-guiding capacity; it can also facilitate goal achievement by motivating the agent to work toward the goal. The action-motivating function of goals is central to goal achievement. Merely knowing what has to be done to reach the goal is not sufficient for it to be achieved; the agent(s) responsible for working toward the goal must also want, or be motivated, to do so.

Arguably, inducement to take measures toward goal achievement could come from sources other than the goal itself (Edvardsson and Hansson 2005). For example, government agencies are often bound by legal rules prescribing that certain measures be taken, in which case the agencies and their employees have little choice but to follow the rules. Inducement to take measures that facilitate goal achievement could also arise if the organization and its employees stand to gain financially or in some other way from efforts taken to reach the goal. Moreover, leadership style and the process through which goals are adopted within an organization can have an impact on the employees’ motivation and willingness to work toward set goals (Bronkhorst et al. 2015; see below). Although these are important factors significantly affecting motivation within organizations and among employees, it is possible that such motivation could also be generated from the goal itself.

What makes a goal motivating is, of course, largely due to its content. Vision Zero for road traffic safety is motivating because many people perceive its end state to be desirable or worth striving for. However, psychological studies confirm that the motivating capacity of a goal can also come from other aspects of the goal than its end state. Locke and Latham (1990, 2002), among others, have showed that the motivating capacity of a goal is tightly linked to the other goal criteria discussed above, that is, it largely depends on how well the goal satisfies the criteria of precision, evaluability, and achievability. For instance, some studies have shown that many agents' goals that are precise and challenging exert a higher degree of motivation (both in terms of intensity and durability) than, for example, do-your-best goals (Locke and Latham 1990, 2002; Wright 2004). Studies have also presented evidence suggesting that goals that are evaluable and evaluated have a positive effect on performance, which is believed to originate from the motivational effect experienced by individuals as they are able to determine where they stand in relation to the goal (Locke and Latham 1990, 2002).

Assuming that a goal's motivating capacity is a function of how well it satisfies the other rationality criteria, it could be questioned whether motivity should really be considered an independent goal criterion. For a goal to be motivating, it would then suffice to ensure that it is sufficiently precise, evaluable, and possible to achieve to a satisfactory degree. However, some academic scholars have argued that there could be additional dimensions of goal motivity that are not adequately captured by the other criteria. Nutt and Backoff (1997), for example, discuss what makes a corporate or organizational vision motivating. Their argument is also relevant for organizational goals. In the authors' view, the degree of motivation exerted by a vision partly depends on its articulation. Here, articulation is understood in broader terms than precision. By formulating a vision through expressive images that directly "crystallize in people's mind what is wanted," a shared understanding of an organization's direction can be promoted among its employees (Nutt and Backoff 1997, p. 314).

Vision Zero for road traffic safety (i.e., nobody should be killed or seriously injured on the road) has the advantage of being both precise in the sense discussed in previous sections and formulated through an expressive image, as elaborated by Nutt and Backoff (1997). (See Rosencrantz et al. (2007) for a more extensive analysis of the precision of the Swedish Vision Zero.) The term "zero" is used here to communicate the message that it can never be ethically acceptable that people are killed or seriously injured in the road transport system (Tingvall and Haworth 1999).

To see how the criterion of motivity could encompass additional dimensions than goal precision, consider the following two goals:

1. In 2020, Sweden should have the lowest number of road traffic fatalities and serious injuries within the EU.
2. Sweden should decrease the number of road traffic fatalities and serious injuries to 15% between 2015 and 2020.

Given that adequate accident data are available, both goals could be said to be precise. However, goal 1 might in addition have the advantage of being slightly more motivating, assuming that the competitive feature of the goal (being ranked at the top of the EU nation list) has this effect. Empirical studies are obviously needed to confirm this. However, the example serves to illustrate that there could be more to the criterion of motivity than what can be captured by the criteria of precision, evaluability, and approachability.

Balancing the Criteria

In summary, a goal can be achievement-inducing (rational, functional, or operative) by virtue of being action-guiding or action-motivating, or both. Edvardsson and Hansson (2005) argued that improved satisfaction of each of the four criteria, namely, precision, evaluability, approachability, and motivity, ceteris paribus makes the goal function better in the achievement-inducing sense. However, conflicts between the criteria could occur. The criteria that make a goal action-guiding could, for instance, make it less motivating and vice versa. Edvardsson and Hansson (2005) provided some examples of such conflicts. Although they will not be repeated here, the main message is that the four criteria need to be balanced from case to case in order to optimize the achievement-inducing function of the goal. Factors beyond the goal itself, such as the implementing agent's background knowledge, will determine the extent to which the four criteria need to be satisfied in each individual case to further goal achievement.

One way of balancing the action-guiding and action-motivating properties of a goal is to adopt goal systems in which some goals primarily motivate action, while others guide action. As an example, in the case of the Swedish Vision Zero, the Swedish Parliament has adopted an overarching, assumingly motivating, vision—"Vision Zero"—that is operationalized through a more precise interim target: "In 2020, no more than 220 people shall die and 4,100 people shall be seriously injured on the Swedish roads."

Rationality Criteria for Systems of Goals

Public policy goals are seldom adopted in isolation but are parts of a system of goals addressing a certain policy problem or issue. One such goal system is the Swedish system of transport policy objectives. It consists of a general transport policy objective ("To ensure the economic efficiency and long-term sustainability of transport provision for citizens and enterprise throughout Sweden") that is operationalized into a "functional objective" and an "impact objective," which, in turn, are specified through time-bound interim targets (Government Offices of Sweden 2016, p. 6) (The *functional objective* states that "The design, function and utilisation of the transport system are to provide everyone with a basic level of accessibility of good quality and usability and to contribute to the development potential of the entire country. The transport system is to be gender equal, meaning it is to meet the transport needs of women and men in an equivalent manner." The *impact objective* states that "The design, function and utilization of the transport system are to be adapted in such a way that no one is killed or seriously injured and further the achievement of the overarching generational goal for the environment and environmental quality objectives and contribute to improving human health.").

Another example is the UN's SDGs, which consist of 17 broad goals and 169 targets to be achieved by 2020. For systems of goals, such as the Swedish transport policy objectives and the SDGs, additional rationality criteria to those discussed above may apply. Below, three such criteria will be discussed: completeness, number of targets, and consistency.

Completeness

In public policy goal systems, goals on a higher administrative level are often operationalized or broken down into sets of sub-goals on a lower level. The question then arises: How should the goals and targets in the system be aligned? A commonly defended idea is that the goals and targets should be aligned such that the higher goal is achieved or at least approached to a significant degree if all targets on a lower level are reached. This requires that the targets, taken together, are complete in the sense that they capture the most salient aspects of the overarching goal. If this does not hold, achieving the targets may give the impression that work toward the desired end state is progressing, while the opposite is true in reality. (See Tingvall et al. (2010) for a similar discussion of the relationship between road traffic safety performance indicators (SPIs) and the overarching goal of creating a safe road transport system.)

The adequate operationalization of an overarching goal requires that the operationalizing agents possess a good understanding of what causes the policy issue, or problem, and how it can be addressed, among other things. For example, the operationalization of the overall goal of road safety (i.e., to avoid fatalities and serious injuries in road traffic) presupposes that one knows who is involved in those accidents and what factors contribute to causing harm to the people involved. Mononen and Leviäkangas (2016) pointed out that one serious shortcoming in road safety work globally is that, although half of all deaths that occur in road traffic are suffered by vulnerable road users, mainly pedestrians and cyclists, very few road safety goals target those groups. Instead, the adopted goals emphasize in-vehicle safety, among others, which primarily affects driver and passenger safety.

When the overarching goals are qualitative, additional problems may arise in the process of goal operationalization. Qualitative goals, such as "maintaining a flourishing flora and fauna" or "providing a high-class education to everyone," are often operationalized through precise and more easily evaluable quantitative targets. In those situations, goal displacement may occur. This happens when the goal-setting and implementing agencies lose sight of the overarching goal and instead treat the quantitative targets as if they were the "ultimate" goals (Bohte and Meier 2000). Goal displacement has at least two unfortunate implications. Unless the quantitative targets are complete in the sense that they can be said to cover the most central aspects of the qualitative goal, achievement of the subordinate targets does not represent achievement of the overarching goal. Moreover, focusing on the quantitative aspects of a policy problem could conceal its political nature and make it appear as if the problem is strictly technical in nature (Cortner 2000). Framing a policy problem as predominantly "political" versus "technical" has consequences for whom is expected and allowed to participate in the efforts to solve the problem.

Admittedly, goal displacement may not be a serious problem in road safety policy, as many road safety targets are of a quantitative kind, even when adopted on an overarching level, as in the case of the Swedish Vision Zero. However, the problem of goal displacement could hypothetically occur if qualitative road safety goals are formulated and operationalized through quantitative sub-goals or targets.

The Number of Targets

One way of ensuring that all aspects of the overarching goal are adequately operationalized is to adopt as many targets as possible, with each target representing some aspect of the overarching goal. Thus, the requirement of completeness appears to favor goal systems consisting of a large number of sub-goals or targets. However, such goal systems have also been criticized, thus raising the question of whether there is a limit to how many goals a goal system should contain to function well in an achievement-inducing sense.

The UN's SDGs are an example of a goal system that has been criticized for being "so sprawling and misconceived that the entire enterprise is being set to fail" (The Economist 2015). One problem with having adopted a large number of goals is that priorities have to be made somewhere along the line. However, in the absence of clear directions for how priorities should be made, there is a risk that the agencies responsible for implementing the goals will focus on less relevant policy aspects than others.

Elvik (2008) appeared to follow this line of reasoning when he argued that one must limit the number of goals in order to create an effective system of road safety management goals. Instead of trying to address all policy problems at once, one should concentrate on a few key areas that have a major impact on safety (see also Smith and Busse 2010). Here, high-quality accident data can play an important part, thereby rendering road safety policy, including the prioritization of road traffic policy goals, to be more evidence-based.

Consistency

When goals are adopted as parts of a goal system, it may be argued that the goals should ideally be consistent in the sense that they do not conflict with one another. The problem with conflicting goals is that efforts to attain one goal make it more difficult to achieve another goal. Thus, the implementing agent will have to prioritize between the goals, which can be resource consuming unless some guidance on how priorities ought to be made has been provided by the goal-setter (e.g., the politicians). Goal conflicts, their formal definition, and the possible ways of addressing them in public policy contexts are issues that have been addressed in past works (Rosencrantz 2008; Nilsson et al. 2016; Carrigan 2018). They will not be discussed at length in this chapter. However, two observations will be briefly presented before proceeding.

First, it is hard to determine the degree of consistency required for a goal system to be rational in the achievement-inducing sense. Complete consistency may come with its own cost. Hansson (1998) warned that attempts to avoid goal conflicts altogether can lead to the adoption of goals with very low ambition levels. Such goals may be easy to co-achieve; however, their achievement will not represent any significant change in the present state of affairs. Put differently, they are not particularly meaningful.

Second, it is worth noting that goal conflicts are addressed in different ways in various policy areas. In some policy areas, compromises and adjustments between (conflicting) goals are made before the goals are set. This is, for instance, common in economic policy. In other policy areas, the goals are set first and compromises are made afterward. This is often the case in health and safety policy. Although traffic and transportation usually follow the first pattern of decision-making, road traffic safety is an exception (Rosencrantz et al. 2007). Road traffic safety work, particularly when discussed in terms of Vision Zero, follows the second pattern. Like public health issues in general, this is based on the ethical premise that it is morally unacceptable that people are killed or seriously injured on the road when mitigating measures can be taken to avoid these.

Why Does a Road Safety Target Have to Be Stable Over Time?

If goals are to fulfil their typical function of regulating action toward goal achievement, they need to have a certain stability. This holds true for both goals set by individuals and goals adopted by organizations. Frequent goal revision makes it difficult for the individual/organization to plan their activities over time. It also makes it more difficult for them to coordinate their actions with other individuals/organizations. Thus, the non-reconsideration of adopted goals appears to be the default position both in private life and in public policy.

However, it is not difficult to think of situations in which, for instance, a government agency has reason to revise one or several of its goals. For example, a road safety target could turn out to be much more (or less) difficult to achieve than initially believed and therefore in need of some modification. To take one example, Wesemann et al. (2010) referred to a set of road safety goals adopted by the Dutch government for which the level of ambition was eventually sharpened as the government found out that an unusually strong decrease in traffic fatalities occurred some years after the goals were adopted.

Baard and Edvardsson Björnberg (2015) identified two types of considerations that could give an organization (or individual) a reason to reconsider its goals: achievability- and desirability-related considerations. On the one hand, the organization could realize that the goal's level of ambition is too high or too low (example above) and thus decide to adjust the goal accordingly (achievability-related considerations). On the other hand, an organization could realize that the value premises upon which the goal was initially set no longer hold (i.e., the end state is no longer considered valuable or is considered much less valuable than when the goal was adopted).

In relation to road safety targets, it is more likely that achievability-related considerations may come into play and justify adjustments in the targets. It would be more difficult to envision that people's preferences and values regarding loss of human life and well-being would change significantly, even over longer time periods, although other social developments leading to more severe losses of human life, such as severe pandemics, could obviously lead to politicians prioritizing other policy measures over road traffic safety.

Obviously, new data can justify the adjustments of the adopted road safety targets. However, Elvik (1993) argued that frequent goal revisions on the basis of accident history and traffic forecasts are problematic, because, over time, such a practice can lead to the present number of accidents being adopted as the target (cf. Bevan and Hood 2006, on ratchet and threshold effects). This clearly reduces the value of the goals as policy-making instruments.

Who Should Be Involved in the Goal-Setting Process?

It is sometimes argued that participatory goal-setting is conducive to goal achievement, at least in employer-employee settings. When an employee is involved in the goal-setting process, he/she will not only be more motivated to reach the goal but also have a better idea of what to do in order to reach the goal, or so it is argued (O'Connell et al. 2011). Jung and Ritz (2014, p. 468), for instance, argued that involving employees in the goal-setting process can improve their "affective organizational commitment." Various psychological mechanisms contribute to this. As noted by the authors, involvement in the goal-setting process sends a signal to the employees that "they are important, worth-while, and valued by their superiors and the organization, which in turn can enhance their self-esteem" (ibid.). Moreover, such involvement can boost the employee's trust in and identification with the organization's goals and its values.

However, mixed empirical results have been obtained in relation to the hypothesis that participatory goal-setting leads to better goal achievement. Certainly, some studies confirmed that employees who participate in the goal-setting process generally perform better than their colleagues who are simply assigned to achieve some goals. However, Latham et al. (2008) pointed out that the reason why performance levels were increased in some of those studies was that significantly more ambitious goals were adopted when participatory goal-setting processes were used. Therefore, these studies indicate that it is the level of ambition, rather than the method of goal-setting, that determines how wide the goal-outcome gap will be. To further support their argument, Latham et al. (2008) cited a study by Latham and Steele (1983), which concluded that "when goal difficulty is held constant, there is no motivational benefit to one method of goal setting versus the other provided that the logic or rationale for an assigned goal is given" (Latham et al. 2008, p. 388). The findings suggest that, when goals are assigned, a clearly stated rationale may fulfil a similar function to that allegedly served by participatory goal-setting, namely, to foster trust, legitimacy, and commitment to the goal.

In public policy settings, goals are commonly set by one agent, in many cases a political decision-maker, and implemented by one or several other agents. In road safety policy, those other agents can be government agencies or various road safety professionals (e.g., national road administrations), local councils, business corporations (e.g., vehicle producers), and individuals. It is sometimes argued that greater acceptance of the goals will be fostered by allowing those other actors to participate in the goal-setting process. Thus, Kristianssen et al. (2018) argued that a road safety target that is "formulated from below by actors within the policy area, can enhance the internal legitimacy of the vision" (p. 266).

Corben et al. (2010) provided an example of a participatory bottom-up approach to the adoption of road safety targets. They described how the Western Australian Government and the Road Safety Council of Western Australia proceeded with the development of a new road safety strategy for the period 2008–2020. The WA Road Safety Council decided that the new road safety strategy should be developed "in a consultative and transparent way to maximize stakeholder and community acceptance" (p. 1085 f.). The development of the strategy thus involved a great degree of stakeholder consultation: over 4,000 people participated in the consultation process, which involved three phases. In phase 1, the community's views on road safety were gathered through a number of community forums. In phase 2, community members were given the opportunity to comment on a recommended package of initiatives developed by Monash University Accident Research Centre (MUARC). This was carried out through community forums and a survey of a representative sample of the population. In phase 3, the endorsed strategy was communicated to the public, the stakeholders, and the Parliament. Using both community forums and survey samples was considered an effective way of gathering the views of those who were specifically interested in road safety issues for some reason (forum attendants) and those who were not (survey). The authors concluded that "to promote community acceptance of the Safe System philosophy and a bold, long term vision for road safety, it has been important to share the research with the community and listen to its views" (Corben et al. 2010, p. 1095).

However, involving the public in the goal-setting and implementation process, as opposed to letting the road safety experts and politicians decide, comes with its own dangers. In the case of Western Australia, analyzed by Corben et al. (2010), the consulted community had divided views on the desirability of speed limit reductions. As a result of public opposition, the WA Road Safety Council did not implement the reductions in speed limit suggested by the MUARC. Instead, a decision was made to focus on demonstration projects to illustrate the effects of speed limit reductions. According to the MUARC's estimates, the proposed speed limit reduction would have reduced the number of killed or seriously injured people by 1,600 over the

12-year life of the strategy. Therefore, in this case, it could be argued that wider community support and greater legitimacy were gained at the potential cost of 1,600 deaths and serious injuries.

In the context of health targets, Smith and Busse (2010) acknowledged that public consultations can be useful in identifying priorities for improvement. However, they cautioned against uncritically accommodating every interest group in the process of target setting. Regardless of policy area, a wide range of considerations and interests come into play when setting a target, including the respective interests of future users, taxpayers, and users of other services. It is the role of the government to balance those (sometimes) conflicting interests and demands. When inviting stakeholders to participate in the goal-setting process, the government must bear this responsibility in mind and actively discourage potential attempts by some stakeholder groups to "hijack" the agenda in order to further their own interests.

What About Contextual Rationality Aspects?

The extent to which goals can further their own achievement depends not only on how they are formulated or how goals and sub-goals are aligned. Instead, factors that are external to a goal may also have a significant impact on how well that goal will be able to guide and motivate action toward its achievement. A number of such factors can be envisaged, and some of them will be outlined below.

A system for monitoring and evaluating progress: One of the conditions for the successful MBO in road safety policy identified by Elvik (2008) is that there should be a system in place for monitoring progress toward the targets and providing feedback to responsible agents. Thus, effective MBO presupposes not only that the goals themselves are evaluable but also that they are, in fact, evaluated on a regular basis. There must be a system of monitoring and evaluating in force that can provide feedback to those responsible for adopting the goals, and in the case of road safety, these include mostly governments at the national and local levels. Sometimes, feedback systems include incentives and disincentives (awards and punishments) that supplement the motivating effects of the goals themselves. These could be official announcements of the performance output, "naming and shaming" or other reputational measures, award of bonuses, etc. (Bevan and Hood 2006). As noted above, evaluation systems that give feedback in the form of awards and punishments may be vulnerable to gaming.

Clear communication channels: Another prerequisite for effective MBO, as pointed out by Wibeck et al. (2006), is that there should be well-developed communication channels between agents operating at various government levels. Effective communication is needed when both implementing and evaluating adopted goals, not least to avoid misunderstandings and controversies concerning the goal content, time frames, and potential goal conflicts. Arguably, this is especially crucial when the MBO system contains qualitative goals. As an example, Wibeck et al. (2006) discussed the case of the Swedish environmental quality objective "a good built environment," which is interpreted in different ways by various agents depending on the administrative context and the ideological perspective. Here, Vision Zero has the advantage of being formulated in quantitative terms, which could make communication regarding goal achievement easier than in many other public policy contexts. However, effective communication channels between agents at different societal levels are nevertheless important in road safety work, not the least to facilitate discussions about the effectiveness of various road safety measures.

Strong political commitment: Finally, though perhaps trivially, for road safety goals to be achieved, it is not sufficient that the goals have the capacity to guide and motivate action, that there are well-designed systems in place for the assessment and evaluation of the goals, and that effective communication channels exist between road safety agents operating at different societal levels; beyond these, there must also be a strong political commitment to the goals in the form of sufficient resource allocation and political prioritization (Elvik 2008).

Conclusions

In this chapter, it has been argued that goal-setting can be an effective management technique in road safety policy. Goal-setting theory, developed by psychologists and management theorists over the last 40 years, supports this argument. Empirical evidence from the research field of road safety confirms that the theoretical claims made in the goal-setting literature are also relevant in a road safety policy context: ambitious quantified targets can indeed reduce the number of dead and seriously injured people on the road. However, for this to hold true, a number of requirements must be satisfied. Not only must the goals be formulated in such a way that they can guide and motivate agents to act in ways that are conducive to goal achievement. In addition, goal-setting requires that there are effective evaluation systems and practices in place; that implementation measures, assessment, and evaluation outputs are communicated and discussed among the road safety agents concerned; and that adequate financial means are allocated to those responsible for implementing and evaluating the goals. In addition, governments that wish to organize their road safety work around one or several road safety targets should keep in mind that, in many public policy settings, goals and goal-setting are vulnerable to gaming. Thus, given that gaming corrupts the point of adopting and working toward goals, it is vital to counteract such behaviors at an early stage in the goal-setting process.

Cross-References

► Arguments Against Vision Zero: A Literature Review

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Zero Visions and Other Safety Principles

2

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Abstract

Safety management is largely based on safety principles, which are simple guidelines intended to guide safety work. This chapter provides a typology and systematic overview of safety principles and an analysis of how they relate to Vision Zero. Three major categories of safety principles are investigated. The *aspiration principles* tell us what level of safety or risk reduction we should aim at or aspire to. Important examples are Vision Zero, continuous improvement, ALARA (as low as reasonably achievable), BAT (best available technology), cost-benefit analysis, cost-effectiveness analysis, risk limits, and exposure limits. The *error tolerance principles* are based on the insight that accidents and mistakes will happen, however much we try to avoid them. We therefore have to minimize the negative effects of failures and unexpected disturbances. Safety principles telling us how to do this include fail-safety, inherent safety, substitution, multiple safety barriers, redundancy, and safety factors. Finally, *evidence evaluation principles* provide guidance on how to evaluate uncertain evidence. Major such principles are the precautionary principle, a reversed burden of proof, and risk neutrality.

Keywords

ALARA · As low as reasonably achievable · Aspiration principles · BAT · Best available technology · Burden of proof · Continuous improvement · Cost-benefit analysis · Cost-effectiveness analysis · Error tolerance principles · Evidence evaluation principles · Exposure limits · Fail-safety · Improvement principles · Inherent safety · Multiple safety barriers · Precautionary principle · Redundancy · Reversed burden of proof · Risk limits · Risk neutrality · Safety barriers · Safety factors · Safety principles · Substitution · Vision zero

Introduction

Much safety work is based on *safety principles*, which are usually simple rules or mottos such as “inherent safety,” “fail-safe” and “best available technology.” Many such principles have been proposed, and there is a considerable overlap between them (Möller et al. 2018). In this chapter, we will see Vision Zero as one of the safety principles and relate it to other such principles. We will begin with its closest relatives and then consider some of its more distant kin. The safety principles discussed in this chapter are summarized in Fig. 1.

The “Zero Family”

The idea that there should be nothing at all of something undesirable must have been close at hand to human thinking since long before recorded history. Concepts of “naught” and “none” are much older than the mathematical concept of zero. For instance, at least since Alcidamas (fourth century BCE), abolitionists have claimed that no single human being should be a slave.

In modern discussions on safety, strivings to get completely rid of something undesirable have emerged in many contexts, probably often independently. The goal of “zero” is therefore an oftentimes reinvented wheel. As Gerard Zwetsloot and his co-authors have pointed out, we have a “family of zero visions” (Zwetsloot et al. 2013, p. 46). Its members are known under a great variety of names, some of which are recorded in Fig. 2. Some of them are “visions” in the sense of being difficult or perhaps impossible to fully achieve. Others are clearly possible to achieve and might

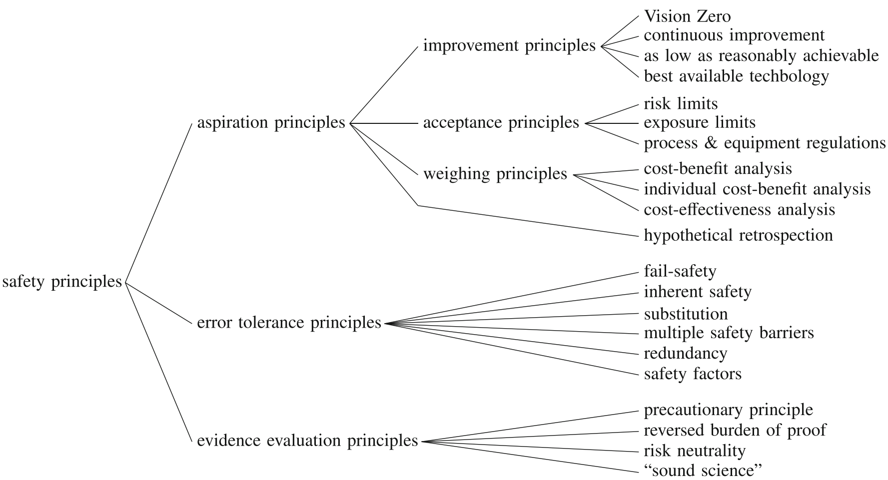
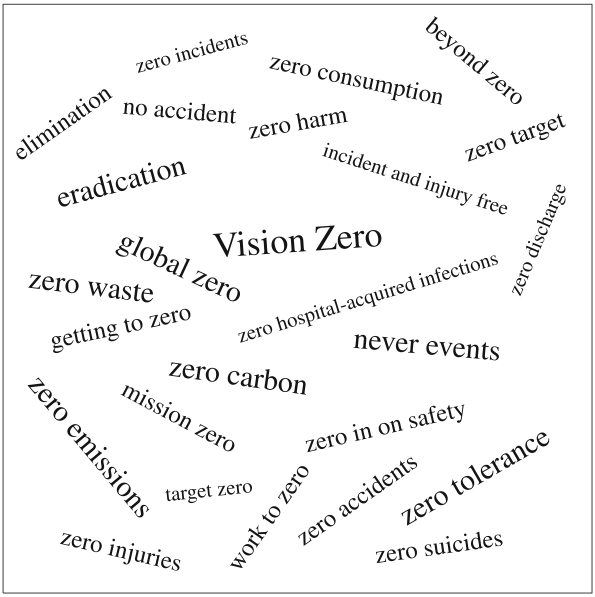


Fig. 1 A typology of the major safety principles discussed in this chapter

Fig. 2 Some of the major members of the "zero family" of safety principles



more appositely be called "zero targets." Both visions and targets can serve useful social purposes. Visions can inspire us to undertake long-term projects whose end points have to be further specified as we go along. Targets, on the other hand, are essential parts of our planning for what to do next (Edvardsson and Hansson 2005; ► Chap. 1, "Vision Zero and Other Road Safety Targets").

Zero Defects

The safety-related zero concepts have been influenced by zero visions in the area of industrial quality. In 1965, the US Department of Defense issued a handbook to be used by defence contractors for "establishing and implementing Zero Defects" as a "motivational approach to the elimination of human error." According to the handbook, the programme had been originated in 1962 by a major (unnamed) defence contractor, which had "established goals for each department to reduce to zero those defects attributable to human error." The programme had been successful, and its ideas had already been "adopted by numerous industrial and Department of Defense activities" (Anon 1965, p. 3). Each individual worker was asked to "accept voluntarily a challenge to do an errorless job," a challenge that would be accepted by those feeling "pride in workmanship" (ibid.). Targets and scorekeeping were essential components of the concept.

The unnamed defence contractor was probably Martin Marietta, a Florida-based company that built missiles for the armed forces. Their employee James F. Halpin has been identified as the inventor of the concept (Peierls 1967). He published a book (Halpin 1966) that made the Zero Defects concept known in wider circles. Halpin was critical of what he called a “double standard” in our attitudes as consumers and as workers. Most consumers expect the products they buy to be free of defects, but the same persons, in their role as workers, consider a certain amount of errors in their work outputs to be acceptable. Zero Defects would remove that contradiction and at the same time improve the quality of working life by making workers more proud of their work (Zwetsloot et al. 2013, pp. 45–46).

Another important promoter of Zero Defects was Philip B. Crosby, who worked in the same missile company as Halpin in the early 1960s. In his book *Quality is Free* (Crosby 1979), he emphasized the hidden costs of low quality and argued that a Zero Defects strategy is beneficial for business. The Zero Defects programme was much in vogue in American industry in the late 1960s and early 1970s, but after that, it receded in importance. Largely due to Crosby’s influence, it had a renaissance in the automobile industry in the 1990s (Lovrencic and Gomišcek 2014, p. 4). Claims have been made that the “zero” concepts of safety engineering have developed out of Zero Defects (Butler 2017, p. 25), but no evidence seems to have been presented that confirms this genealogy of the concepts.

Workplace Safety

A large number of zero concepts have been used to express the goal that no one should be injured or harmed in their workplace. Common terms are “zero harm,” “zero injuries,” “zero accidents,” “zero incidents” and “incident and injury free” (abbreviated IIF) (Zou 2010; Lovrencic and Gomišcek 2014). If the phrases are interpreted literally, there is a large difference, for instance, between “zero accidents” and “zero incidents,” but in actual practice, the choice among these phrases does not say much about how safety work is conducted in the workplace. The variations in terminology seem to mark different national and industry-based traditions rather than different approaches to safety.

In the **United States**, a two-year safety programme named “Zero in on Safety” was launched in 1971 in all federal agencies. Its aim was to reduce the number of injuries and other losses on federal workplaces (Anon. 1971). However, the expression “zero in on” seems to have been used in the common sense “concentrate attention on,” rather than referring to a zero target.

The American construction industry has been prominent in promoting zero approaches to workplace safety. In 1989, the Construction Industry Institute (CII) started a project called “Zero Accidents Techniques,” which led up to a “zero injury” target that was launched in 1993. It was based on detailed analyses of accidents on construction sites and means to prevent them. The programme had an emphasis on worker compliance. For instance, it included a drug-testing policy according to which a worker with a positive drug test was expelled from the workplace in the following 60 days (Hinze and Wilson 2000; Lovrencic and Gomišcek 2014). In an interview, the CEO of Bechtel, one of the largest construction companies in the United States, explained the rationale behind the Zero Accidents objective as follows:

> I sincerely believe all accidents and all injuries are preventable. Accidents don't just happen. They occur primarily because of someone's unsafe behaviour. Correcting that behaviour is the only way we'll get to Zero Accidents. Zero Accidents means exactly that – zero. When it comes to preventing accidents, nothing less than perfection will do. (Zou 2010, p. 15)

However, this company also has a more empowering approach to employees' contributions to safety. It has authorized all employees to stop work which they consider to be unsafe; "If it's not safe, don't do it" (Zou 2010, p. 14). Emmit J. Nelson, who was chair of the original CII Zero Accidents Task Force, has explained the justification of zero targets with the following hypothetical example:

> Last year, a small 100-employee company experienced five serious lost-workday cases. Accident costs were high, but the misery that followed the injuries was even more devastating. The owner vowed to take action.
>
> After consulting with company leaders, the owner set a goal of only two lost-workday cases for the upcoming year. At the next safety meeting, the owner voiced his concern about the five lost-workday cases and announced the new goal. Everyone was enthusiastic and seemed to buy into the plan.
>
> Question: On the first workday in January, how many of the 100 employees think (as far as the goal is concerned) that it is okay for them to have an injury that results in a lost-workday case?
>
> Answer: All 100. Each employee thinks that, provided the goal of two is not reached, it is acceptable for a serious injury to occur.
>
> What has the new goal inadvertently accomplished? It has said it is acceptable for injuries to occur (provided no more than two occur). This certainly is not the 'Let's stop injury' message the owner intended to deliver. . ..
>
> Zero is the correct approach. Such commitment sends an unmistakable message to all employees that injury is unacceptable. (Nelson 1996)

In 2019, the National Safety Council (NSC) launched a campaign called *Work to Zero 2050*. Its purpose is to achieve zero fatalities on workplaces by the year 2050. The NSC pointed out that when the campaign was introduced, the number of workplace fatalities was 5000 per year, as compared to 50,000 per year in the early 1900s, although the number of people working had increased from 30 million to 160 million in the same period. This was largely due to technology innovation, and new technology will be an essential component of the new campaign. "Its purpose is to *eliminate* death on the job by the year 2050. Period. No hedging, no qualifiers" (McElhattan 2019).

In **Japan**, a government-sponsored Zero-Accident Total Participation Campaign (Zero-Accident Campaign) was introduced in 1973 by the Japan Industrial Safety and Health Association (JISHA). Reportedly, the campaign was inspired by the American "Zero in on Safety" campaign. It was also influenced by the quality improvement movement (JICOSJ n.d.). (Dekker (2017, p. 125) claims that the Japanese "Zero-Accident Total Participation Campaign" took place in the 1960s, but this is not corroborated by the Japanese sources I have had access to.) The target of the campaign was set high:

> 'Zero accidents' means to achieve an accident free workplace (not only no fatal accidents or accidents causing absent from work, but also no accidents, including industrial accidents,

> occupational illness, and traffic labor accidents) by detecting, understanding, and solving all hazards (problems) in everybody's daily life as well as potential hazards existing in workplaces and work. (JICOSJ n.d.)

In the **United Kingdom**, the first recorded use of a zero goal for workplace safety seems to have been in 1988. In that year, the British Steel plant in Teesside in North East England launched a programme of "total quality performance." The training material used in meetings with the whole workforce included a short text on accident prevention with the two headings "Total Quality is no Accident" and "Zero Defect = Zero Accidents" (Procter et al. 1990). Thus, safety was included as part of a campaign whose primary goal was product quality. The campaign was based on the notion of "continuous improvement" (see subsection "Continuous Improvement"). The site manager had visited an American steel plant that used the slogan "Total Quality is no Accident," which was the inspiration for including safety in the quality campaign. The safety team in Teesside adopted a "zero-accident philosophy" for their work. A considerable reduction in accidents was reportedly achieved (Ball and Procter 1994).

In later years, the British construction industry has taken a leading role in applying zero approaches to safety. The best-known example is the construction of the venues of the 2012 Summer Olympics and Paralympics in London. The Olympic Delivery Authority adopted a "zero tolerance" approach to unsafe and unhealthy working conditions on their building sites. This was a five-year project involving 12,000 workers who worked a total of 80 million hours. The accident rate was unusually low for a building project, and there was no fatality. This seems to have been the first fatality-free Olympic construction project in modern history. The Olympic Delivery Authority received a special reward from the Royal Society for the Prevention of Accidents for this achievement (Wright 2012).

Most major building companies in the United Kingdom have adopted a zero aim for their safety work. A variety of two-word brands are in vogue, such as "zero harm," "mission zero," "target zero," "zero target" and "beyond zero" (Sherratt 2014). The last-mentioned catchphrase may be somewhat surprising, given the considerable difficulties that the building industry has had in eliminating accidents leading to fatalities and severe injuries. Fred Sherratt, a researcher in construction management, noted that the Beyond Zero programme "boldly announces 'Zero incidents? We can do better than that!' on its webpage." This, she says

> . . .could suggest achieving zero incidents is an easy target. This reading was identifiable elsewhere in the text, 'aiming for zero accidents was a soft target and was not the final word in what could be achieved'. Here, Zero is arguably belittled beyond itself: positioned as 'soft', something so easily attainable that it should not be considered a target, just something to be looked beyond. When considered in the context of one of the highest risk industries in the UK. . . this appears to be rather empty rhetoric. (Sherratt 2014, p. 742)

In **New Zealand**, the New Zealand Aluminium Smelters Limited (NZAS) introduced zero target thinking in 1990 and adopted the slogan "Our Goal is Zero." This resulted in a considerably lower accident rate than that of most other aluminium smelters in in the world (Young 2014).

In **Australia**, most zero-aiming safety activities are performed under the designation of “zero harm,” which was introduced in an influential agreement in 2002 between the Australian Chamber of Commerce and Industry (ACCI) and the Australian Council of Trade Unions (ACTU). The term “zero harm” has become so popular that it has to a large extent replaced references to safety. Workplace health and safety personnel are recruited to positions as “zero harm manager,” “zero harm reporting coordinator” and “zero harm advisor.” Reporting of accidents and incidents is done on a “zero harm reporting app,” and safety culture is referred to as “zero harm culture” (Butler 2017, p. 28). In a PhD thesis on the Zero Harm movement in Australia, Keith Butler noted that “Zero Harm has been popularised as a mantra,” but he recognized that “industry is also actively implementing Zero Harm as a goal or vision and even as a numerical target based on the concept that if a single day without an injury can be achieved, then 365 days without an injury is also achievable” (ibid., p. 2).

In **Finland**, the Finnish Zero Accident Forum was established in 2003 as a voluntary network to help workplaces promote health and safety. It has now changed name to the Finnish Vision Zero Forum. Its membership consists of 440 workplaces, whose 450,000 employees comprise 16% of the country’s workforce (https://www.ttl.fi/en/vision-zero-not-a-numerical-goal-but-a-mindset/. Accessed August 19, 2020). Members of the Forum have improved their safety performance, as measured in terms of lost-time accidents, whereas non-members were on average less successful in this respect (Zwetsloot et al. 2017b, p. 22).

In **Sweden**, the government introduced a Vision Zero strategy for workplaces in 2016. Its focus is on fatal accidents, and the central formulation is as follows:

> No one should have to die as a result of their job. Concrete measures are necessary in order to prevent work-related accidents leading to injury or death. (Quoted in Kristianssen et al. 2018, p. 265)

The strategy requires measures to prevent work-related injuries and to improve psychosocial work environments.

Sweden also has a Vision Zero for fire safety since 2010, stating “No one shall die or be seriously injured due to fire.” Contrary to the goal for workplace safety, the fire safety goal is combined with interim goals. (Kristianssen et al. 2018, p. 263).

Traffic Safety

This subsection is included as a brief introduction to a topic that is treated in much more detail in other chapters of this handbook.

Vision Zero as a goal for traffic safety was first adopted by the Swedish Parliament in 1997. The Bill stated that “the long-term goal of traffic safety is that nobody shall be killed or seriously injured as a consequence of traffic accidents” and that “the design and function of the transport system shall be adapted accordingly” (Government Bill 1996/97, p. 137). Vision Zero has its focus on severe accidents, i.e. accidents leading to fatalities or serious injuries. Its basic message is that as long as serious accidents still occur, there is a need to improve traffic safety. This has been described as a radically different approach from previously dominating road safety policies, in which a certain death toll in traffic was more or less openly accepted as a price for the advantages of mobility. However, it is also stated in the Bill that Vision Zero is not intended to eliminate every traffic accident that gives rise to property damages or light personal injuries (Belin et al. 2012, p. 171). This is a matter of priorities. As long as there are a large number of deaths and serious injuries in road traffic, they have to be the prime target in traffic safety work.

Vision Zero has had significant impact on the traffic safety work of the Swedish Road Administration. The following four changes on Swedish roads have resulted from systematic work to implement Vision Zero:

- *More roundabouts*: Roundabouts have become more common in intersections, in particular within population centers. Roundabouts significantly reduce vehicle velocities. If collisions take place, their consequences will be less severe than in regular intersections, due both to reduced speed and different angles of collision.
- *Roads with midrails*: The so-called 2+1 road is a three-lane road with two lanes in one direction and one in the other. A mid barrier separates traffic going in opposite directions. The direction of the middle lane alternates so that overtaking is always possible within a few kilometres. In this way, head-on collisions are prevented, which has led to a significant reduction in fatalities and serious injuries. The 2+1 road was introduced in 1998 on a route that had previously been the scene of many fatal accidents. There was much initial scepticism towards the new road design, but it has proved effective against accidents, and this road design is now widely used in Sweden. It reduces the number of fatalities by around 80% (Johansson 2009, p. 826).
- *Lower speed limits within population centers*: In order to implement Vision Zero, local municipalities have been authorized to lower speed limits to 30 km/h. The purpose of this is to reduce fatalities among unprotected road users.
- *Safer roadsides*: Efforts have been made to mitigate accidents where vehicles drive off the road. Rails have been set up, and roadsides have been cleared of dangerous objects such as boulders and trees (Vägverket 2004).

The measures taken to implement Vision Zero have led to a considerable reduction in road accidents in Sweden. The number of road traffic fatalities per year was reduced from 541 to 221 in the period from 1997 to 2019 (https://www.transportstyrelsen.se/sv/vagtrafik/statistik/olycksstatistik/statistik-over-vagtrafikolyckor/. Last accessed August 11, 2020).

In September 2000, the Norwegian Parliament adopted a vision of zero killed or seriously injured. Denmark adopted a similar vision with the slogan "every accident is one too many" (Færdselssikkerhedskommissionen 2000). Other countries in Europe have adopted their own variants of Vision Zero, and so have Australia and several states and major cities in the United States (Mendoza et al. 2017). Several car manufacturers have also taken up Vision Zero as a goal for technological developments, aiming at "zero crash cars" (Zwetsloot et al. 2017c, p. 96).

Crime Prevention

The application of zero goals to the prevention of criminal and deviant behavior has mainly taken place in the United States, and it has almost invariably been associated with the phrase "zero tolerance." The application of this phrase to anti-crime policies dates back to 1983, when forty submarine sailors were reassigned by the US Navy for having used drugs. The term was picked up by a district attorney in San Diego, who developed a programme called "zero tolerance" in 1986. The main purpose of that programme was to prosecute all drug offenders however minor their offence was. Sea vessels carrying any amount of drugs were to be impounded (Skiba and Peterson 1999, p. 373; Skiba 2014, p. 28; Stahl 2016).

The programme received the attention of members of the US government, including the Customs Commissioner William von Raab, who decided to implement a similar approach on a national level. A government committee, called the White House Conference for a Drug-Free America (WHCDFA), issued a report in June 1988, concluding: "The U.S. national policy must be zero tolerance for illegal drugs" (Newburn and Jones 2007, pp. 223–224). Initially, the programme resonated well with sentiments in large parts of the general public. However, its implementation in the day-to-day activities of customs officials was far from frictionless. In 1990, two research vessels were seized due to small amounts of marijuana that had been found on-board. This was generally recognized as disproportionate, and after that, the US Customs Service discretely discontinued its zero tolerance programme (Skiba and Peterson 1999, p. 373). But in spite of the practical problems, the political appeal of "zero tolerance" was unscathed, and the concept had already started to proliferate in other social areas.

Two campaigns focusing on violence against women, one in Canada and one in Scotland, took up the "zero tolerance" motto. In 1993, the Canadian Panel on Violence Against Women, which had been appointed by the prime minister two years earlier, presented an action plan declaring zero tolerance. By this was meant that "no level of violence is acceptable, and women's safety and equality are priorities." Inspired by the Canadian initiative, the Women's Committee of the Edinburgh City Council initiated a Zero Tolerance Campaign (ZTC) in late 1992. The campaign launched posters and cinema adverts with a prominently featured Z symbol, emphasizing that male violence against women and children should never be tolerated. A Zero Tolerance Charitable Trust was established in 1995 (Newburn and Jones 2007, pp. 224–225). It is still active, waging campaigns throughout Scotland with the goal "a world free of men's violence against women" (https://www.zerotolerance.org.uk/about/. Last accessed August 19, 2020).

In 1990, when the US Customs Service abandoned their zero tolerance policies, school districts across the United States were busy introducing their own versions of zero tolerance. Already in the previous year, school districts in California, New York and Kentucky had adopted zero tolerance procedures that targeted drugs and weapons on school premises. Dissemination was rapid, and in 1993, such procedures were implemented in schools throughout the country. The scope of the policies was significantly extended after the Columbine school shooting in April 1999 in Littleton, Colorado. Throughout the country, school security was strengthened with measures such as metal detectors, increased surveillance and greater presence of security personnel. The lists of behaviors punished with school suspensions and exclusions became much longer. In many schools, misdemeanours such as swearing, truancy and dress code violations would lead to suspension (Skiba and Peterson 1999; Stahl 2016).

Consequently, the number of suspended and expelled students increased, in some cases dramatically. Media started to report on suspensions that appeared to be inordinately harsh. One twelve-year-old student was suspended for violating her school's drug policy by sharing her inhaler with a student who had an asthma attack on a bus (Skiba and Peterson 1999, p. 375). A ten-year-old girl found a small knife in her lunchbox, where her mother had placed it for cutting an apple. She realized that it was a forbidden object and immediately handed it over to her teacher, but she was nevertheless suspended for bringing a weapon to school (APA Taskforce 2008, p. 852). A five-year-old bringing a plastic toy axe to school was suspended for the same reason. Worst of all, an eleven-year-old boy died because the school's drug regulations forbade him to bring his inhaler to school (Martinez 2009, p. 155).

Research does not confirm the assumption that suspending students from school improves their law abidance and keeps them away from crime. To the contrary, numerous studies have shown school suspensions to be associated with higher risks of school dropout, failure to graduate and criminal activity (Martinez 2009, p. 155; APA Task Force 2008; Stahl 2016). In addition, zero tolerance policies in schools have turned out to be highly discriminatory. African American students have been suspended 3–4 times more frequently than other students (Hoffman 2014, p. 71; Lacoe and Steinberg 2018, p. 209). The widely held assumption that Black students earn their higher rate of school suspensions by their own behavior is not borne out by research. Instead, research shows that African American students are disciplined more than other students for less serious misbehavior (APA Task Force 2008; Skiba 2014, p. 30). However, in recent years, many states have reduced the punitive elements of their zero tolerance programmes and replaced suspensions by policies and interventions that keep the students in the classrooms (Lacoe and Steinberg 2018, pp. 207–208).

In 1991, zero tolerance policies were adopted by the federal Department of Housing and Urban Development. A very low bar was set for evicting a tenant from public housing programmes. Tenants could even lose their apartment without doing anything reproachable themselves; it was sufficient to have visitors engaging in criminal activity in or near the apartment. For instance, an elderly couple was thrown out of their home because their grandson had smoked marijuana in the parking lot. The immediate consequence of zero tolerance was described as follows by a researcher:

> Creating homelessness is the [sic] one of the main outcomes of "zero-tolerance" policies. People are evicted from their housing units under these policies and they are left without any other place to live. That is, in fact, the main purpose of these policies. And since people are most often in government-supported housing programs because they do not have other options, eviction typically results in making the person homeless. (Marston 2016)

Often, those evicted had to move to another neighborhood, with negative effects on their social networks. Frequent moves are particularly problematic for families with children, who run increased risks of lower school achievement, school dropout and substance abuse (Marston 2016). In housing, just as in schools, zero tolerance policies have largely been counterproductive, fuelling rather than reducing social exclusion and criminality.

The most well-know application of zero tolerance policies took place in a number of police forces, most notably the New York Police Department. Zero tolerance policing was inspired not only by other zero tolerance programmes but also by the so-called "broken windows" approach to police work, which was introduced in the early 1980s by James Q. Wilson and George L. Kelling. They argued that "if a window in a building is broken and is left unrepaired, all the rest of the windows will soon be broken." In the same way, they said, minor disturbances of order in a neighborhood could, if not curbed in time, lead to an uncontrollable escalation of criminality. In such a process, "[t]he unchecked panhandler is, in effect, the first broken window." To prevent such negative developments, they proposed that police departments should cease assigning resources "on the basis of crime rates (meaning that marginally threatened areas are often stripped so that police can investigate crimes in areas where the situation is hopeless)." Instead, priority should be given to "neighborhoods at the tipping point – where the public order is deteriorating but not unreclaimable" (Wilson and Kelling 1982).

These ideas became a central part of the "zero tolerance" policies that were introduced under William Bratton, who was appointed commissioner of the NYPD in 1994. The programme had a strong focus on aggressive police crackdowns on various forms of minor misconduct in the public space, such as drunkenness, urination, squeegeeing, fare dodging and begging. A similar programme was run by the London Metropolitan Police in the King's Cross area in December 1996. In London, police raids against minor public order offences led to the removal of beggars and inebriated and homeless people from public areas (Innes 1999; Newburn and Jones 2007).

Homicides were substantially reduced in New York City in the period 1991–1997. This decrease has often been attributed to the zero tolerance and broken window policies. However, in this period, many other changes took place that could have influenced homicide statistics. Criminological research does not confirm the usual "success story" for zero tolerance (Bowling 1999). An interesting comparison can be made with San Diego, where a more community-oriented policing programme was carried out in about the same period. The two cities experienced similar reductions in severe crime. However, whereas there was a dramatic increase in legal actions taken against the NYPD for police misconduct, no such effect occurred in

San Diego (Greene 1999). It should also be observed that resource-demanding measures against petty crimes will necessarily divert resources that might have been directed at more serious crimes. A major assumption behind zero tolerance programmes appears to be that harsh and legalistic action against juveniles committing minor offences will deter them from a criminal career. This is not substantiated by the criminological evidence. To the contrary, harsh and legalistic treatment of young offenders is associated with a larger number of rearrests and a higher future participation in crime (Klein 1986; Innes 1999; Petrosino et al. 2014).

Against this background, it should be no surprise that the use of zero tolerance concepts has decreased considerably in police work (Wein 2013, p. 4). As an example of this, the NYPD has retreated from its zero tolerance strategy for policing (Anon. 2017).

Preventive Medicine

The prevention of diseases is one of the areas where zero targets naturally spring to mind. Why should the prevention of a disease have a less ambitious goal than its complete eradication? Ideas about eradicating infectious diseases are much older than the zero concepts discussed in the previous subsections. In later years, disease eradication has also been promoted for various iatrogenic diseases. Furthermore, a zero vision much inspired by the Vision Zero of traffic safety has been introduced in suicide prevention. This subsection is devoted to these three areas of zero-aiming medical goal setting.

Apparently, the first proposal to eradicate a disease can be found in a book published in 1793 by the English physician John Haygarth (1740–1827). He proposed that smallpox could be exterminated through a combination of obligatory variolation and strict measures to prevent contagion (Haygarth 1793). Variolation consisted in infecting a person with scabs or fluid from the skin bumps of a person with smallpox. This usually resulted in a less severe disease than after natural contagion. Variolation was far from risk-free, but the vast majority survived, and they acquired immunity against the disease. Three years after Haygarth published his book, Edward Jenner (1749–1823) made his first experiment with vaccination. He infected human subjects with pus from cowpox blisters (containing what we now know to be live viruses). Cowpox is a much milder disease than smallpox, but it gives rise to immunity also against smallpox. In 1801, Jenner published a short pamphlet on vaccination in which he made the bold prediction that it was “too manifest to admit of controversy, that the annihilation of the Small Pox, the most dreadful scourge of the human species, must be the final result of this practice” (Jenner 1801, p. 8; Fenner 1993).

In modern terminology, the word eradication is used for a “permanent reduction to zero” of the worldwide incidence of an infectious disease, such that no further interventions are needed to prevent new cases. Thus, eradication is a global concept. For regional or national absence of a disease, the word elimination is used instead (Hinman 2018; Kretsinger et al. 2017).

Smallpox was indeed possible to eradicate. It satisfies a crucial condition for this, namely, that it has no animal reservoir. If there is a species of wild animals that serve as alternative hosts for a human pathogen, then that pathogen can always survive in the wild, whatever measures we take to prevent its spread among humans. But the smallpox virus can only survive in humans. Therefore, if its dissemination in the human population could be stopped through vaccination and other efficient measures, then the virus would die out. Attempts to engage the WHO in a programme to eradicate smallpox were made in 1953, but the idea was dismissed as unrealistic. It was only in 1958 that a decision was made to introduce such a programme. An internationally funded and coordinated programme was not in place until 1967. In that year, the yearly death toll of smallpox was about two million people, and the disease was endemic (regularly present) in 32 countries. The programme had three major components. The first was mass vaccination to ensure that at least 80% of the population was vaccinated in all countries where the disease was endemic. In this way, the disease would be reduced to a level where all outbreaks could be effectively contained. The second component was an efficient reporting and response organization in all countries where the disease occurred. Places with outbreaks were visited by a team that searched for additional cases and vaccinated everyone who could have been infected. The third component was an international exchange of reports that kept all participants in the programme informed of developments throughout the world (Fenner 1993; Henderson 2011).

The programme was successful. The last case of smallpox occurred in 1978, and in 1980, the world was officially declared free of smallpox. This was 179 years after Jenner's prediction that smallpox would eventually be "annihilated" by vaccination. The eradication of smallpox put an end to an immense amount of suffering that had haunted humanity since ancient times. Only in the twentieth century, at least 300 million people died from smallpox (Henderson 2011, p. D8).

In 1988, a new disease eradication programme was started, the Global Polio Eradication Initiative (GPEI). In its more than three decades of operation, it has radically reduced the number of polio cases. In 1988, there were around 350,000 cases, distributed over 125 countries. In 2018, there were 33 cases, all of which occurred in Pakistan and Afghanistan (Polio Global Eradication Initiative 2019). The campaign is now described as an endgame, but it operates under grave difficulties caused by militant anti-vaccination propaganda and violent groups targeting vaccination workers (Kaufmann and Feldbaum 2009). In the years 2012–2015, 68 government employees working with the administration of polio vaccine were killed in Pakistan (Kakalia and Karrar 2016). In 2019, the number of polio cases increased again (https://www.who.int/news-room/detail/03-10-2019-statement-of-the-twenty-second-ihr-emergency-committee-regarding-the-international-spread-of-poliovirus. Last downloaded August 19, 2020).

In spite of these remaining difficulties, discussions are ongoing on how the extensive infrastructure and capabilities created by the Global Polio Eradication Initiative can be used after polio has finally been defeated. The most common answer is that these resources should be retained and utilized in efforts to eradicate measles and rubella (Kretsinger et al. 2017; Cochi 2017). Measles is a major cause of child fatalities. In 2018, more than 140,000 measles deaths were reported globally, most of them in children (https://www.who.int/news-room/fact-sheets/detail/measles. Downloaded Dec 7, 2019). In industrialized countries, around 3 of 1000 children who catch measles will die from the disease, but in countries with widespread malnutrition (in particular, vitamin A deficiency) and insufficient healthcare resources, the death toll can be in the range between 100 and 300 per 1000 children with the disease (Perry and Halsey 2004). Rubella is transferred from the pregnant woman to the foetus, and it is a major cause of congenital diseases. About 100,000 children are born each year with rubella-induced inborn diseases, such as deafness, severe heart diseases, glaucoma and diabetes (Lambert et al. 2015; Banatvala and Brown 2004). Both measles and rubella are clearly possible to eradicate. Neither of them has an animal reservoir, both are preventable with two doses of vaccine and both have easily detectable clinical symptoms. Major efforts are ongoing to eliminate these diseases in most regions of the world, but progress has been slow, largely due to disinformation spread by anti-vaccination propagandists (Benecke and DeYoung 2019).

In 1986, the Carter Center in cooperation with the WHO started a campaign to eradicate the Guinea-worm disease (GWD, also called dracunculiasis). This is a painful but seldom deadly disease affecting people in Africa and Asia. The infection is spread by drinking water containing water fleas that are infected by guinea worm larvae. The disease can be prevented with relatively simple measures such as providing safe water, blocking the use of infected water sources and boiling or filtering water before drinking (Tayeh et al. 2017). The eradication programme has succeeded in drastically reducing the number of cases. In 1986, 3.5 million cases were recorded worldwide, whereas the number of cases was only about 30 in the years 2017 and 2018 (https://www.cartercenter.org/news/pr/guinea-worm-worldwide-cases-jan2019.html. Last accessed August 19, 2020). This shows that the disease can be contained on a very low level. However, the discovery that the disease has animal reservoirs in both dogs and frogs has dampened hopes of its eradicating (Callaway 2016; Eberhard et al. 2016).

In 2011, the Joint United Nations Programme on HIV and AIDS (UNAIDS) adopted a vision of three zeros: zero new HIV infections, zero discrimination and zero AIDS-related deaths. The World AIDS Day 2011 had the motto "getting to zero" (Garg and Singh 2013). Currently, this seems to be extremely difficult to achieve (https://www.unaids.org/sites/default/files/media_asset/UNAIDS_FactSheet_en.pdf. Last accessed August 19, 2020). There is still no vaccine suitable for mass vaccination. A study of the potential for getting "close to zero" concluded that a radical reduction in the number of new cases would nevertheless be possible through "the global implementation of a bundle of prevention strategies that are known to be efficient, including anti-retroviral therapy to all who need it (which currently does not happen due to insufficient healthcare resources) and condom promotion and distribution (which is currently prevented by ruthless religious hypocrisy)" (Stover et al. 2014). As long as these hurdles remain, it does not seem possible to defeat this disease.

One might expect the eradication of severe diseases to be an unusually uncontroversial undertaking, but that has not been the case. Anti-vaccination propagandists cause considerable problems for vaccination campaigns worldwide. Their activities have delayed the eradication of polio and led to outbreaks of measles in countries that had for long been spared from that disease (Kakalia and Karrarb 2016; Hussain et al. 2018). Recently, a group of biologists have questioned the eradication of pathogens and hosts transmitting them to humans, appealing to the ethical standpoint that "each species may have a right to exist, independent of its value to human being [sic]" (Hochkirch et al. 2018, p. 2). Their main example was the campaign to eradicate trypanosomiasis, a deadly disease caused by a parasitic protozoan spread by bites by tsetse flies. They wanted to "stimulate discussions on the value of species and whether full eradication of a pathogen or vector is justified at all" (ibid., p. 1). This discussion should be seen in the perspective that about 10% of the earth's about six million insect species are threatened by extinction (Diaz et al. 2019). The role of disease prevention and eradication in species extinction is minuscule in comparison to other causes of reduced biodiversity.

Zero targets have also become popular in connection with iatrogenic diseases. In particular, infections spread in hospitals and clinics have been targeted in initiatives with names such as "zero hospital-acquired infections," "zero healthcare-associated infections," "zero tolerance for healthcare-associated infections" and "zero tolerance to shunt infections" (Warye and Granato 2009; Warye and Murphy 2008; Choksey and Malik 2004). Such zero targets have the purpose to "set the goal of elimination rather than remain comfortable when local or national averages or benchmarks are met" (Warye and Murphy 2008). In the discussion on these goals, phrases reminding of discussions on zero goals for workplace and traffic safety are common, for instance, "even one H[ealthcare] A[ssociated] I[nfection] should feel like too many" (Warye and Murphy 2008). However, as evidenced by frequent use of the term "zero tolerance," the focus on individual compliance is often more pronounced in the medical context:

> Lapses in [surgical] theatre discipline were not tolerated, and this attitude was inculcated into all present; we term this 'zero tolerance'. (Choksey and Malik 2004)

> A major impediment to achieving H[ealthcare] A[ssociated] I[nfection] zero tolerance has been a lack of accountability of hospital administrators and clinicians (including unit/ward/service directors). Where in the world would we be allowed to walk into the operating room and do surgery without complying with rules/regulations/culture of the operating room (e.g., strict hand hygiene, gowns, gloves, masks, sterile techniques, etc.)? Virtually nowhere. Yet, almost everywhere, I[ntensive] C[are] U[nit] directors, ward attendants, etc., commonly witness clinicians throughout their units/wards or healthcare facility (e.g., ICUs, wards, outpatient services, emergency departments, etc.) fail to comply with recommended infection control precautions and yet they say nothing. We must engage our hospital administrators and transition from a culture of benchmarking (i.e., are we as good as others like us) to a culture of zero tolerance (i.e., are we preventing all the H[ealthcare]A[ssociated]I[nfection]s we can prevent). Furthermore, hospital administrators must make it clear that unit/service/ward directors will be held accountable for the HAIs that occur in their patients in their units. . . No excuses should be tolerated. (Jarvis 2007, p. 8)

There has also been criticism against the use of zero goals in healthcare, in particular concerning iatrogenic infections. No medical intervention is completely free of risk, and sometimes, an intervention is justified although the risk of infection cannot be eliminated (Worth and McLaws 2012). A focus on zero targets may, according to some authors, be dangerous since it makes it "increasingly difficult to educate the public about the sources of risk of healthcare interventions" (Carlet et al. 2009).

The National Quality Forum in the United States, an umbrella organization of private and public healthcare organizations, conducts a campaign against "never events." By this is meant three types of surgical mistakes: wrong site, wrong procedure and wrong person. Wrong site operations are usually either left/right mistakes or operations on an incorrect level, e.g. surgery on the wrong vertebra or (in dentistry) wrong tooth extraction. Wrong procedure operations take place on the correct site but with the wrong type of surgery. An example would be the removal of a patient's ovaries along with the uterus, when the purpose of the operation was only to remove the uterus. Wrong patient operations depend on confusions of patients, for instance, patients with the same name. With careful preoperative and operative procedures, the risk of these never events can be substantially reduced (Michaels et al. 2007; Ensaldo-Carrasco et al. 2018). The British National Health Service (NHS) employs a more extensive list of never events, which includes, for instance, retention of a foreign object in the patient's body after surgery, overdoses of insulin and transfusion with incompatible blood (https://improvement.nhs.uk/documents/2899/Never_Events_list_2018_FINAL_v7.pdf. Last accessed August 19, 2020).

A Vision Zero for suicide was adopted by the Swedish government in 2007. It states, "No one should find him- or herself in such an exposed situation that the only perceivable way out is suicide. The government's vision is that no one should have to end their life" (Kristianssen et al. 2018, p. 264). In 2011, the US National Action Alliance for Suicide Prevention (NAASP) published an ambitious action plan against suicides. It set the goal Zero Suicide, by which is meant that no suicide should take place among patients under treatment in the healthcare system. It is thus less ambitious than the Swedish goal, which also covers suicides by persons who are not patients. By adopting Zero Suicide, the organization tried to achieve "a transformation of a mindset of resigned acceptance of suicide into a mindset of active prevention of suicide as an outcome of treatment. Instead of asking how not to have more suicides than usual, a Zero Suicide organization challenges itself to have no suicides at all" (Mokkenstorm et al. 2018). Both the Swedish and the American zero suicide goals have been subject to criticism by authors who consider these goals to be unrealistic (Holm and Sahlin 2009; Smith et al. 2015). For an in-depth discussion on the goal of zero suicides and strategies to approach it, see Wasserman et al. (▶ Chap. 37, "Vision Zero in Suicide Prevention and Suicide Preventive Methods").

Environmental Protection

The term "zero waste" was used in environmental discussions already in the 1970s. In 1975, two American researchers described how a water purification plant could achieve "'zero' waste discharge," by which they meant total recycling of all wastes generated in the plant (Wang and Yang 1975, p. 67). The phrase "zero waste" is now quite common, often in combination with other terms to denote an area or activity that is free from waste: “zero waste campus,” “zero waste community,” “zero waste city,” “zero waste living” (Zaman 2015), “zero waste product” (Zaman 2014, 2015) and even “zero waste humanity” (Zwier et al. 2015).

However, there are widely divergent opinions on what should be meant by “zero waste.” This can be illustrated by the various ways in which the term is used about the treatment of household waste in cities. One common definition of zero waste in that context is “diversion from landfill”; in other words, that no waste goes to landfill (Zaman 2014, p. 407). As Atiq Zaman has pointed out, this is an unambitious goal since it “does not place enough emphasis on how waste can be reused as a material resource (as opposed to being incinerated, for instance)” (ibid., p. 408).

Another, much more ambitious, interpretation identifies zero waste with total recycling. On that interpretation, “[a] 100% recycling of municipal solid waste should be mandatory to achieve zero waste city objectives” (Zaman and Lehmann 2011, p. 86). Contrary to the less ambitious goal of avoiding landfill, the goal of total recycling cannot be achieved by cities and municipalities alone. Only if the products discarded by city dwellers consist of 100% recyclable material can the city achieve zero waste in this sense. Therefore, product design has to be a crucial component of the strategy (ibid., p. 86).

However, not even 100% recycling means that nature is unscathed by the city’s activities. Recycling does not necessarily mean that a product gives rise to raw material of the same quality and quantity as the material it was made from. Some authors have required that instead of becoming waste, materials should enter an “endless scheme” and “pass through the process of usefulness without losing their capacity to feed the system again after being used” (Orecchini 2007, p. 245):

> The challenge is to achieve completely closed cycles. Anything but a closed cycle, which starts from useful resources and returns to them after their use, is unable to realize truly sustainable development: diffused, shared, and ideally endless for the entire human society. (Orecchini 2007, p. 246)

Material included in such cycles will not be consumed in the usual sense of the word, and therefore, systems based on these principles have been called systems of “zero consumption” (ibid., p. 245).

Zero waste and related concepts have also been applied to industrial processes. In that case as well, there are large variations in how the terms are defined. Sometimes, remarkably lenient interpretations have been used. For instance, consider the following definition of “zero discharge”:

> [A] Z[ero] D[ischarge] system is most commonly defined as one from which no water effluent stream is discharged by the processing site. All the wastewater after secondary or tertiary treatment is converted to a solid waste by evaporation processes, such as brine concentration followed by crystallization or drying. The solid waste may then be landfilled. (Das 2005, pp. 225–226)

This means that a factory is said to have "zero discharge" if all its waste is put in a landfill, even if there is toxic leakage from that landfill. As this example shows, claims that an activity produces "zero" environmental harm can be severely misleading if the "zero" does not cover all environmental detriments associated with that activity.

The term "zero emissions" was used in a legal text adopted in California in 1990, namely, the Zero Emission Vehicle Mandate. It specified steps that the automobile industry had to take towards the introduction of zero emission vehicles (Kemp 2005). The definition of the term "zero emissions" is equally problematic as that of "zero waste." For instance, battery electric vehicles are typically called "zero emissions" vehicles because they have zero tailpipe emissions of greenhouse gases. However, the production of these cars gives rise to greenhouse gas emissions, and the electricity used to charge the batteries may not have an emission-free source (Ma et al. 2012). Similarly, the claim that a biofuel is "zero-carbon" or has "net zero emissions" needs some qualification. The greenhouse effect of a carbon dioxide molecule from a biofuel is the same as that of a carbon dioxide molecule coming from coal. The advantages of the biofuel will only materialize through replanting resulting in photosynthesis that "compensates" the emissions from burning the fuel. This effect is delayed and depends on the future use of the harvested land (Sterman et al. 2018). Therefore, although replacing fossil fuel with biofuel is a clear advantage from the viewpoint of climate change mitigation, claims of net zero emissions cannot usually be validated.

Disarmament

The pacifist's credo is a "zero": no wars! In arms control negotiations, total abolishing of certain types of weapons has had a prominent role. In the world's first treaty on chemical weapons, signed in Strasbourg in 1675, France and the Holy Roman Empire agreed not to use any poisoned bullets. The Geneva Protocol that went into force in 1929 prohibits all uses of chemical and biological weapons in war (Coleman 2005). This prohibition is still a cornerstone in the international law of war.

After World War II, considerable efforts have been made to outlaw and eliminate the third major type of weapons of mass destruction, namely, nuclear weapons. The very first resolution adopted by the United Nations General Assembly, on a session in London on January 24, 1946, mandated work that would lead to "the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction" (United Nations 1946). A large number of attempts have been made to reinvigorate this mission. Perhaps most remarkably, at the Reykjavík Summit in 1986, Ronald Reagan and Mikhail Gorbachev agreed to work for an agreement to eliminate all nuclear weapons. However, no such agreement materialized. One of the more prominent independent initiatives towards nuclear disarmament is the "Global Zero" initiative, which was launched in Paris in 2008 and is still highly active. It aims for a structured destruction of all nuclear weapons, ultimately resulting in a world without such weapons. In a speech in Prague on April 5, 2009, President Barack Obama expressed “America’s commitment to seek the peace and security of a world without nuclear weapons” (Holloway 2011). At the time of writing, chances of nuclear disarmament seem to be at a low point.

However, in 1999, the Ottawa Treaty against Anti-Personnel Landmines came into force. Its signatories comprise the vast majority of the world’s countries (but as yet neither China, Russia, nor the United States). Each state that has signed the treaty is committed to “never under any circumstances” use anti-personnel mines and to destroy all such mines in its possession (http://www.icbl.org/media/604037/treatyenglish.pdf. Last accessed August 19, 2020).

Comparisons

As we have seen, the “zero family” is broad and diverse. In this subsection, we are going to consider three major ways in which the members of this family differ from each other: (1) how realistic they are; (2) the objects of the zero goals or, in other words, what it is that one strives to make zero; and (3) the subjects, i.e. the persons or organizations tasked with achieving or approaching zero.

Realism

The zero targets we have examined above cover a wide range of degrees of realism, from the proven (but initially doubted) realism of eradicating smallpox to goals such as zero deaths on all American workplaces that seem to be exceedingly difficult to fully achieve.

Criticism of “zero” as too unrealistic is one of the recurrent themes in the literature on zero targets (▶ Chap. 3, “Arguments Against Vision Zero: A Literature Review”). For instance, Goh and Xie claim that the “zero defects” goal is impossible to reach due to “one fundamental characteristic of nature, namely that all natural elements are subject to variation”:

> By deduction, therefore, ‘zero defect’ by itself is a pseudo-target, attractive and even seductive when brandished at management seminars, but misleading or self-deluding on the shop floor. For example, has anyone ever claimed, directly or indirectly, to have run a printed circuit board soldering machine ‘right the first time’ and obtained ‘zero defect’ in the soldered joints all the time? (Goh and Xie 1994, p. 5)

In consequence, they propose that “do it better each time” is a better slogan than “zero defects” (Goh and Xie 1994, p. 5). Similar criticism has been waged, for instance, against Vision Zero for traffic safety (Elvik 1999) and against zero targets for iatrogenic infections (Carlet et al. 2009).

Defenders of zero targets have pointed out that what initially seems to be unrealistic may become realistic if old ways of thinking are broken up. Setting zero goals can be an efficient way to overcome fatalism (Zwetsloot et al. 2013, pp. 44–45) and to defeat “the subtle message that fatal injuries will occur and are acceptable” (Nelson 1996, p. 23). For instance, the zero suicide goal can serve to induce “a transformation of a mindset of resigned acceptance of suicide into a mindset of active prevention of suicide as an outcome of treatment” (Mokkenstorm et al. 2018, p. 750).

Obviously, partial achievement of a zero goal can be a great step forward. For instance, the drastic reduction in polio cases that has been achieved in the programme for polio eradication is already an outstanding accomplishment in terms of human health and welfare, even though the disease has not (yet) been fully eradicated. Even in cases when full attainment is not within reach, zero goals can be efficient means to inspire important improvements. In other words, goals can be achievement inducing even if they cannot be fully attained (Edvardsson and Hansson 2005; ▶ Chap. 1, “Vision Zero and Other Road Safety Targets”).

Our traditions and conventions concerning the realism of goals differ considerably between social areas (see Fig. 3). In some areas, the tradition is to set goals only after carefully investigating and taking into account what is feasible and what compromises with other objectives are necessary. We can call this *restricted goal setting*. For instance, goals for economic policies are usually set in this way. Another example is the setting of occupational and environmental exposure limits, which is usually preceded by careful investigations of what exposure levels can be achieved in practice.

In other areas, the tradition is instead to set goals without first determining what is in practice feasible. We can call this *aspirational goal setting*. For instance, it is desirable that no one should be exposed to violence, but unfortunately, this is not a realistic goal that can be fully achieved. However, law enforcement agencies do not

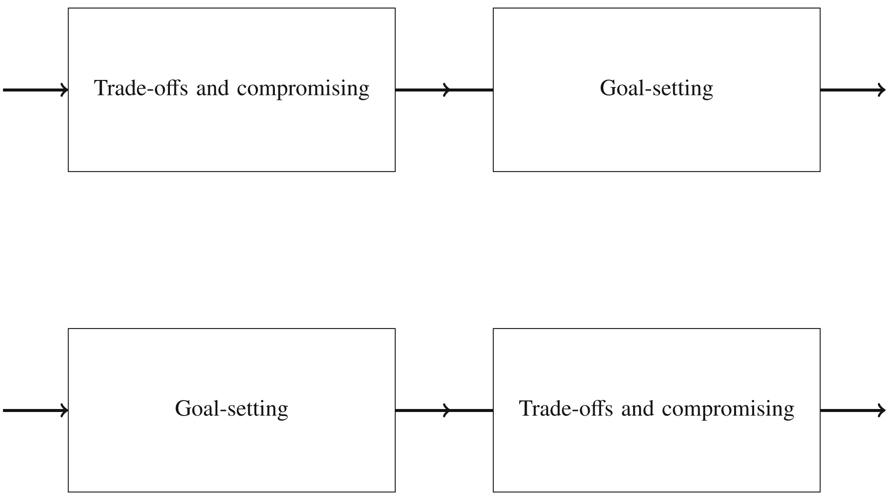


Fig. 3 Above, restricted goal setting. Below, aspirational goal setting

operate with "compromised" goals such as "at most 10 murders and 20 rapes in this district next year." The reason for this is of course that the "uncompromised" goal of no violent crimes is good enough as an indication of what they should strive for.

It is reasonable to assume that aspirational goal setting tends to result in goals that are more inspiring than those emerging from restricted goal setting. On the other hand, the latter goals are often more suitable for guiding policy implementation and evaluation. In many cases, the best solution can be to combine both types of goals, in order to obtain both inspiration and practical guidance (Edvardsson and Hansson 2005; ► Chap. 1, "Vision Zero and Other Road Safety Targets").

The Zero Object

By the object of a zero goal or target, we mean that which is required to be zero. Zero objects can be classified according to how narrow or broad they are. For instance, the Vision Zero of traffic safety has a fairly narrow zero object: The goal is explicitly limited to fatalities and serious injuries, and it does not require strivings for zero occurrence of less serious accidents. As we saw above, some of the measures taken to implement Vision Zero do in fact increase the frequency of less serious accidents. For instance, the introduction of roundabouts in four-way crossings decreases the risk of high-speed collisions with fatal outcomes, but it also increases the risk of low-speed collisions with at most minor personal injuries. The "Work to Zero" goal of the US National Safety Council has a similar approach; its zero object is limited to fatal accidents at workplaces (McElhattan 2019).

However, many other zero goals in workplace safety operate with a broad zero object. For instance, Emmit J. Nelson recommends "first setting the injury commitment to zero lost-workday cases." When that has been achieved, "the commitment can then become zero recordables" (Nelson 1996, p. 23). Even wider zero objects that include incidents (near accidents) are also common in workplace safety (Zou 2010).

Does a broad zero object, which includes incidents and minor accidents, divert attention and resources away from the most serious accidents, which should have top priority? Or is a broad approach, to the contrary, a superior way to prevent serious accidents, since it stops the beginnings of event chains that would later lead to a serious accident? The answer to these questions will depend on the extent to which the most serious accidents begin in the same way as the less serious ones, or as Sidney Dekker expressed it, "If preventing small things is going to prevent big things, then small and big things need to have the same causes" (Dekker 2017, p. 127).

In this respect, there are large differences between different types of accidents. Fires in households are an example with a large overlap. Most big fires in housing areas begin as small fires. The prevention of small home fires is therefore an efficient – and necessary – means to prevent big fires in housing areas. On the other hand, large accidents in a nuclear plant (such as those in Chernobyl in 1986 and Fukushima in 2011) do not typically start in the same way as small accidents in the same plants. Preventing accidents with handheld tools, or falls from scaffolding, in a nuclear plant, is of course important for its own sake. However, it does not usually contribute much to preventing the event sequences that end up in large accidents with massive emissions of radioactive material to the surroundings. There are similar situations in other industries. The BP Deepwater Horizon explosion in April 2010, which killed eleven workers and gave rise to the largest marine oil spill in human history, seems to be a case in point. The accident was reportedly preceded by six years of injury-free and incident-free operations on the rig. The explosion was the result of other types of failures than those that lead to smaller workplace accidents (Dekker 2017, p. 125). Zero tolerance in law enforcement is an interesting parallel case. Its efficiency depends on the degree to which the targeted minor offences are parts of the causal chains that lead to more serious, violent crimes. The failure of some zero tolerance programmes seems to have been due to lack of such overlaps in causal chains.

We can learn from examples like these that the choice between broad and narrow zero objects has to be informed by a careful analysis of overlaps between different kinds of undesirable event chains. This may of course result in broad zero goals being chosen in some areas and narrow goals in others.

Some organizations have a whole package of zero goals, referring, for instance, to different aspects of product quality, waste reduction, etc. Zero goals for workplace safety have often been integrated as one of several zeros in such combinations. It would not be unreasonable to worry that the safety-related zero will be outcompeted by other, perhaps more economically important, goals in the same package. However, experience reported in the literature indicates that inclusion in such comprehensive zero packages strengthens the safety goal by increasing management commitment (Twaalfhoven and Kortleven 2016, p. 65; Zwetsloot et al. 2017c, pp. 95–96):

> For example, Paul O'Neill, the former chief executive officer of aluminum manufacturer Alcoa, made a public commitment to his employees, the media, and investors that Alcoa would target zero accidents in its plants. He then made it the single most important performance metric for everyone in his organization, including himself. At the time O'Neill introduced this effort, many were concerned that Alcoa might be "overinvesting" in safety such that, on the margin, the benefits of added safety would be exceeded by the costs of the productivity lost in trying to achieve it. The history of Alcoa's efforts, however, suggested that there was no such trade-off between safety and productivity. In fact, O'Neill's aspirational push led to improvements on both dimensions for Alcoa. (Huckman and Raman 2015, p. 1811)

But obviously, such a conflict-free relation between safety and productivity cannot be taken for granted. Equally obviously, safety goals may have to be pursued even when they clash with other important goals. (Zwetsloot and co-workers (2017a, p. 261) report that "commitment to product safety in the Chinese industry may decrease the commitment to work safety," but no confirmation of that claim could be found in the source referred to.)

The Zero Subject

Since the early twentieth century, two major approaches to responsibilities for accidents and other untoward events have been prominent in safety management.

One of them is the *environmental theory* that received much of its scientific basis in the work that the American sociologist Crystal Eastman (1881–1928) presented in a seminal book on workplace accidents, published in 1910. Based on detailed investigations of a large number of accidents, she showed that the same types of accidents were repeated again and again and that they could be prevented by appropriate measures on the workplace. This approach put the responsibility for workplace safety on employers, in contrast with two attitudes that were common at the time, namely, that accidents were unavoidable "acts of God" and that they were the results of workers' carelessness. Eastman's work had considerable influence in safety engineering, and it was instrumental in the creation of a worker's compensation law. Safety work in this tradition, with its emphasis on technological and organizational measures that make workplaces less dangerous, has been instrumental in reducing risks of accidents on all kinds of workplaces (Swuste et al. 2010).

In the 1920s, psychologists Eric Farmer and Karl Marbe independently developed another approach, often called the *accident-proneness theory*. Their basic idea was that most accidents are caused by a minority of workers who behave dangerously on the workplace. Therefore, accidents could be avoided by psychological testing that would identify and exclude these workers (Swuste et al. 2010, 2014). However, contrary to the environmental theory, the accident-proneness theory did not contribute much to improved safety. No tests were developed that could identify workers with an increased proneness to accidents. In addition, the basic assumptions of the theory turned out not to hold. For instance, much of its alleged scientific support came from studies showing that accidents are quite unevenly distributed among workers in the same workplace. This could of course depend on some workers having more dangerous tasks and working conditions than others. Such differences were not taken into account in these studies, and therefore, no conclusions can be drawn from them (Rodgers and Blanchard 1993). The theory fell into disrepute among safety professionals, but it has not entirely died out. Various attempts have been made to revive it, but it is still fraught with the problems that caused its decline in the 1950s and 1960s. In 1975, the road safety researcher Colin Cameron summarized the situation as follows:

> For the past 20 years or so, reviewers have concluded, without exception, that individual susceptibility to accidents varies to some degree, but that attempts to reduce accident frequency by eliminating from risk those who have a high susceptibility are unlikely to be effective. The reduction which can be achieved in this way represents only a small fraction of the total. Attempts to design safer man–machine systems are likely to be of considerably more value. (Cameron 1975, p. 49)

This conclusion still stands. Or as Sidney Dekker, another safety researcher, concluded in a recent review of the literature:

> The safety literature has long accepted that systemic interventions have better or larger or more sustainable safety effects than the excision of individuals from a particular practice. (Dekker 2019, p. 79)

The contrast between the environmental theory and the accident-proneness theory comes out clearly in the above review of zero targets and goals. Most of the zero goals have been operationalized in the tradition of the environmental theory. That applies, for instance, to Vision Zero in traffic safety and to most of the zero targets for workplace safety. However, there are also zero goals with a strong focus on correcting or removing individuals whose behavior is deemed undesirable. The clearest example of this is zero tolerance in law enforcement. Notably, applications of Vision Zero in traffic and workplace safety have on the whole been successful, whereas zero tolerance in law enforcement has largely been abandoned since it did not deliver. Against the background of previous experiences with the two major approaches to safety, this should be no surprise.

But obviously, an environmental, or as we can also call it, system-changing, approach to safety should not be taken as a reason for individuals to be careless about safety and leave everything to the system. Individual attention to safety is still needed. Furthermore, improvements of safety do not come by themselves. They require individuals who propose, demand and implement them.

Improvement Principles

The various zero targets and goals refer to different categories of risks, but their common message is that no level of risk above zero is fully satisfactory. Consequently, improvements in safety should always be striven for as long as they are at all possible. Several other safety principles have essentially the same message. Among the most prominent of these are continuous improvement, as low as reasonably achievable (ALARA) and best available technology (BAT). These principles differ in their origins, and they are used in different social areas, but they all urge us to improve safety whenever we can do so. We can call them *improvement principles* (Hansson 2019).

Continuous Improvement

The so-called quality improvement movement in industrial management originated in the United States in the 1920s and 1930s. Walter A. Shewhart (1891–1967), W. Edwards Deming (1900–1993) and Joseph Moses Juran (1904–2008) were among its most important pioneers. Their focus was on the quality of industrial products and production processes, which they succeeded in improving by means of new methods of quality control and new ways to incentivize workers. Their ideas were adopted not only in the United States but even more in Japan, whose fledgling export industry was struggling to wipe out its reputation for producing low-quality products. The widespread adoption of American ideas of quality improvement has often been cited as an explanation of the so-called Japanese economic miracle, a long period of economic growth that began after World War II and lasted throughout the 1980s (Bergman 2018, p. 333; Berwick 1989, p. 54). Japanese companies with strict devotion to quality throughout their organization often achieved results that astonished Western visitors:

> When a team of Xerox engineers visited Japan in 1979, they discovered that competitors were manufacturing copiers at half of Xerox's production costs and with parts whose freedom from defects was better by a factor of 30. (Abelson 1988)

The word "kaizen," which means "improvement," was used in the Japanese quality improvement movement as a general motto, covering all the aspects in which industrial products and processes should be improved. In English, "kaizen" has frequently, but not quite accurately, been translated as "continuous improvement," abbreviated CI (Singh and Singh 2009). With this terminology, the quality improvement ideas developed in the United States in the 1920s and 1930s were reimported into the United States and other Western countries in the 1980s and 1990s. The main ideas were summarized by a group of British management researchers as follows:

> In its simplest form CI can be defined as a *company-wide process of focused and continuous incremental innovation*. Its mainspring is incremental innovation–small step, high frequency, short cycles of change which taken alone have little impact but in cumulative form can make a significant contribution to performance. (Bessant et al. 1994, p. 18)

The concept of continuous improvement also found resonance in the safety professions. However, in spite of its origin in industrial management, it is not in workplace safety but in patient safety that continuous improvement has been most successful. Beginning in the 1980s, professionals working with patient safety in hospitals and clinics around the world have adopted continuous improvement as an overarching idea for their activities (Batalden and Stoltz 1993; Bergman 2018; Berwick 1989, 2008; Berwick et al. 1990). A major reason for its success in healthcare is that continuous improvement fits well into the evaluation culture in modern healthcare, with its use of standardized treatment protocols. Just as in industrial management, continuous improvement in healthcare means that there is no "optimal quality level beyond which further improvement would not be worth the incremental cost of achieving it"; to the contrary, "each instance of improvement is an invitation to consider options for further improvement" (Huckman and Raman 2015, p. 1811). This way of thinking is very much in agreement with Vision Zero and other zero goals.

There is also another interesting similarity between continuous improvement and Vision Zero: They both tend to be closely aligned with the environmental approach to accidents and other untoward events (cf. section "The Zero Subject"). Although doctors and nurses are still personally responsible for the treatments they recommend and administer, the focus in healthcare is shifting away from individual weaknesses to weaknesses in routines, technologies and organizational structures (Kohn et al. 2000). The reason for this is that, perhaps in particular in healthcare, "defects in quality could only rarely be attributed to a lack of will, skill, or benign intention among the people involved with the processes" (Berwick, 1989, p. 54). The need for an organizational focus in patient safety was explained as follows by two researchers in healthcare management:

> M[aintenance] O[f] C[ertification] aims to certify that individuals are proficient in their target responsibilities. This individual certification offers some degree of reassurance to patients who want to know that they are receiving treatment from qualified physicians. Continuous process improvement, however, assumes that quality primarily depends on the process, not simply the individuals who execute it. A central tenet of continuous process improvement is that the problem must be separated from the person. This recognition is important for at least [two] reasons. First, it focuses attention on the process, which is often the root cause of a defect. Second, it makes it safe for workers to highlight issues without concern that they or their colleagues will experience adverse consequences, such as being blamed as the source of the problem. (Huckman and Raman 2015)

In healthcare, continuous improvement has mostly been applied as a principle only for safety. It has usually not been directly aligned with improvements in terms of other goals, such as cost containment or increased productivity. In contrast, the application of continuous improvement in industrial safety is usually part of a more general management strategy, which also includes improvements in other respects than safety. Cost reduction is often a dominant criterion of what constitutes an improvement (Baghel 2005, pp. 765–766). In the literature on continuous improvement, examples are often given that show how productivity, quality, safety and economic output can all be improved at the same time. Potential conflicts among these goals are less often discussed. A prominent exception can be found in a 2002 report from the Nuclear Energy Agency of the OECD on improvements in nuclear plants:

> The modern equipment often detects cracks and faults in components and welds that were undetectable by the equipment available when the plant was constructed. If the plant has operated safely and reliably for many years, and there is good evidence that the defect is not "growing", should the regulator require the defect to be repaired, especially if the repair might degrade other safety features of the plant? Such questions present a real challenge to the regulator when he has to decide how to react to such new information and he must be clear whether he is requiring the licensee to maintain safety or to improve safety. The costs involved can be very great and, in the present financial climate, utilities are likely to mount strong challenges to requirements which they perceive go beyond the original design basis. . .
>
> The lesson for nuclear safety here may very well be: qui n'avance pas recule! [Who doesn't advance retreats.] (Nuclear Energy Agency 2002, pp. 11 and 17)

Similar situations may well occur in other areas and should then be discussed and dealt with in a transparent and responsible manner.

As Low as Reasonably Achievable (ALARA)

The as low as reasonably achievable (ALARA) principle originated in mid-twentieth century radiation protection.

Within 5 years after Röntgen's discovery of X-rays in 1895, researchers working with radioactive material noted that high exposures gave rise to skin burns. It was generally believed that exposures low enough not to produce such acute effects were innocuous, but some physicians warned that radiation might have unknown detrimental effects (Kathren and Ziemer 1980; Oestreich 2014). In the Manhattan project, which developed the first nuclear weapons, the radiologist Robert S. Stone (1895–1966) in the Health Division of the Metallurgical Laboratory in Chicago was assigned to determine "tolerance levels" for radiation exposures of workers. He reported that there was no known safe level for such exposures. Instead of fixed tolerance levels, he proposed that exposures should be kept as low as practically possible. His proposal was accepted (although some wartime exposures were very high, judged by modern standards) (Auxier and Dickson 1983).

After the war, this precautionary no-limit approach was much strengthened by growing awareness that exposure to ionizing radiation increases the risk of leukaemia. The risk appeared to be stochastic. It increases with increasing exposures, but researchers could not identify any "threshold dose," i.e. any exposure level above zero, below which the risk would be zero. Many scientists believed that the risk of radiation-induced leukaemia was approximately proportionate to the radiation dose (the "linear dose-response model") (Lewis 1957; Brues 1958; Lindell 1996). In consequence, Robert Stone's approach was adopted by the US National Committee on Radiation Protection (NCRT). In a 1954 statement, they declared that radiation exposures should "be kept at the lowest practical level" (Auxier and Dickson 1983). In 1958, the International Commission on Radiological Protection (ICRP) took a similar standpoint, based on a review of what was then known about the dose-response relationships of leukaemia and other cancers:

> The most conservative approach would be to assume that there is no threshold and no recovery, in which case even low accumulated doses would induce leukaemia in some susceptible individuals, and the incidence might be proportional to the accumulated dose. The same situation exists with respect to the induction of bone tumors by bone-seeking radioactive substances. . .
>
> It is emphasized that the maximum permissible doses recommended in this section are *maximum* values; the Commission recommends that all doses be kept as low as practicable, and that any unnecessary exposure be avoided. (ICRP 1959, pp. 4 and 11)

This recommendation has been reconfirmed in a long series of decision by the ICRP. In 1977, it was rephrased as a requirement that "all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account" (ICRP 1977, p. 3). This principle goes under many names. Apparently, it was first called "as low as practicable" (ALAP), but that name was soon replaced by "as low as reasonably achievable" (ALARA) and "as low as reasonably practicable" (ALARP) (Wilson 2002). Currently, it is known under the following names and abbreviations (Reiman and Norros 2002; Nuclear Energy Agency 2002, p. 14; HSE 2001, p. 8):

As low as practicable (ALAP)
As low as reasonably achievable (ALARA)

As low as reasonably attainable (ALARA)
As low as reasonably practicable (ALARP)
So far as is reasonably practicable (SFAIRP)
Safety as high as reasonably achievable (SAHARA)

ALARA is now recognized worldwide as a principle for radiation protection. It is usually applied to collective doses (i.e. the sum of all individual doses in a plant or an activity), rather than to individual doses. It is therefore often seen as a utilitarian principle. However, it is combined with upper limits for individual exposures, which can be interpreted as based on deontological principles (Hansson 2007a, 2013b). In most countries, this principle is not much used outside of radiation protection. The major exception is Britain, where it has an important role in general worker's health and safety. In this application, it is mostly applied to individual risks (HSE 2001).

In the interpretation of ALARA, it is essential to pay attention to the meaning of the term "reasonable" (alternatively "achievable" or "practicable," in other names of the principle). This term is often used in legal texts such as regulations and rulings, where it has two major functions (Corten 1999). First, it makes regulations adaptable and allows their interpretation to be adjusted to circumstances unforeseen by the lawmaker. In this way, the word "reasonable" can resolve "a contradiction between the essentially static character of legal texts and the dynamic character of the reality to which they apply" (ibid., p. 615). Secondly, references to reasonableness provide legitimacy to a legal order "by presenting an image of a closed, coherent and complete legal system." The notion "masks persistent contradictions regarding the meaning of a rule, behind a formula which leaves open the possibility of divergent interpretations" (ibid., p. 618).

The reasonableness of the ALARA principle (the "R" in the acronym) appears to have both these functions. The first function becomes apparent in the use of "reasonableness" in adjustments to various kinds of economic and practical constraints. It allows the ALARA principle to be "balanced against time, trouble, cost and physical difficulty of its risk reduction measures" (Melchers 2001). The second function shows up when divergences between safety and other considerations are "internalized" within safety management by treating certain potential solutions to safety problems as unreasonable, instead of presenting these divergences as conflicts to be resolved.

According to the original conception of ALARA, it applies to all non-zero risks. For instance, even very low radiation doses should be eliminated if this can be done. However, ALARA has often been reinterpreted so that it only applies to risks above a certain threshold of concern. Hence, the Health and Safety Executive (HSE) in Great Britain has introduced a three-levelled approach to risk, dividing risk exposures into three ranges. In the highest range, risks have to be reduced irrespective of the costs, and there is no need for ALARA considerations. In the lowest range, risks are assumed to be acceptable, which means that there is no need for reducing them, and consequently, ALARA does not apply. It is only in the medium range that ALARA-based activities are said to be applicable. According to the HSE's tentative limits for the three regions, the “ALARA region” comprises activities with an individual risk of death per year between one in a million and one in one thousand (HSE 2001, pp. 42–46). A similar three-levelled approach has also been proposed for exposures to ionizing radiation (Kathren et al. 1984; Hendee and Edwards 1986).

Such interpretations of ALARA, which disallow its application to risks below a certain level, regardless of how cheaply and easily they can be reduced, make ALARA considerably weaker than full-blown improvement principles such as Vision Zero and continuous improvement. The problems with such a weakening were eloquently expressed already in 1981 by two leading radiation protection experts, Bo Lindell (1922–2016) and Dan J. Beninson (1931–1994):

> [I]n each situation, there is a level of dose below which it would not be reasonable to go because the cost of further dose reduction would not be justified by the additional eliminated detriment. That level of dose, however, is not a *de minimis* level below which there is no need of concern, nor can it be determined once and for all for general application. It is the outcome of an optimization assessment which involves marginal cost-benefit considerations... It is not reasonable to pay more than a certain amount of money per unit of collective dose reduction, but if dose reduction can be achieved at a lesser cost even at very low individual doses, the reduction is, by definition, reasonable. (Lindell and Beninson 1981, p. 684)

Best Available Technology (BAT)

Probably the first legal requirement to employ the best practicable technology to solve environmental problems can be found in the British Alkali Act of 1874. After specifying in some detail how emissions of hydrogen chloride should be reduced, the Act continued:

> In addition to the condensation of muriatic acid gas [hydrogen chloride] as aforesaid, the owner of every alkali work shall use the best practicable means of preventing the discharge into the atmosphere of all other noxious gases arising from such work, or of rendering such gases harmless when discharged. (Anon 1874, p. 168)

The term “best practicable means” was interpreted as referring to both economic limitations and technological feasibility (Holder and Lee 2007, p. 331).

When new and more ambitious environmental regulations were introduced in the 1960s and 1970s, it was soon discovered that statutes requiring specific technological solutions have two important problems: They are *unadaptable*, since they do not allow industry to achieve the same effect with different technical means, and they are also *slow-moving* and tend to lag behind when new and better technological solutions become available. Regulations specifying maximal allowed emissions are more adaptable, since they leave it to industry to decide how to achieve the required emission standard. However, they are just as slow-moving as statutes requiring a specific technology (Sunstein 1991, pp. 627–628n; Ranken 1982, p. 162). Legislation based on the best available technology (BAT) was introduced as a way to solve both these problems and make legislation both adaptable and sufficiently fast-moving. The basic idea was to require use of the best available emission-reducing technology. Such a rule is technology neutral; if there are alternative ways to reach the best result, then each company can make its own choice among these alternatives. Furthermore, BAT statutes can stimulate innovations in environmental technology. If a new technological solution surpasses those previously available, then it becomes the new BAT standard to which industry must adjust.

A large number of synonyms and near-synonyms of "best available technology" have been used in different legislations, including the following (Merkouris 2012; Vandenbergh 1996; Ranken 1982):

Best available control technology (BACT)
Best available techniques (BAT)
Best available technology not entailing excessive costs (BATNEEC)
Best environmental practice (BEP)
Best practicable control technology (BPT)
Best practicable environmental option (BPEO)
Best practicable means (BPM)
Lowest achievable emissions rate (LAER)
Maximum achievable control technology (MACT)
Reasonably achievable control technology (RACT)

Several of the above terms, perhaps in particular LAER, can also be interpreted as variants of the ALARA principle. In some legislations, more than one of these concepts are used, often with different specifications. For instance, in American legislation, "best practicable control technology" (BPT) has been used for lower demands on emissions control than the stricter "best available technology" (BAT).

In the United States, BAT strategies were introduced in most environmental legislations in the 1970s and 1980s and became "a defining characteristic of the regulation of the air, water, and workplace conditions" (Sunstein 1991, pp. 627–628). Legislation based on the BAT concept has also been introduced in most European countries and in legislation on the European level. The European Directive on Industrial Emissions does not allow large industrial installations to operate without a permit that imposes emission standards based on best available techniques (Merkouris 2012; Schoenberger 2011). The BAT concept is also employed in several international treaties, such as the 1992 Convention on the Protection of the Marine Environment of the Baltic Sea Area (the Helsinki Convention) and the Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention) from the same year (Merkouris 2012).

BAT requirements are widely used in emissions control. However, there is one major category of emissions for which they are not much used: Legislation on the limitation and reduction of greenhouse gas emissions has in most cases been based on other regulatory principles, including standards based on current technologies and tradable emission permits. Perhaps surprisingly, the BAT concept does not either seem to have been used systematically in safety legislation. For instance, type approval and similar procedures for motor vehicles, aircraft, electrical appliances, etc. are based on well-defined technical standards, and there does not seem to be a movement towards replacing such standards by reference to the best available technology. Proposals have sometimes been made to apply the BAT concept to other areas than emissions control, but with relatively little success (Helman and Parchomovsky 2011). One of the few cases in which BAT principles have been applied to safety is the 1967 guidelines for the safety standards to be developed by the US National Highway Traffic Safety Administration. Such standards were to be "stated in terms of performance rather than design specifying the required minimum level of performance but not the manner in which it is to be achieved" (Blomquist 1988, p. 12).

Just as the stringency of ALARA principles depends on how the R ("reasonable") is interpreted, the stringency of BAT principles hinges on the interpretation of the A ("available"). Originally, BAT regulations did not require a cost-benefit analysis. This has often been an advantage from the viewpoint of safety. For instance, this made it possible for American regulators to ensure that offshore technologies "truly implement the best available technology as opposed to technology that is only economically convenient" (Bush 2012, p. 564). However, in some BAT regulations, "available" is interpreted as economically feasible. This has led to the linguistically somewhat awkward situation that there are technologies on the market that are better than the "best available technology" (but too expensive). Such technologies have been called "beyond BAT" (Schoenberger 2011).

On the other hand, there are cases in which not even the best technology that is at all available (at any price) is good enough to protect the environment. In some such cases, regulatory agencies have been authorized to impose requirements stricter than the BATs in order to achieve sufficient protection of the environment (Vandenbergh 1996, pp. 837–838 and 841). Some authors claim that BAT regulations are inadequate since they put focus on what can currently be done rather than on what is most important to do, thereby distracting "from the central issue of determining the appropriate degree and nature of regulatory protection" (Sunstein 1991, p. 629; cf. Ackerman and Stewart 1988, pp. 189–190).

Summary

The improvement principles that we have studied in this and the previous section have much in common. They all carry the same basic message, namely, that as long as improvement in safety is possible, it should be pursued. They therefore serve as antidotes to fatalism and complacency.

None of this disallows economic and other competing considerations from having a role in determining the pace and means of implementation. It would be futile to prescribe that all improvements should be implemented immediately, regardless of costs. But there is an important difference between postponing a safety improvement and dismissing it altogether. When compromises with other social objectives are necessary, the improvement principles induce us to see these compromises as temporary, unsatisfactory concessions. This is a clear signal that currently unrealistic safety improvements should be pursued if and when they become realistic and that innovations that put them within reach are most welcome.

However, several of the improvement principles have been subject to reinterpretations that dismiss instead of postpone currently unrealistic safety improvements. For ALARA, this has taken the form of interpreting the R ("reasonable") as excluding the reduction of comparatively small risks, even if such reductions can be done with very small effort and sacrifice. For BAT, the A ("available") has been reinterpreted so that costly but affordable reductions in emissions are not required. It is one of the advantages of Vision Zero and other zero goals that they do not easily lend themselves to such debilitating reinterpretations.

Aspiration Principles

The improvement principles form part of a larger group of safety principles, namely, those that tell us what levels of safety or risk reduction we should aim at or aspire to. This larger group can be called the *aspiration principles* (Hansson 2019). As shown in Fig. 1, we can distinguish between three major types of aspiration principles, in addition to the improvement principles.

Acceptance principles draw a line between acceptable and unacceptable risks. That limit depends on the risks alone, without taking the benefits that come with the risks into account. We will consider three types of acceptance principles: *risk limits*, *exposure limits* and *equipment and process regulations*.

Weighing principles require that we weigh safety against other objectives, such as productivity and economic gains, and strike a balance between them. Whereas acceptance principles usually have an affinity with deontological (duty-based) moral thinking, weighing principles have much in common with consequentialist ethics. We will discuss three types of weighing principles, namely, *cost-benefit analysis*, *individual cost-benefit analysis* and *cost-effectiveness analysis*.

Finally, we will discuss *hypothetical retrospection*, a safety principle requiring that our decisions will be defensible also in the future.

Risk Limits

In the early days of risk analysis, some risk analysts maintained that all dangers falling below a certain *risk limit* are acceptable. That limit was usually expressed as a probability of death, often a "cut-off level of 10^{-6} individual lifetime risk [of death]" (Fiksel 1985, pp. 257–258). That idea has now largely been replaced by more sophisticated approaches that weigh risks against the benefits they are accompanied by. However, the idea of a risk limit has repeatedly been revived, usually under the auspices of a "de minimis" position in risk regulation, according to which there is a probability threshold, below which a risk is always acceptable even if it comes without any advantages.

It does not take much intellectual effort to see that this is an untenable approach (Pearce et al. 1981; Bicevskis 1982; Otway and von Winterfeldt 1982; Hansson 2013a, pp. 97–98). To begin with, since the "de minimis" principle is applied to each risk individually, it does not protect us against large cumulative effects of a large number of risks, each of which falls below the limit. For instance, in modern societies, we are exposed to a large number of chemical substances. If each of them were to give rise to a "de minimis" risk, the combination of them all could nevertheless be far above the risk limit.

More fundamentally, even risks with very low probabilities are clearly unjustified if they bring nothing good with them. For a simple example, suppose that someone constructs a bomb connected to a random generator, such that the probability is 10^{-9} that the bomb will detonate. The bomb has been covertly mounted in a place where it will kill exactly one (unsuspecting) person if it explodes. The risk associated with such a device is "de minimis" according to the usual criteria. However, it is clearly unacceptable, for the simple reason that it imposes a frivolous, completely unjustified risk on a person who did not ask for it. On the other hand, we routinely take risks of 10^{-9} or higher in order to gain some advantage. Travelling an hour by car is one example of this (International Transport Forum 2018, p. 21). We can conclude from examples like this that the acceptability of a risk imposition cannot be determined based only on the size of the risk. Other factors, such as the associated benefits, have to be taken into account, even if the risk is very small. Reliance only on the size of the risk has been called the "sheer size fallacy" in risk analysis (Hansson 2004a, pp. 353–354).

Exposure Limits

Our second group of acceptance principles is *exposure limits*, numerical upper bounds on allowable exposures to chemical substances and to physical hazards such as noise and radiation. Exposure limits can be based on the same types of considerations as risk limits, but they are much easier to implement, since exposures can usually be measured with well-established chemical and physical methods.

The first limits for occupational exposures were proposed by individual researchers in the 1880s. In the 1920s and 1930s, several lists were published in both Europe and the United States, and in 1930, the USSR Ministry of Labor issued what was probably the first official list (Cook 1987, pp. 9–10). In 1946, the American Conference of Governmental Industrial Hygienists published the first edition of their list. This list, which is revised yearly, has long been a standard reference for official lists all over the world. Since the 1970s, most industrialized countries have their own lists of occupational exposure limits. Exposure limits for ambient air were introduced in the same period (Greenbaum 2003). In food safety, exposure limits were introduced in the 1960s under the name of "acceptable daily intake" (Lu 1988).

The first proposed exposure limit for ionizing radiation was published in 1902. It aimed to protect against the acute effects, but it was based on a rather primitive and unreliable method of measurement. In the 1920s and 1930s, improved methods for dose measurements were developed and put to use in the implementation of more precise exposure limits. In the 1950s, exposure limits were adjusted to take the long-term carcinogenic effects of ionizing radiation into account (Parker 1980, pp. 970–971; Broadbent and Hubbard 1992).

Ideally, one might hope that exposure limits should guarantee safety, in the sense that exposures below the limits impose no risk. Unfortunately, that is often not the case, for three major reasons. First, many standards, in particular those for occupational exposures, result from compromises with economic considerations. This has often led to exposure limits at levels that are known to be associated with occupational disease (Hansson 1997b, 1998a, b; Johanson and Tinnerberg 2019). These risks can be considerable for the average worker, but they are even greater for workers who are particularly sensitive, for instance, due to pregnancy or prior disease (Johansson et al. 2016; Hansson and Schenk 2016). Secondly, long-term effects of chemical exposures are difficult to determine, and some exposure limits that were believed to be safe have later been shown to be unsafe due to previously unknown effects of the substance. One example of this is the drastic reduction of the exposure limit for vinyl chloride from 500 ppm (parts per million) to 1 ppm when the carcinogenicity of this substance was discovered in 1974 (Soffritti et al. 2013). Thirdly, for many carcinogenic substances, it is impossible to determine a risk-free exposure level above zero. The best estimate seems to be that the risk of cancer is proportional to the exposure, which means that every non-zero exposure limit is associated with an implicit level of accepted risk. For all these reasons, exposure limits should not be considered as safe limits. Gains in safety can be expected if exposures are reduced as far below current exposure limits as possible.

Exposure limits are constructed to have a very wide application. Occupational exposure limits for chemical substances apply to all workplaces where the substances are used. Similarly, air quality standards for ambient air apply to outdoor air everywhere in the jurisdiction. This general applicability is unproblematic for health protection if the exposure limit represents a level below which there are no adverse effects on the exposed population. However, if the limit represents a compromise between health protection and economic considerations, then the general applicability tends to lead to exposure limits that are unnecessarily high in many of the places where they apply. This is because economic considerations at the places where exposure reductions are expected to be most costly tend to dominate the standard-setting process. A classic example of this is the exposure limit of 1 ppm for the carcinogenic substance benzene that was adopted by the US Occupational Safety and Health Administration in 1987. Values lower than this were considered infeasible due to excessive compliance costs in the petrochemical, coke and coal industries. However, only 2.2% of the workers exposed to benzene worked in these industries (Rappaport 1993, p. 686). The remaining 97.8% of American workers exposed to benzene, about 230,000 workers, had a weaker protection against benzene than what would have been economically feasible in their own branches of industry.

It is not unreasonable to ask: If workers in a particular industry have to be exposed to high levels of a hazardous substance, is that really a reason to accept equally high levels in other industries where it would be comparatively easy and inexpensive to comply with a considerably lower exposure limit? An alternative approach in this situation would be to adopt a lower general exposure limit that is realistic on most workplaces, in combination with regularly reviewed, higher, exception values for branches of industry that are not yet capable of complying with the general value (Hansson 1998a, pp. 106–109).

Process and Equipment Regulations

Our third group of acceptance principles is *process and equipment regulations.* Regulations requiring machines to be equipped with certain safety features have a long tradition, in particular in occupational safety. In Britain, already the pioneering Factories Act of 1844 contained stipulations on both equipment and work processes. All mill gearing, as well as certain other moving parts of machines, had to be securely fenced. Furthermore, it was prohibited to use children or young workers to clean the mill gearing while it was in motion (Hutchins and Harrison 1911, pp. 85–87; Tapping 1855, pp. 43–47). This was the beginning of increasingly strict regulations on equipment and processes, which have contributed much to the reduction of many types of workplace injuries. Hand injuries from mechanical power presses are among the best known examples.

Such regulations have been equally important in road vehicle safety. Since its beginnings in the late nineteenth century, the legislation on motor vehicles has developed gradually from an almost exclusive focus on driver behavior to increasingly strict requirements on vehicle construction. For instance, the first British legislation on motor cars was the Locomotives on Highways Act of 1896, in which motor cars were called “light locomotives.” That legislation was focused on the behavior of drivers, who were required to have a license, which could be suspended in case of misconduct. A general speed limit of 14 mph (23 km/h) applied to all “light locomotives.” In the detailed regulations based on the Road Traffic Act of 1930, much more emphasis was put on the construction of vehicles, which were, for instance, required to have unimpaired view ahead, safety glass in windscreens and rear-view mirrors. This was followed in 1937 by requirements for windscreen wipers and speed indicators (Tripp 1938). In the 1960s, important further steps were taken in many countries towards making vehicles safer (Furness 1978). The United States had an important role in this development. The National Traffic and Motor Vehicle Safety Act of 1966 introduced a new way of thinking about traffic safety. A federal agency, the National Highway Traffic Safety Administration, which is still in operation, was created with the explicit task to make manufacturers produce vehicles with reduced risk of crashes and improved protection of the occupants of the vehicle in case of a collision (Mashaw and Harfst 1987; Blomquist 1988). The general approach taken by the administration was to reduce traffic casualties as much as possible. This was noted by economist Glenn Blomquist in a book criticizing their approach:

> Each year the NHTSA [National Highway Traffic Safety Administration] prepares a report on its activities under the Vehicle Safety Act. Each year changes in the number of traffic fatalities and in the fatality rate (per vehicle miles) are described. Some years the fatalities and rates are up and some years the fatalities and rates are down compared to previous years. Every year, however, the implication is the same: the traffic safety problem deserves more attention than ever before. Travel risks are not zero despite effective policy is the contention. The reasoning seems to be if fatalities and rates are up then more aggressive policy is needed to bring them down, and if fatalities and rates are down, then more aggressive policy is needed to reduce them further. (Blomquist 1988, pp. 115–116)

According to Blomquist, this showed that the NHTSA entertained a "risk-free goal." In his view, such a goal is "unwise and futile" since "no agency will ever have sufficient power or resources to completely control individual behavior" (ibid., p. 115). There is of course another side to this; with a more positive view on zero goals, the NHTSA can instead be described as a forerunner of a modern, more progressive approach to technology improvement.

Today, the development of safety standards for motor vehicles is largely driven through international cooperation, in which the World Forum for Harmonization of Vehicle Regulations has a central role. In this and other areas, technological safety regulations tend to be quite specific on what is required, and best available technology (BAT) clauses are seldom if ever used. However, in areas such as motor vehicle safety where regulators actively follow the technology development in detail, technological improvements can still be introduced by timely amendments of regulations.

Cost-Benefit Analysis

We will now turn to the next main category of aspiration principles, namely, weighing principles. These are principles demanding the weighing of safety objectives against various other objectives with which they may run into conflict, such as ease of work, product quality, environmental protection, productivity, cost containment and economic gains. Most of the discussion has focused on conflicts between safety and economic limitations, but in practice, safety concerns can also clash with various non-economic constraints and objectives. The dominant weighing principle is cost-benefit analysis (CBA). It is a powerful economic tool, but it is based on simplifying assumptions that are far from unproblematic.

The basic idea of cost-benefit analysis is quite simple: In order to compare the advantages and disadvantages of decision alternatives, they are all assigned a monetary value. Suppose that a proposed new road project costs 25 million euros. Furthermore, it is expected to lead to a total reduction in traffic time for all its users of 6,000,000 hours and the loss of four unique local species of hoverflies. We assign the value of 5 euros to each gained hour and the value of 1 million euros for each hoverfly species. If these are the only factors to be taken into account, then the total value of the project is as follows:

$$5 \times 6,000,000 - 4 \times 1,000,000 - 25,000,000 = 1,000,000 \text{ euros.}$$

Since the total value is positive, the analysis recommends that the road be built. A major problem in this example is of course how to determine the economic values of travel time and lost species. Proponents of cost-benefit analysis emphasize that since we do not have unlimited amounts of money, there is no way to avoid weighing non-monetary values against monetary costs. For instance, we take measures to save a hoverfly species if doing so does not cost much, but we will not do it at any price. According to the proponents of cost-benefit analysis, the major difference is that with this method, we make these decisions transparently, basing our decisions on known prices, rather than unarticulated intuitions. If we use the same monetary values in different decisions, then we can also achieve increased consistency in our decision-making processes.

When cost-benefit analysis is applied to safety decisions, uncertain outcomes will have to be included in the analysis. This is usually done by assigning to each such outcome the best available estimate of its expectation value (probability-weighted value). For instance, suppose that 200 deep-sea divers perform an operation in which the risk of death is 0.001 for each individual. Then, the expected number of fatalities from this operation is $0.001 \times 200 = 0.2$. If we apply a “value of life” of 3 million euros, then the monetary cost assigned to this series of dives is 0.6 million euros.

Cost-benefit analysis involves a rather radical simplification of multidimensional real-life problems in order to make them accessible to a transparent and easily manageable one-dimensional analysis. Unsurprisingly, this gives rise to a host of philosophical and interpretational issues (Hansson 2007c). Here, we will focus on four problems that are highly relevant for safety applications, namely, incommensurability, incompleteness, collectivism and complacency.

By incommensurability between two values is meant that they are so different in nature that no translation between them is possible. Probably the most common criticism of cost-benefit analysis is that it violates the incommensurability between human life and money. The assignment of a monetary value to human lives is said to violate the sanctity of life (Anderson 1988; Sagoff 1988; Hampshire 1972, p. 9). One reason why this criticism is so widespread may be that cost-benefit analysts have failed to explain the difference between the calculation values used in their analyses and prices on a market. The assignment of a sum of money to the loss of a human life does not imply that someone can buy another person, or the right to kill her, at that price. A more serious problem may be the arbitrariness of the values used in cost-benefit analyses. Not only do we lack a well-founded answer to what calculation value should be used for the loss of a human life. We also lack definite answers to questions such as how many cases of juvenile diabetes correspond to one death or what amount of human suffering or death corresponds to the extinction of an antelope species. Methods have been developed to determine monetary values for these and other seemingly non-monetary assets, but these methods are all fraught with uncertainty, and none of them has a reasonably sound philosophical foundation (Heinzerling 2000, 2002; Hausman 2012).

By incompleteness is meant in this context that factors that could legitimately have an influence on a decision are left out of the analysis. Even quite extensive cost-benefit analyses of societal projects tend to leave out decision effects that are difficult to express in quantitative terms. This applies, for instance, to risks of cultural impoverishment, social isolation and increased tensions between social strata. Such issues may nevertheless be important considerations for decision-makers. Unfortunately, there is often a trade-off between attempted solutions to the incompleteness problem and incommensurability problems. In order to solve incompleteness, we would have to assign monetary value to additional potential effects, such as social incohesion, which are extremely difficult to monetize. But by doing so, we would aggravate the problem of incommensurability.

The collectivism of standard cost-benefit analysis is a consequence of its aggregation of all effects to a single number, irrespectively of whom they accrue to. In our above example of a road project, the reduction in travel time was judged by the total sum for all travellers, 6,000,000 h. The distribution of these gains has no influence on the analysis. This net gain could, for instance, arise as a result one million long-distance travellers gaining 7 h each, whereas each of five thousand local travellers has to spend 200 h more travelling. This would be very different from a situation where only one hundred thousand travellers were affected, and they all gained 60 h each (Nordström et al. 2019). Standard cost-benefit analysis makes no difference between these two situations, since the total net effect on travel time is the same. Even worse, cost-benefit analysis treats serious risks such as death risks in the same way. Distributional issues are simply not part of its standard considerations. This is of course particularly problematic if the benefits and the disadvantages of a project are received by different groups of people.

The complacency induced by cost-benefit analysis consists in its tendency to foster acceptance of those evils that cannot currently be rectified with a positive cost-benefit analysis. For an example, suppose that a country has a large number of unguarded railroad crossings in thinly populated areas. Each year, several fatalities are caused by collisions between trains and vehicles or pedestrians passing one of these crossings. The number of fatalities can be drastically reduced by installing traffic lights and half-barrier gates, operated by the rail traffic control system. However, this would be much too expensive, due to the large number of crossings in places with few road users. The message of a cost-benefit analysis in such a situation would be that the life-saving traffic control system is simply not optimal and cannot be defended. In contrast, the message emerging from Vision Zero or other improvement principles would be that the life-saving system is indeed desirable but cannot be implemented at present, due to other, even more pressing priorities. The latter message has the obvious comparative advantage of being more conducive to cost-reducing innovations and more promotive of continued social activities in the issue.

But as already mentioned, there are other ways to balance advantages against disadvantages. In the next two subsections, we will briefly consider two alternatives to standard cost-benefit analysis.

Individual Cost-Benefit Analysis

In *individual cost-benefit analysis*, costs and benefits affecting different individuals are not added up. Instead, a separate cost-benefit analysis is made for each individual or, in practice, for each type of concerned individual (Hansson 2004b). For instance, in a road project, separate cost-benefit analyses can be made for categories such as local inhabitants, people driving a private car to and from work on the road and people travelling daily on it in buses. The outcomes of these different cost-benefit analyses will typically differ, and they may even point in different directions concerning the value of the project. This should not be seen as a disadvantage. A necessary first step towards solving conflicts of interest is to recognize them.

Cost-Effectiveness Analysis

The other, probably more important, alternative to standard cost-benefit analysis is *cost-effectiveness analysis* (CEA), which compares costs and benefits by calculating cost-effect ratios. For instance, if the desired effect of a technological innovation in motor cars is to reduce the number of fatalities, then the outcome can be reported as the expected cost per life saved by introducing the innovation in question.

Cost-effectiveness is mostly applied to healthcare interventions, where the most commonly used ratios are (i) cost per life-year gained and (ii) cost per quality-adjusted life-year gained. (The number of saved quality-adjusted life-years is the product of the number of saved life-years with a factor that is 1 if these are years lived in good health but smaller if they are years lived with a severe medical condition.) For instance, a French study investigated the costs and effects of smoking cessation counselling and treatment. It showed an average expected cost of less than 4000 euros per life-year gained (Cadier et al. 2016). Other studies of smoking cessation give similar results. This is an unusually low cost for a life-saving medical intervention, and smoking cessation is therefore an unusually cost-effective medical intervention.

Cost-effectiveness studies are comparatively uncommon outside of the healthcare sector, but there are plenty of examples showing their usefulness. For instance, in studies intended to guide energy saving in buildings, it is highly useful to calculate the cost per kWh energy saved with different energy efficiency measures (Tuominen et al. 2015). Houseowners and other decision-makers can then obtain maximal energy savings for their money by giving priority to the most cost-efficient measures. The cost-efficiency approach appears to be much more appropriate in this case than a cost-benefit analysis, which would divide the measures into two classes, those approved and those disapproved. Safety measures can also be evaluated in this way. For instance, one study showed that engineering control programmes to reduce silica exposure on workplaces are highly cost-effective; some such measures had a cost of only about USD 110 per quality-adjusted life-year (Lahiri et al. 2005; cf. Tengs et al. 1995).

Cost-effectiveness analysis is eminently useful when a proposed safety measure has to be evaluated in terms of its effects on safety and its cost, and no additional factors need to be taken into account. The application of this method is much less clear-cut if there are also other effects, say effects on the environment, that have to be taken into account. It can also be difficult to apply if the safety measure is an integrated part of some larger project. For instance, if a new road is built to replace an old unsafe road with too little capacity, then it is usually not possible to divide up the project costs between costs for increased safety and costs for increased capacity. But in the cases with well-defined costs for safety, cost-effectiveness analysis has distinct advantages over cost-benefit analysis and should probably be used more often.

Hypothetical Retrospection

Safety management is largely a matter of giving sufficient weight to untoward events that might happen in the future. A basic type of reasoning to that effect is the "foresight argument" (Hansson 2007b, p. 147). It urges us to take into account the possible effects of what we do now on what can happen later. The argument has both a deterministic and an indeterministic variant. As an example of the deterministic variant, some of the consequences of drinking excessively tonight can, for practical purposes, be regarded as foreseeable. As an example of the indeterministic variant, driving drunk substantially increases the risk of causing an accident, but of course, there is also a considerable chance that nothing serious will happen. Nevertheless, the increased risk is reason enough not to drink and drive.

The indeterministic variant of the foresight argument is highly useful for thinking about safety. It requires that we think through the various ways in which the future can develop and pay special attention to those "branches" of future development in which things go seriously wrong. It can therefore be described as the very antithesis of wishful thinking. Its purpose is to ensure, as far as possible, that whatever happens in the future, it will not give us reason to say that what we do now was wrong. To achieve this, we can systematically consider what we plan to do now from alternative future perspectives. This way of thinking is called *hypothetical retrospection*.

This may seem difficult and perhaps overly abstract, but it is in fact a way of thinking that we teach our children when trying to help them become responsible and thoughtful persons. "Do not leave all that homework to tomorrow! You know very well how you will feel tomorrow if you do so." "Save some of the ice-cream for tomorrow. You know that you will regret if you don't do it." And of course, as grown-ups, we sometimes wish that we had been more proficient at "thinking ahead" about various subject matter. To apply hypothetical retrospection in safety management means to methodically develop and apply that way of thinking in one's area of professional responsibility.

The following example exemplifies what this can mean in practice:

> A factory owner has decided to install an expensive fire alarm system in a building that is used only temporarily. When the building is taken out of use, the fire alarm has yet never

> been activated. The owner may nevertheless consider the decision to install it to have been right, since at the time of the decision other possible developments (branches) had to be considered in which the alarm would have been life-saving. This argument can be used not only in actual retrospection but also, in essentially the same way, in hypothetical retrospection before the decision. Similarly, suppose that there is a fire in the building. The owner may then regret that she did not install a much more expensive but highly efficient sprinkler system. In spite of her regret, she may consider the decision to have been correct since when she made it, she had to consider the alternative, much more probable development in which there was no fire but the cost of the sprinklers had made other investments impossible. (Hansson 2013a, pp. 68–69; cf. Hansson 2007b, pp. 148–149)

For most practical purposes, the application of hypothetical retrospection in safety management consists in following a simple rule of thumb: "Make a decision that you can defend also if an accident happens." The application of this principle will typically support strivings for risk reduction, and it is therefore concordant with zero goals and other improvement principles.

Summary

In this section, we have studied various aspiration principles, other than the improvement principles that were the topics of the two previous sections. Some of the principles discussed in this section tend to run into conflict with the improvement principles, since they support acceptance of conditions in which safety can still be improved. This applies in particular to cost-benefit analysis, risk limits and exposure limits. These principles share a major problem: they tend to support the presumption that the compromises that have been made (perhaps for good reasons) between safety and other social goals represent a satisfactory state of affairs, thus downplaying the need for future enhancements that go beyond them.

On the other hand, two of the aspiration principles that we have studied in this section, namely, cost-effectiveness analysis and hypothetical retrospection, are easily compatible with the improvement principles. Cost-effectiveness analysis, in particular, can serve as a priority-setting tool to support the application of Vision Zero, continuous improvement and other improvement principles. In a situation with limited economic resources, cost-effectiveness analysis can act as a pathfinder, helping to identify the largest improvements in safety that can be achieved as the next step.

Error Tolerance Principles

Two of the most important insights in safety engineering and safety management are that *things go wrong* and that *humans make mistakes* however much we try to avoid it. Therefore, it is not sufficient to reduce the risk of failures as much as we can. We also have to ensure that the consequences of failures are as small as possible. This is not a new insight. More than 500 years ago, Leonardo da Vinci (1452–1519) wrote as follows in one of his notebooks:

> In constructing wings one should make one cord to bear the strain and a looser one in the same position so that if the one breaks under the strain the other is in position to serve the same function. (Hart 1962, p. 321)

Some of the most important safety principles recommend that equipment, procedures and organizations be so constructed that failures have as small negative consequences as possible. We can call them error tolerance principles. In this section, we will have a close look at six such principles: fail-safety, inherent safety, the substitution principle, safety factors, multiple safety barriers and redundancy.

Fail-Safety

An equipment or procedure is *fail-safe* if it can "fail safely," which means that the system is kept safe in the case of a failure. Fail-safety can refer to two types of failure: device failure and human failure. The requirements of a fail-safe system have been usefully summarized as follows:

> The basic philosophy of fail-safe structures is based on:
> (i) the acceptance that failures will occur for one reason or another despite all precautions taken against them.
> (ii) an adequate system of inspection so that the failures may be detected and repaired in good time.
> (iii) an adequate reserve of strength in the damaged structure so that, during the period between inspections in which the damage lies undetected, ultimate failure of the structure as a whole is remote. (Harpur 1958)

The safety valve is a classic example of a design that makes a system fail-safe. Safety valves are mounted on pressure vessels in order to prevent explosions. (Other means to achieve the same effect are rupture disks, also called burst diaphragms, which act as one-time safety valves, and leak-before-burst design, by which is meant that a crack will give rise to pressure-releasing leakage rather than an explosion.) The origin of the safety valve is not known with certainty, but it is usually credited to the French physicist and inventor Denis Papin (1647–1713), in whose book from 1681 on pressure cookers it was first described (Papin 1681, pp. 3–4; Stuart 1829, p. 84; Le Van 1892, pp. 10–11). In the eighteenth century, safety valves became a standard feature of steam engines. However, enginemen soon found that they could be used to control the machine. Safety valves were frequently tied down or loaded with heavy objects in order to increase the working pressure. These work practices resulted in serious accidents (Hills 1989, p. 129). To prevent such calamities, engine makers provided steam engines with two safety valves. One of them could be operated by the enginemen, whereas the other was inaccessible to them. It could, for instance, be contained in locked, perforated box. This was common practice at the beginning of the nineteenth century (Partington 1822, pp. 80, 88, 90, 98, 100, 106, 107–108, 109, 114, 115, 116, 122 and Appendix, p. 76). In 1830, an American railway company applied it as a safety rule for their locomotives:

> There must be two safety valves, one of which must be completely out of the reach or control of the engine man. (Thomas 1830, p. 373)

Notably, the requirement of a tamperproof safety valve is an early example of a construction tailored to protect not only against machine failures but also against mistakes by the operators.

Another classic example of a fail-safe construction is the so-called dead man's handle (dead man's switch), a control device that has to be pressed continuously in order to keep a machine going or a vehicle moving. The term "dead man's handle" was used already in an American engineering magazine in 1902. The author emphasized that the motorman could only drive the train if he held the handle at all times "and should he drop dead or become disabled, the train will stop of itself, and will not run wild" (Anon. 1902). (However, the handle might not be released if the driver fell over it. Therefore, more advanced vigilance systems are used in modern trains.) Today, similar mechanisms can be found on lawnmowers and on handheld machines such as drills and saws.

A similar mechanism, triggered by device failure rather than human failure, was introduced in the early 1850s by the American inventor Elisha Otis (1811–1861) in his so-called safety elevator. The elevator car was equipped with brakes that automatically gripped the vertical guide rails if the tension of the cord was released, for instance, in the event of a cord break. This invention made elevators safe enough for general use, and it was one of the technical preconditions for the building of skyscrapers that began in the 1880s.

A fail-safe system should go to a safe state in the event of failure. However, technical systems differ in what that safe state is. Trains, lawnmowers, elevators and handheld electric drills can be made safe (or as safe as possible) by being stopped. In all these cases, fail-safety is achieved with a negative feedback that stops movement in the system if a failure occurs. The same applies to a nuclear reactor, in which dangerous conditions should lead to an automatic shutdown. In all these cases, the system is fail-safe if it is *fail-passive* (*fail-silent*) (Hammer 1980, p. 115). However, there are also technical systems in which safety requires normal operations to continue as long as possible even in the event of failure. This applies, for instance, to airplanes. In such cases, a fail-safe system should be *fail-operational* (*fail-active*). This is achieved if the device is sturdy enough to fulfil its function for a sufficient time after it is damaged. This is called *fault tolerance* (*damage tolerance*) and is often achieved with the help of *safety factors* or with *redundancy*, i.e. the duplication of vital components or functions.

Several alternative terms are used for fail-safety when it is primarily aimed to protect against human failures. A system is said to be *foolproof* (*idiot-proof*) if nothing dangerous happens when it is used incorrectly, tampered with or used in unintended ways. Design making a system foolproof is often called *defensive design*.

The Japanese term *poka-yoke* means mistake-proof. It is often used about constructions that prevent human mistakes from leading to product defects, rather than to safety problems.

In 1974, W.C. Clark proposed a distinction between the two terms safe-fail and fail-safe (Jones et al. 1975, p. 1n.). According to this proposal, “fail-safe policy strives to assure that nothing will go wrong,” whereas “safe-fail policy acknowledges that failure is inevitable and seeks systems that can easily survive failure when it comes” (Jones et al. 1975, p. 2). However, these definitions do not correspond to common linguistic practice. The term “safe-fail” is seldom used, and what Jones and co-workers called by that name is usually called “fail-safe.” What Jones and co-workers called “fail-safe” is designated by other terms, such as “inherent safety.”

Inherent Safety

By inherent safety is meant that untoward events are eliminated or made impossible. This contrasts with fail-safety, which reduces the negative effects of untoward events, rather than preventing them from happening. For a simple example, consider a process in which inflammable materials are used. If we replace them by non-inflammable materials, then we have achieved inherent safety. If we still have them but have reduced the consequences of a fire, for instance, by keeping them in containers at safe distance from all buildings, then we have achieved fail-safety.

This distinction has a long tradition. Around 1950, it became common to use the term “primary prevention” for measures against a disease that have the effect of “keeping it from occurring” and “secondary prevention” for “halting the progression of disease after early diagnosis” (Sabin 1952, p. 1270). These terms were soon adopted in accident prevention. In an article in an international road safety journal in 1961, the influential Norwegian civil servant Karl Evang wrote that the concepts of primary prevention (prevention of occurrence) and secondary prevention (prevention of progress) “have now been generally accepted in the field of preventive medicine.” He proposed that they should also be used in the area of traffic safety (Evang 1961, p. 42n).

“Primary prevention” is essentially a synonym of “inherent safety” and “secondary prevention” a synonym of “fail-safety.” The phrase “inherent safety” has been used at least since the 1920s (Bouton 1924), but it acquired its modern sense in the discussions that followed after the disastrous explosion in a chemical plant in Flixborough in June 1974, which caused the death of 28 persons and seriously injured 36. Trevor Kletz (1922–2013), a chemist working for one of the large chemical companies, showed that the accident would not have reached its catastrophic proportions if simple measures had been taken to reduce the hazards. Perhaps most notably, large quantities of inflammable chemicals had been stored close to occupied buildings. Based on these tragic experiences, Kletz proposed that whenever possible, the chemical industry should eliminate hazards rather than just try to manage them. He originally used the term “intrinsic safety” for this concept but soon replaced it by “inherent safety” (Kletz 1978). Four major types of measures are included in the concept of inherent safety that he and other safety professionals in the chemical industry have developed (Khan and Abbasi 1998; Bollinger et al. 1996):

Minimize (*intensify*): use smaller quantities of hazardous materials
Substitute: replace a hazardous material by a less hazardous one
Attenuate (*moderate*): use the hazardous material in a less hazardous form
Simplify: avoid unnecessary complexity in facilities and processes, in order to make operating errors less likely.

Full inherent safety, i.e. total absence of hazards, is seldom if ever achievable. Therefore, it is well advised to avoid the absolute term "inherently safe" and instead refer to "inherently safer" technologies and procedures. For instance, it may be impossible to eliminate an explosive reactant. Usually, it is nevertheless possible to substantially reduce the hazard it gives rise to by drastically reducing the inventories of the substance. One way to do this is to produce the substance locally in a continuous process. In terms of the four above-mentioned strategies, this means that minimization is chosen instead of substitution.

The disaster in a chemical factory in Bhopal, India, in 1984, illustrates this. With an official death toll of 2259, it is the largest accident in the history of the chemical industry, and it has also been called "the worst example of an inherently unsafe design" (Edwards 2005, p. 91). Methyl isocyanate, the substance that caused the calamity, was an intermediate that was stored in large quantities (ibid.). The final product could have been obtained from the same raw materials via an alternative chain of reactions in which methyl isocyanate is not produced. This and other alternative processes should have been considered. Even if a process involving methyl isocyanate was chosen, storage of large quantities of the substance could and should have been avoided.

In general, solving a problem with inherent safety is preferable to relying on interventions at later stages in a potential chain of events leading up to an accident. A major reason for this is that as long as a hazard still exists, it can be activated by some unanticipated triggering event. Even with the best of control measures, some unforeseen event can give rise to an accident. Even if a dangerous material is safely contained in the ordinary process, there is always a risk that it will escape, for instance, due to a fire, an uncontrolled chemical reaction, sabotage or an unusual mistake (Hansson 2010). Even the best add-on safety technology can fail or be destroyed in the course of an accident. An additional reason is that inherent safety is usually more efficient against security threats than fail-safety. Add-on safety measures, which are typically required for fail-safety, can often easily be deactivated by those who wish to do so. When terrorists enter the plant with the intent to blow it up, it does not matter much if all ignition sources have been removed from the vicinity of explosive materials. They will bring their own ignition source. Similarly, even if a toxic substance has been securely contained in a closed process, they can usually find ways to release it. In contrast, if explosive and toxic substances have been removed or their quantities drastically reduced, then the plant is safer, not only against accidents but also against wilfully created disasters.

Safety measures based on the ideas of inherent safety have contributed much to reducing hazards in the chemical industry (Hendershot 1997; Overton and King 2006). However, several commentators have complained that progress in the implementation of inherent safety is too slow (Kletz 2004; Edwards 2005; Srinivasan and Natarajan 2012). Indeed, 24 years after the Bhopal accident, investigations of a fatal accident at a chemical plant in West Virginia revealed considerable safety problems in the plant. A large inventory of methyl isocyanate, up to 90,000 kg, was stored on the plant. Luckily, no detectable release of the substance took place in the 2008 accident. (The death toll of the Bhopal accident was due to release of 47,000 kg of the same substance.) Inherently safer alternatives to this massive storage of the substance had previously been considered but had been rejected as too expensive (Ogle et al. 2015).

It has often been proposed that the ideas of inherent safety should be exported to other industries, including mining, construction and transportation (Gupta and Edwards 2003). However, the only other industry in which inherent safety has a major role is the nuclear industry. Much effort has been devoted to developing nuclear reactors that are inherently safer than those currently in use. By this is meant that even in the case of failure of all active cooling systems and complete loss of coolant, fuel element temperatures should not exceed the limits below which most radioactive fission products remain confined within the fuel elements (Elsheikh 2013; Adamov et al. 2015).

Several authors have discussed the application of inherent safety to the construction of road vehicles and infrastructure. Inherent safety is often mentioned as a means to make progress towards Vision Zero for traffic safety. One recurrent idea is that speeds should be kept at levels low enough for the inherent safety of the system to prevent serious accidents (Tingvall and Haworth 1999; Khorasani-Zavareh 2011; Hakkert and Gitelman 2014). Arguably, much ongoing work in the construction of safer road vehicles can be described as applications of the basic principles of inherent safety. However, contrary to the literature on chemical and nuclear engineering, the technical literature on vehicle safety seldom refers to the notion of inherent safety.

The Substitution Principle

As we saw in the previous subsection, the substitution of hazardous substances by less dangerous ones is one of the major methods to achieve inherent safety. Independently of the inherent safety principle, a "substitution principle" has gained prominence in chemicals policy. The substitution principle requires the replacement of toxic chemicals by less dangerous alternatives. According to most versions of the principle, the replacement may be either another chemical or some non-chemical method to achieve the same or a similar result. The earliest example on record of a general rule requiring such substitutions seems to be a paragraph in the Swedish law on workplace health and safety from 1949:

> A poisonous or otherwise noxious substance shall be replaced by a non-toxic or less harmful one whenever this can reasonably be done considering the circumstances. (Svensk författningssamling 1949, p. 401)

A special “substitution principle” for hazardous chemicals was introduced into the European health and safety legislation in 1989 (European Union 1989). It states that the employer has to implement preventive measures according to a series of “general principles of prevention,” one of which is “replacing the dangerous by the non-dangerous or the less dangerous” (European Union 1989, II.6.2). Substitution was also emphasized as a major risk-reducing strategy in the discussions in the 1990s that led up to a new European chemicals legislation (Sørensen and Petersen 1991; Antonsson 1995). The European Commission’s 2001 White Paper recommended “the substitution of dangerous by less dangerous substances where suitable alternatives are available” (European Commission 2001). Following this, a substitution principle was integrated into the European chemicals legislation (the REACH legislation), which was adopted in 2006. The substitution principle has also had an important role in various projects for chemical safety promoted by both government agencies and industrial companies (Lissner and Romano 2011; Hansson et al. 2011). Increasingly, the substitution principle has become associated with the movement for green chemistry, i.e. chemical engineering devoted to developing less hazardous chemical products and processes (Fantke et al. 2015; Tickner et al. 2019).

Decisions based on the substitution principle are often hampered by lack of reliable knowledge on the effects of both the chemicals currently in use and their potential alternatives (Rudén and Hansson 2010). Due to incomplete or inaccurate information, attempts to apply the substitution principle have sometimes led to the replacement of an unsafe product by another product that is in fact no better:

> The chemical trichloroethylene (TCE), a volatile organic chemical, was widely used as a degreaser in the manufacture of electronic circuits and components until concerns about TCE’s environmental effects led the industry to replace it with trichloroethane (TCA), which has similar chemical structure. TCE and TCA were among the most widely used industrial degreasers, and they are now found in many of the hazardous cleanup sites listed on the National Priorities List. TCA, in turn, was replaced as a degreaser by chlorofluorocarbons such as Freon when ozone depletion concerns were raised about TCA in the 1990s. The use of Freon as a chemical degreaser was eventually phased out due to its own health and environmental concerns. Now, new mixtures of solvents are being used in vapor degreasing. (Bent 2012, pp. 1402–1403)

Generally speaking, the difficulties in assessing health risks and environmental risks are larger for chemical substances than for most other sources of potential hazards (Rudén and Hansson 2010). Therefore, a double strategy for chemical safety is advisable: Systematic work to replace hazardous substances and processes by less hazardous alternatives needs to be combined with equally methodical endeavours to reduce emissions and exposures.

In applications of the substitution principle, priority is usually given to substituting the most hazardous products and processes, but there is no predetermined level of risk below which further substitutions to even less perilous substances and methods are considered unnecessary. Furthermore, the principle is not “subordinated to purely economical considerations” (Szyszczak 1992, p. 10). This is in line with the above-mentioned European health and safety legislation from 1989, which says the following:

> The employer shall be alert to the need to adjust these measures to take account of changing circumstances and aim to improve existing situations. (European Union 1989, II.6.1)

Notably, this requirement is not restricted to companies in which existing conditions are below a certain standard. With this interpretation, the substitution principle is well in line with improvement principles such as Vision Zero and continuous improvement. It can also, with this interpretation, be classified as an improvement principle (Hansson 2019).

However, the substitution principle has sometimes been interpreted in ways that weaken its effects. In particular, high demands on the functionality of the replacement can sometimes block health and safety improvements. For instance, the substitution principle has been defined as “the replacement of a substance, process, product, or service by another that maintains the same functionality” (UK Chemicals Stakeholder Forum 2010). This would mean that a substitution can only be required if the replacement functions at least as well as the harmful substance that one wishes to avoid. To mention just one example, it would imply that a company using a highly toxic metal degreaser could not be required to substitute it by something less dangerous if the best replacement would require a small increase in the time that the metal parts have to be immersed in the solvent. With such an interpretation, the substitution principle would lose much of its effect (Hansson et al. 2011).

Safety Factors

A *safety factor* is a numerical factor (i.e. a number) that is used as a rule of thumb to create a margin to dangerous conditions. The most common uses of safety factors are in structural mechanics and in toxicology. In structural mechanics, to apply a safety factor x means to make a component x times stronger than what the predicted load requires. In toxicology, to apply a safety factor x means to only allow exposures that are at least x times smaller than some dose believed to be barely safe.

Safety factors provide a safety reserve, i.e. a distance or difference between the actual conditions and the conditions expected to cause a failure. You introduce a safety reserve if you hang your child’s swing with a stronger rope than what you actually believe to be necessary to hold a person using the swing. If you do this intuitively, the safety reserve is non-quantitative. If you ask the shop attendant for a rope that holds three times the highest load you expect, then your safety reserve is quantitative and expressible as a safety factor of three.

Non-quantitative safety reserves have been used in the building trades since prehistoric times (Randall 1976; Kurrer 2018). The early history of safety factors does not seem to have been written before, and a brief account will therefore be given here. The earliest record of a quantitative safety factor may be a letter written in March 1812 by the English inventor Richard Trevithick (1771–1833), where he described how he used what we would today call a safety factor of 4 in the testing of steam engines:

> To prevent mischief from bad castings, or from the fire injuring the surface of cast iron, I make the boilers of wrought iron, and always prove them with a pressure of water, forced in equal to four times the strength of steam intended to be worked with. (Trevithick 1872, p. 14)

The use of a safety factor for steam pressure seems to have been a common practice in Britain in the early nineteenth century. In his book on steam engines from 1822, the British science writer Charles Frederick Partington referred to four engine makers who all recommended the practice. However, they had widely different views on what an appropriate safety factor should be. One said that steam engines should be tested at 2 to 3 times higher pressure than the intended work pressure, another recommended 10 to 12 times higher pressure, a third 14 to 20 times higher, and a fourth 50 times higher (Partington 1822, pp. 109, 112, 113, and Appendix, p. 76). We can conclude that the notion of a safety factor was well known among engine makers at this time, although they neither had a name for it nor a common view on its value.

In his 1827 book on steam engines, the influential English civil engineer Thomas Tredgold (1788–1829) referred to the "excess of strength" that is required in a boiler. Although he wrote only five years later than Partington, he reported a consensus in the matter: "it has been almost universally allowed, that three times the pressure on the valve in the working state, should be borne by the boiler without injury." However, he was critical of that consensus. He proposed that the factor of 3 could be lowered to 2 for "ordinary low-pressure steam boilers," whereas high-pressure boilers required higher factors, depending on their construction (Tredgold 1827, pp. 257–258). His statement that a factor of 3 was customary is confirmed in a call for tenders for new locomotive steam engines that was sent out in 1830 by an American railway company. They stated that they considered themselves at liberty to put the engine "to the test of a pressure of water, not exceeding three times the pressure of the steam intended to be worked, without being answerable for any damage the machine may receive in consequence of such test" (Thomas 1830, p. 373).

In his three-volume book on bridge-building, published in 1850, the English civil engineer Edwin Clark (1814–1894) reproduced a text from 1846 describing the construction of a bridge such that "its breaking-weight is seven times as great as any weight with which in practice it can ever be loaded." He called this number a "factor of safety" and discussed how it should be used in calculations, given that the bridge's own weight had to be taken into account (Clark 1850, pp. 514–515). He reported that the famous Scottish engineer Robert Stephenson (1772–1850) favoured a factor of 7. This gives the impression that the use of safety factors was well established at the time, not only in boilermaking but also in civil engineering. Its earlier background in civil engineering remains to be investigated.

In 1859, the Scottish engineer and physicist William Rankine (1820–1872) published a table of "factors of safety" for different materials. This factor was, essentially, a ratio between breaking load and working load. He recommended safety factors of 10 for timber, 8 for stones and bricks and between 4 and 8 for different types of iron and steel (Rankine 1859, p. 65).

In 1873, the American engineer Barnet Le Van wrote a report to the Franklin Institute on a boiler explosion in Pennsylvania that had killed 13 persons and wounded many more. He concluded that proper maintenance and regular examination and testing of the boiler, in accordance with well-established routines, would have prevented the accident. However, he also had a more general conclusion:

> In conclusion, I would call the attention of the Institute to the factor of safety for boilers as being entirely too low. The great number of disastrous explosions that have lately occurred in different parts of the country are the best evidences of the fact. The Bridge Engineers have long since come to this conclusion, and have fixed their factor of safety at one-eighth the ultimate value of the material. (Le Van 1873, p. 253)

The value of the safety factor for boilers that he criticized is not mentioned in his text, but it may well have been 3.

Today, safety factors are almost ubiquitous in engineering design. It is generally agreed that their main purpose is to compensate for five major sources of error in design calculations (Knoll 1976; Moses 1997):

1. Higher loads than those foreseen
2. Worse properties of the material than foreseen
3. Imperfect theory of the failure mechanism in question
4. Possibly unknown failure mechanisms
5. Human error (e.g. in design)

In toxicology, the first proposal to apply safety factors seems to have been Lehman's and Fitzhugh's proposal in 1954 to calculate the Acceptable Daily Intake of food additives by dividing the highest dose (in milligrams per kilo body weight) at which no effect had been observed in animals by 100 (Dourson and Stara 1983). Today, safety factors are essential components of regulatory food toxicology. They are also widely used in ecotoxicology. In both these applications, it is common to construct an overall safety factor by multiplying several safety factors for various uncertainties and variabilities. Thus, the traditional 100-fold factor is commonly accounted for as a combination of a factor of 10 for interspecies variability (between experimental animals and humans) in response to toxicity and another factor of 10 for intraspecies variability (among humans). In more recent approaches, toxicological safety factors often incorporate additional subfactors, referring, for instance, to differences between experimental and real-life routes of exposure, extrapolation from short-term experimental to life-long real-life exposures, and deficiencies in the available data (Gaylor and Kodell 2000). However, consistent use of safety factors has not been introduced into the process of setting occupational exposure limits. That area is still dominated by case-by-case compromises between health protection and economic considerations, often resulting in exposure limits at levels where negative health effects are expected (see section "Exposure Limits").

Since the 1990s, the use of safety factors in both structural engineering and toxicology has been criticized by scientists who want to replace them by calculated failure probabilities. However, in practice, the safety factor approach is still dominant, and it has only rarely been replaced by probability calculations. One reason for this is that probabilistic calculations are often much more complicated and time-consuming than the use of safety factors. Another reason is that meaningful probabilities are not available for some of the potential failures that safety factors are intended to protect against. In structural mechanics, this applies, for instance, to unknown failure mechanisms and imperfections in the calculations. In toxicology, it applies to unknown metabolic differences between species and unknown effects only occurring in parts of the human population (Doorn and Hansson 2011).

Multiple Safety Barriers

When several measures are employed to improve safety, they can often be perceived as a chain of safety measures or as they are then often called: a chain of safety barriers. Each of these barriers should be as independent as possible of its predecessors in the sequence, so that if the first barrier fails, then the second is still intact, etc. The use of multiple barriers is often advisable even if the first barrier is strong enough to withstand all foreseeable strains and stresses. The reason for this is that we cannot foresee everything. If the first barrier fails for some unforeseen reason, then the second barrier can provide protection.

The archetype of multiple safety barriers is an ancient fortress. If the enemy manages to pass the first wall, then there are additional layers that protect the defending forces. This is an age-old practice. As early as 3200 BCE, the Sumerian town Habuba Kabira (now in Syria) was surrounded by double walls (Keeley et al. 2007, p. 86). Double and triple walls were also erected around other major cities in the ancient Near East (Mielke 2012, p. 76). In the early Iron Age (around 450 BCE), hill forts were built in Britain with up to four concentric ramparts (Armit 2007).

Some engineering safety barriers exhibit the same spatial pattern as the concentric barriers of a fortification. Illustrative examples of this can be found in nuclear waste management. For instance, the nuclear industry in Sweden has proposed that spent fuel from the country's nuclear reactors should be placed in copper canisters constructed to resist all foreseeable stresses. The canisters will be surrounded by a layer of bentonite clay, intended to protect against movements in the rock and to absorb radionuclides, should they leak from the canisters. This whole construction is placed in deep rock, in a geological formation that has been selected to minimize transportation to the surface of any possible leakage of radionuclides. The idea behind this construction is that the whole system of barriers should have a high degree of redundancy, so that if one of the barriers fails, then the remaining ones will suffice to keep the radionuclides below the surface (Jensen 2017; Lersow and Waggitt 2020, pp. 282–287).

More generally, the safety measures ("barriers") included in a multiple-barrier system should be arranged in a temporal or functional sequence, such that the second barrier is put to work if the first one fails, etc. The barriers may, but need not, be sequentially arranged in space. The combination of inherent safety and fail-safety can be used as an example of a temporally but not spatially sequential arrangement of barriers. Inherent safety is the first barrier. If it fails, then fail-safety should come in as a second resort. A systematic theoretical discussion of consecutive barriers in safety management was provided by William Haddon (1926–1985). He proposed that the protection against mechanical accidents such as traffic accidents should be conceptualized in terms of four types of barriers:

> In the context of the recognition that abnormal energy exchanges are the fundamental cause of injury, accident prevention and hence accident research aimed at prevention are easily sorted into several types, each concerned with successive parts of the progression of events which lead up to these traumatic exchanges. In general, measures directed against accidental or deliberately inflicted injuries attempt: *first*, to prevent the marshalling of the hazardous energy itself, and *second*, if this is not feasible, to prevent or modify its release. *Third*, if neither of these is successful, they attempt to remove man from the vicinity, and *fourth*, if all of these fail, an attempt is made to interpose an appropriate barrier which will block or at least ameliorate its action on man. (Haddon 1963, p. 637)

For another example, consider a chemical process in which hydrogen sulfide is used as a raw material in the production of organosulfur compounds. Hydrogen sulfide is a deadly and treacherous gas, and it is therefore imperative to protect workers against exposure to it. This can be done with the help of a series of five barriers. The first barrier consists in reducing the use of the substance as far as possible. If it cannot be dispensed with completely, then resort must be had to the second barrier, which consists in encapsulating the process efficiently so that leakage of hydrogen sulfide is excluded as far as possible. The third barrier is careful maintenance, including regular checking of vulnerable details such as valves. The fourth barrier is an automatic gas alarm, combined with routines for evacuation of the premises in the case of an alarm. The fifth barrier is efficient and well-trained rescue and medical services. Importantly, even if the first, second, third and fourth of these barriers have been meticulously implemented, the fifth barrier should not be omitted. Doing so amounts to what we can call the "Titanic mistake."

The sinking of the Titanic on April 15, 1912, is one of the most infamous technological failures in modern history. The ship was built with a double-bottomed hull that was divided into sixteen compartments, each constructed to be watertight. At least two of these could be filled with water without danger. Therefore, the ship was believed to be virtually unsinkable, and consequently, it was equipped with lifeboats only for about half of the around 2200 persons on-board. This was in line with the regulations at the time, which only required lifeboats for 990 persons for this ship (Hutchinson and de Kerbrech 2011, p. 112). Archibald Campbell Holms

(1861–1954), a prominent Scottish shipbuilder (also known as a leading spiritualist), commented as follows on the accident in his textbook on shipbuilding:

> As showing the safety of the Atlantic passenger trade, may be pointed out that, of the six million passengers who crossed in the ten years ending June 1911, there was only a loss of six lives. The fact that *Titanic* carried boats for little more than half the people on board was not a deliberate oversight, but was in accordance with a deliberate policy that, when the subdivision of a vessel into watertight compartments exceeds what is considered necessary to ensure that she shall remain afloat after the worst conceivable accident, the need for lifeboats practically ceases to exist, and consequently a large number may be dispensed with. The fact that four or five compartments were torn open in *Titanic*, although no longer an inconceivable accident, may be regarded as an occurrence too phenomenal to be used wisely as a precedent in deciding the design and equipment of all passenger vessels in the future. (Holms 1917, p. 374)

Needless to say, this is an unusually clear example of the type of thinking that the concept of multiple safety barriers is intended to overcome. Luckily, most reactions to the accident were wiser than that of Campbell Holms. In consequence of the disaster, maritime regulations for long sea voyages were changed to require lifeboats for all passengers. However, the changes did not apply to shorter sea voyages. As late as in the 1960s, a night ferry between Belfast and the English seaport Heysham took up to 1800 passengers but had lifeboats only for 990 (Garrett 2007).

Redundancy

The notion of multiple barriers can be generalized to that of *redundancy*. By redundancy is meant that safety is upheld by a set of components or processes, such that more than one of them have to fail for conditions to become unsafe (Downer 2011; Hammer 1980, pp. 71–75). The redundant components can be arranged in different ways, for instance, in parallel or consecutively. If the arrangement is consecutive, then we have the special case of multiple barriers. Redundancy with a parallel arrangement can be exemplified by the engine redundancy in aircraft. This means that an airplane can reach its destination or at least the nearest airport, even if not all the engines are operative (DeSantis 2013). As this example shows, redundancy can be a way to achieve fail-safety.

The major difficulty in constructing redundant systems is to make the redundant parts as independent of each other as possible. If two or more of them are sensitive to the same type of impact, then one and the same destructive force can get rid of them in one fell swoop. For instance, any number of concentric walls around a fortified city could not protect the inhabitants against starvation under siege. Similarly, ten independent emergency lights in a tunnel can all be destroyed in a fire, or they may all be incapacitated due to the same mistake by the maintenance department. The Fukushima Daiichi nuclear accident in 2011 was caused by a natural disaster (an earthquake and its resultant tsunami), which shut down both the reactors' normal electricity supply and the emergency diesel generators. In consequence, the emergency cooling system did not work, which led to nuclear meltdowns and the release of radioactive material. This would not have happened if the emergency generators had been placed at a higher altitude than the reactors. In general, how much safety is obtained with an arrangement for redundancy depends to a large degree on how sensitive the system is to failures affecting several redundant parts at the same time ("common-cause failures"). Often, safety is better served by few but independent barriers than by many barriers that are sensitive to the same sources of incapacitation.

The quality of redundancy systems is often discussed in terms of diversity and segregation. By *diversity* is meant that redundant parts differ in their constructions and mechanisms. For instance, in order to avoid dangerously high temperatures in a chemical reactor, we may introduce two temperature guards, each of which automatically turns off the reactor if a certain temperature limit is exceeded. The redundancy obtained by having two instruments is improved if they are of different types. It is also improved if we employ different software for their operations (Vilkomir and Kharchenko 2012). By *segregation* is meant that redundant components are physically separated from each other. This is done in order to reduce the risk of spatially limited common-cause failures produced, for instance, by fire, explosion, flooding, structural failure or sabotage. Segregation is more easily achieved in large industrial buildings or complexes than in operations with limited space such as ships, offshore platforms and aircrafts. However, the principle has been applied with success in the latter types of workplaces as well (Kim et al. 2017).

Summary

The various error tolerance principles that we have discussed in this section – fail-safety, inherent safety, substitution, safety factors, multiple safety barriers and redundancy – are all perfectly compatible with Vision Zero and other improvement principles. At least one of them, namely, inherent safety, has also been discussed in connection with Vision Zero. The error tolerance principles can all be seen as means to implement the improvement principles. In general, it is advisable to combine several error tolerance principles, as explained above in the subsections on multiple barriers and redundancy.

Evidence Evaluation Principles

Decisions on safety often have to be based on information that may be difficult to obtain. We may have to ask questions such as: Can this structure sustain the additional load we intend to place on it? Is this chemical exposure hazardous to human health? How reliable is the gas alarm? Sometimes, trustworthy answers to such questions can be obtained, but on other occasions, we have to make decisions based on uncertain or insufficient evidence. This section is devoted to such principles. We will begin with the *precautionary principle* and then discuss three of its alternatives, namely, *reversed burden of proof*, *risk neutrality* and "*sound science*".

The Precautionary Principle

According to a common misconception, the precautionary principle says that all our decisions should be cautious. According to that reading of the principle, we all apply the precautionary principle when we wear a seat belt or have our children vaccinated. But this is not what the precautionary principle means. It is a well-defined principle for the evaluation of evidence, defined in international treaties and also in the European legislation. What it means is, essentially, that even if the evidence of a danger is uncertain, we may, and often should, take precautionary measures against it.

This is of course no new way of thinking. Presumably, our ancestors refrained from entering a cave if they heard a suspicious growl from it, even if they were far from convinced that the animal they heard was dangerous. An illustrative, more recent example is the closing of a water pump in London in 1854. In early September that year, the city was struck by cholera, and 500 people died in 10 days. The physician John Snow notified the authorities that according to his investigations, a large number of those affected by the disease had drunk water from a pump on Broad Street. The authorities had no means to verify that this was more than a coincidence. According to the prevalent opinion among physicians, cholera was transmitted through air rather than water. However, although the evidence was uncertain, the authorities decided to have the handle removed from the pump. This had the effect hoped for, and the cholera epidemic was curbed (Snow 2002; Koch and Denike 2009).

The modern precautionary principle had precursors in Swedish and German legislation and in treaties on protection of the North Sea in the 1980s (Hansson 2018b). It rose to international importance through the Rio Declaration on Environment and Development that was a major outcome of the 1992 so-called Earth Summit in Rio de Janeiro:

> Principle 15. Precautionary principle
>
> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (United Nations 1992)

The European Union and several of its member states have incorporated the precautionary principle into their legislations. Through the 1992 Maastricht amendments to the European Treaty (Treaty of Rome, now known as the Treaty on the Functioning of the European Union), the precautionary principle was written into European legislation (Pyhälä et al. 2010, p. 206). According to the treaty, union policy "shall be based on the precautionary principle" (European Union 2012). In February 2000, the Commission issued a Communication on the Precautionary Principle that further clarified its meaning:

> The precautionary principle is not defined in the Treaty, which prescribes it only once – to protect the environment. But *in practice*, its scope is much wider, and specifically where preliminary objective scientific evaluation, indicates that there are reasonable grounds for

> concern that the potentially dangerous effects on the *environment*, *human, animal or plant health* may be inconsistent with the high level of protection chosen for the Community...
>
> Recourse to the precautionary principle presupposes that potentially dangerous effects deriving from a phenomenon, product or process have been identified, and that scientific evaluation does not allow the risk to be determined with sufficient certainty.
>
> The implementation of an approach based on the precautionary principle should start with a scientific evaluation, as complete as possible, and where possible, identifying at each stage the degree of scientific uncertainty...
>
> [M]easures based on the precautionary principle should be maintained so long as scientific information is incomplete or inconclusive, and the risk is still considered too high to be imposed on society, in view of chosen level of protection. (European Commission 2000)

It can clearly be seen from this and other official texts that the precautionary principle is a principle for decision-making in situations with uncertainty about a potential hazard. In the United States, the precautionary principle has seldom been invoked by policymakers, but some administrations have taken measures based on similar thinking, using other terms such as "better safe than sorry" (Wiener and Rogers 2002). Even in Europe, the precautionary principle is seldom referred to outside of the policy areas that concern health, safety and the environment. However, similar approaches to evidence are prevalent in a wide range of policy areas although no reference is made to the precautionary principle. For instance, economists commonly agree that action should be taken against a potential financial crisis even in the absence of full evidence that it will otherwise take place. Similarly, a military commander who waits for full evidence of an enemy attack before taking any countermeasures would be regarded as incompetent.

The following two, hypothetical but realistic, examples can be used to exemplify the precautionary principle:

> *The volcano example*
>
> A group of children are tenting close to the top of an old volcano that has not been active for thousands of years. While they are there, seismographs and gas detectors suddenly indicate that a major eruption may be on its way. A committee of respected volcanologists immediately convene to evaluate the findings. They conclude that the evidence is uncertain but weighs somewhat in the direction that a major eruption will take place in the next few days. They unanimously conclude that although the evidence is not conclusive, it is more probable that an eruption is imminent than that it is not. (Hansson 2018b, pp. 269)

> *The baby food example*
>
> New scientific evidence indicates that a common preservative agent in baby food may have a small negative effect on the child's brain development. According to the best available scientific expertise, the question is far from settled but the evidence weighs somewhat in the direction of there being such an effect. A committee of respected scientists unanimously concluded that although the evidence is not conclusive, it is more probable that the effect exists than that it does not. The food safety agency has received a petition whose signatories request the immediate prohibition of the preservative. (Hansson 2018b, pp. 268–269)

As these examples exemplify, there are occasions when we wish to take measures against a possible danger, although the scientific information is not sufficient to establish that the danger is real. At least in the second case, this would (in Europe) be described as an application of the precautionary principle.

However, there are also dangers with basing decisions on less than full scientific evidence. If we give up the scientific basis entirely, then we run the risk of making decisions that have no foundation at all, leaving room for decisions based on prejudice and uninformed suppositions (Hansson 2016, 2018a). It is necessary to ensure that full use is made of the available scientific information even when we are willing to base decisions on incomplete evidence. The following three principles have been proposed as guidelines (Hansson 2008, pp. 145–146). They can be called the principles of *science-based precaution* in practical decision-making:

1. The evidence taken into account in the policy process should be the same as in a purely scientific evaluation of the issue at hand. Policy decisions are not well served by the use of irrelevant data or the exclusion of relevant data.
2. The assessment of how strong the evidence is should be the same in the two processes.
3. The two processes may differ in the *required* level of evidence. It is a policy issue how much evidence is needed for various practical decisions.

A Reversed Burden of Proof

In particular in the discussion on chemical hazards, it has often been claimed that the onus of proof should fall to those who claim that a substance can be used without danger, rather than those who wish to restrict its use. This is commonly called the "reversed burden of proof" (Wahlström 1999, pp. 60–61). If by the burden of proof is meant the duty to pay for the required investigations of the effects of a substance, then this is a burden that can and arguably should be borne by those who wish to put the substance on the market. In many jurisdictions, considerable duties of investigation have already been imposed on companies wishing to put a chemical substance on the market. However, in discussions of chemical risks, the term "burden of proof" usually means something else, which is close to what legal scholars call "burden or persuasion": It is claimed that unless the company in question can prove that the substance is harmless, the substance should not be used. On the face of it, this seems to be an excellent safety principle: We should only use provenly harmless substances. Who can be against that?

Unfortunately, this principle has a fundamental defect: It cannot be realized. It can often be proved beyond reasonable doubt that a substance has a particular adverse effect. However, it is often impossible to prove beyond reasonable doubt that a substance does not have a particular adverse effect, and in practice, it is always impossible to prove that it has no adverse effect at all (Hansson 1997a). The major reason for this is that with respect to serious health effects, we care about risks that are small in comparison to the limits of detection in scientific studies. If we only cared about whether an exposure kills more than one-tenth of the exposed population, then this problem would not arise. But for ethical reasons, we wish to exclude even much lower frequencies of adverse effects.

As a rough rule of thumb, epidemiological studies can only detect reliably excess risks that are about a tenth of the risk in the unexposed population. For instance, suppose that the lifetime risk of a deadly heart attack (myocardial infarction) is 10% in a population. Furthermore, suppose that a part of the population is exposed to a substance that increases this risk to 11%. This is a considerable risk increase, leading to the death of one in a hundred of those exposed. However, even in large and well-conducted epidemiological studies, chances are slim of detecting such a difference between the exposed and the unexposed group (Vainio and Tomatis 1985). There are similar statistical problems in animal experiments (Weinberg 1972, p. 210; Freedman and Zeisel 1988; Hansson 1995).

The lesson from this is that it is in general impossible to prove that an exposure has no negative effects. Demands for such proofs can be counterproductive since they contribute to the misconception that chemical risks can be eliminated with substance choice, without any measures to reduce exposure. A realistic strategy to minimize chemical risks should be based on a multiple-barrier approach. Appropriate pre-market investigations of substances, constructed to discover negative health effects as far as possible, can serve as a first barrier. However, this has to be followed by other barriers, including measures that reduce exposures as well as check-ups to discover unexpected harmful effects.

Many technological devices are accessible to more reliable pre-market testing than chemical substances. The reason for this is that relevant failure types, such as mechanical and electrical failures, are much better understood than toxicity, which makes more reliable testing possible. (A caveat: This does not always apply to software failures.) However, this does not exclude the need for a “second barrier” in the form of post-marketing follow-ups. Experiences from safety recalls in the motor vehicle, aircraft, toy, food, pharmaceutical and medical device industries show that even in industries with a comparatively high focus on safety, the “first barrier” of pre-market testing and assessment does not always exclude the marketing of unsafe products (Rupp 2004; Bates et al. 2007; Berry and Stanek 2012; Nagaich and Sadhna 2015; Shang and Tonsor 2017; Niven et al. 2020; Johnston and Harris 2019). Proposals have been made to introduce routines for safety recalls in industries still lacking recall traditions, such as the building materials industry (Huh and Choi 2016; Bowers and Cohen 2018; Watson et al. 2019).

Risk Neutrality

Opponents of the precautionary principle have often proposed that it should be replaced by a risk-neutral or, in a common but rather misleading terminology, “risk-based” approach (Klinke et al. 2006, p. 377). By this is meant that risks should be assessed according to their expectation values, i.e. the product of some measure of the expected damage with its probability. This is the way in which risks are assessed in cost-benefit analysis. As we saw above, this is a method with considerable drawbacks. Attempts to use it as a replacement for the precautionary principle will also run into an additional, quite severe problem: The precautionary principle is a principle for the interpretation of uncertain or limited evidence. For that task, meaningful probabilities are usually not available. In practice, "risk-based" decision-making tends to proceed by neglecting uncertainties and only taking known dangers into account.

The following, somewhat stylized, example serves to illustrate the point: Consider two substances A and B, both of which are alternatives for being used in an application where they will leak into the aquatic environment. A has been thoroughly tested and is known to be weakly ecotoxic. It is not known whether B is ecotoxic. (No exotoxicity was discovered in the standard tests, but due its chemical structure, some researchers have expressed worries that it may be toxic to other organisms than those included in those tests.) However, B is known to be highly persistent and bioaccumulative. This means that *if* B is ecotoxic, then it can be highly potent since it will accumulate in biota. The ecological risks of using substance A can be quantified and entered into a cost-benefit analysis and a "risk-based" decision procedure. However, since no meaningful probability can be assigned to the eventuality that B is ecotoxic, we cannot perform a "risk-based" assessment of its potential to harm the environment. Therefore, a "risk-based" assessment will show that A poses an ecological risk, but it will have no risk to report for B. In contrast, an assessment in line with the precautionary principle will put focus on the serious but unquantifiable risks that B may give rise to. Thus, in spite of its name, a "risk-based" assessment will in this case tend to downplay risks that are taken seriously if the precautionary principle is applied.

"Sound Science"

If "sound science" means good science, then all rational decision-makers should make use of sound science, combining it with decision criteria that are appropriate for the purposes of the decision. However, in recent discussions, the phrase "sound science" has acquired a different meaning. It was adopted as a political slogan in 1993, when the tobacco company Philip Morris initiated and funded an ostensibly independent organization called The Advancement of Sound Science Coalition (TASSC). Its major task was to promulgate pseudoscience in support of the claim that the evidence for health risks from passive smoking was insufficient for regulatory action (Ong and Glantz 2001). The term "sound science" has also been used in similar lobbying activities against reductions in human exposure to other toxic substances (Rudén and Hansson 2008, pp. 300–301; Samet and Burke 2001; Francis et al. 2006). Considerable efforts have been made to create "sound science" alternatives to the scientific consensus on climate change summarized by the IPCC (Cushman 1998; Boykoff 2007, p. 481; Dunlap and McCright 2010, p. 249; Hansson 2017).

The major effect of the requirements for “sound science” has been to delay and prevent health, safety and environmental regulations by incessantly questioning the evidence on which they are based (Neff and Goldman 2005). Decision-making based on uncertain evidence is consistently repudiated. However, disregarding well-grounded evidence of danger whenever it is not strong enough to dispel all doubts is nothing less than blatantly irrational. Even if you do not know for sure that a dog bites, reasonable suspicions that it does are reason enough to prevent your child from playing with the dog. Scientific evidence of danger should be treated in the same way.

Summary

In this section, we have studied four approaches to the evaluation of uncertain evidence. The precautionary principle, interpreted in the science-based way described above, is fully compatible with improvement principles such as Vision Zero, and it can be used to support their implementation. The idea of a reversed burden of proof, in its most common interpretation, is much more problematic. It cannot be implemented in practice, and its promotion tends to support a once-and-for-all approach to chemical safety, rather than a more appropriate multiple-barrier approach. Risk-neutral (“risk-based”) assessments of uncertain evidence are usually not feasible since they require probability values that cannot be obtained. Finally, “sound science,” in the sense that the phrase has acquired through the activities of tobacco lobbyists and their allies, should not be classified as a safety principle. It epitomizes the kind of risk-taking that has always stood in the way of safety.

Conclusion

We began our exploration of safety principles with an overview of how zero goals and targets have been used in widely different areas. We found that strivings for zero of something undesirable have the important advantage of counteracting fatalism and complacency. After that, we broadened our attention to a larger group of safety principles, containing continuous improvement, as low as reasonably achievable (ALARA) and best available technology (BAT). All these principles can be called improvement principles, since they convey the message that no level of risk above zero is fully satisfactory and that consequently, improvements in safety should always be striven for as long as they are at all possible. These principles are all fully compatible with each other, and we can see the different improvement principles as different ways to express the same basic message.

Next, we explored some other principles that tell us what levels of safety or risk reduction we should aim at (aspiration principles). Several of these principles tend to classify some unsafe and improvable conditions as acceptable. Such principles are not easily combined with Vision Zero and other improvement principles. However, we also found that one of these aspiration principles, namely, cost-effectiveness analysis, fits in very well with the improvement principles. Cost-effectiveness analysis can be used to choose the safety measures that yield the largest improvements.

We then turned to the error tolerance principles, which are safety principles telling us that since failures are unavoidable, we have to ensure that the consequences of failures will be as small as possible. We discussed six such principles: fail-safety, inherent safety, substitution, safety factors, multiple safety barriers and redundancy. All of these principles are highly compatible with Vision Zero and other improvement principles. We can see them as complementary strategies for implementing the improvement principles.

Finally, we considered four evidence evaluation principles. One of them, namely, the precautionary principle, is well in line with Vision Zero and the other improvement principles.

Safety work is complex and in need of guidance on many levels. Therefore, we need several safety principles. Vision Zero and other improvement principles can tell us what we should aspire to. Error tolerance principles provide essential insights on the means that can lead us in that direction. We can use cost-effectiveness analysis to prioritize among the measures that are available to us and the precautionary principle to deal with uncertainties in the evidence available to us.

Cross-References

- ▶ Suicide in the Transport System
- ▶ Vision Zero and Other Road Safety Targets
- ▶ Vision Zero in Disease Eradication
- ▶ Vision Zero in Suicide Prevention and Suicide Preventive Methods
- ▶ Vision Zero in Workplaces
- ▶ Vision Zero on Fire Safety
- ▶ What Is a Vision Zero Policy? Lessons from a Multi-sectoral Perspective
- ▶ Zero-Waste: A New Sustainability Paradigm for Addressing the Global Waste Problem

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Arguments Against Vision Zero: A Literature Review

3

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Abstract

Despite Vision Zero's moral appeal and its expansion throughout the world, it has been criticized on different grounds. This chapter is based on an extensive literature search for criticism of Vision Zero, using the bibliographic databases Philosopher's Index, Web of Science, Science Direct, Scopus, Google Scholar, PubMed, and Phil Papers, and by following the references in the collected documents. Even if the primary emphasis was on Vision Zero in road traffic, our search also included documents criticizing Vision Zero policies in other safety areas, such as public health, the construction and mining industries, and workplaces in general. Based on the findings, we identify and systematically characterize and classify the major arguments that have been put forward against Vision Zero. The most important arguments against Vision Zero can be divided into three major categories: moral arguments, arguments concerning the (goal-setting) rationality of Vision Zero, and arguments aimed at the practical implementation of the goals. We also assess the arguments. Of the 13 identified main arguments, 6 were found to be useful for a constructive discussion on safety improvements.

Keywords

Vision Zero · Nollvisionen · Criticism · Road safety · Ethics · Systems thinking

Introduction

The adoption of Vision Zero ("Nollvisionen") in Sweden in 1997 represented a crucial shift in road safety management (Government Bill 1996/97:137). Road safety work at the time was heavily influenced by utilitarian cost-benefit analysis and by an approach that considered failing road users to be the main cause of road accidents. In contrast, Vision Zero emphasized the responsibility of system designers and clearly prioritized safety over mobility and cost containment. It declared that the fatalities and serious injuries that result from preventable crashes are morally unacceptable. Moreover, it assumed that road users want health and self-preservation and that this is what the design and operation of the road system has to deliver. The moral appeal and relative success of Vision Zero has led to its acceptance in more and more countries, states, and cities around the world, and it has had a considerable impact also in other areas of public safety than road traffic (Mendoza et al. 2017; Kristianssen et al. 2018).

However, the global proliferation of Vision Zero policies does not imply that it is without flaws. In fact, Vision Zero has sustained a fair amount of criticism, both in academic literature and in the public debate. So far, these criticisms have not been investigated systematically. Therefore, in this chapter we aim to identify, categorize, and critically assess the arguments that have been put forward against Vision Zero. Our categorization of arguments is based on a desk-based review of academic research articles, reports, and policy documents from the last two decades. The documents were retrieved through searches in the bibliographic databases, Philosopher's Index, Web of Science, ScienceDirect, Scopus, Google Scholar, PubMed, and Phil Papers, and by following the references in the collected documents. Even if the primary emphasis was on Vision Zero in road traffic, our search also included documents criticizing Vision Zero policies in other safety areas, such as public health, the construction and mining industries, and workplaces in general.

Our analysis shows that the most important arguments against Vision Zero can be divided into three major categories: moral arguments, arguments concerning the (goal-setting) rationality of Vision Zero, and arguments aimed at the practical implementation of the goals (see Fig. 1).

Firstly, critics target the central moral assumptions behind Vision Zero, such as its uncompromising prioritization of safety and its assumption that deaths and serious injuries in the road traffic system are morally unacceptable. For instance, the ethical assumption behind Vision Zero has been criticized by authors who claim that it is morally acceptable that some people die on the road, since driving is a risky activity that they chose voluntarily to engage in. Moreover, it has been argued that the resources required to realize Vision Zero will have to be taken from other policy areas where they could be used to greater advantage from an ethical point of view. Vision Zero has also been accused of being paternalistic and unjust, and some of the measures proposed to realize it have been accused of threatening the freedom, autonomy, and privacy of road users.

Secondly, critics question the rationality of setting and working toward the goal to prevent all fatalities and serious injuries in traffic safety. It has been argued that such a goal is unrealistic and therefore irrational to pursue. Doing so is counterproductive, according to the critics, since the agents who are responsible for achieving it will become demotivated when they realize that no matter how great effort they invest, the goal will never be achieved. In addition, Vision Zero has been criticized for being too imprecise to be serviceable as a goal for public policy.

Thirdly, criticisms target specific operationalizations of Vision Zero that have been used in its practical application. The ways in which safety is measured in the application of Vision Zero to road system design has been criticized. Some critics have claimed that too little responsibility is assigned to system designers. Others maintain that system designers are assigned too much responsibility and that this will reduce drivers' sense of responsibility and make them drive more dangerously.

In section "Vision Zero: What It Is," we introduce Vision Zero and its central assumptions. Sections "Moral Criticism," "Rationality-Based Criticism," and "Operational Criticism" present and analyze the arguments that we have found in each of the three categories just mentioned. Section "Conclusion" summarizes our findings and identifies some arguments against Vision Zero that are, in our view, particularly worthy of further consideration and analysis.

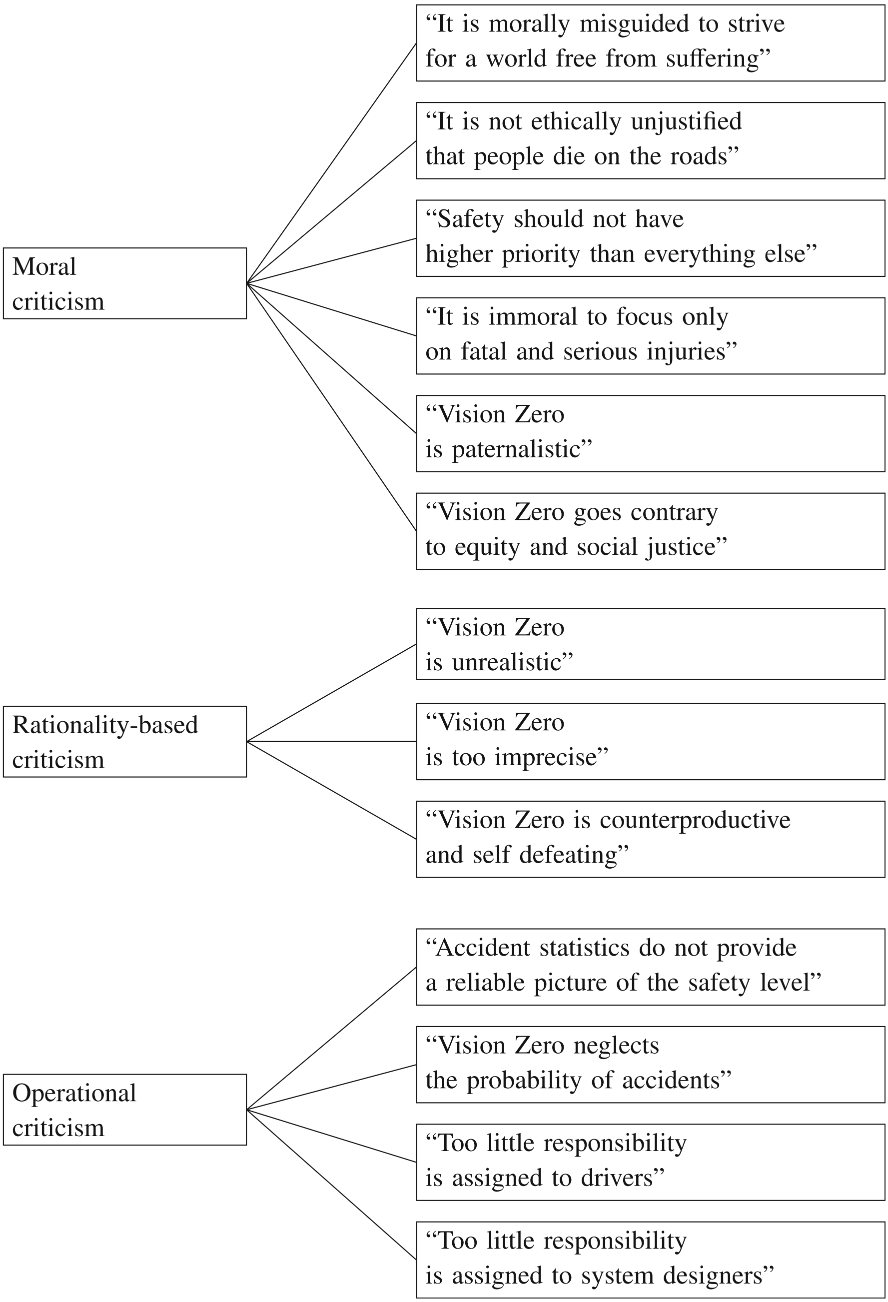

Fig. 1 The arguments against Vision Zero discussed in this chapter

Vision Zero: What It Is

A significant number of countries have adopted and are committed to Vision Zero. It was first adopted in 1997 when the Swedish parliament unanimously endorsed it as the country's traffic safety policy (Belin and Tillgren 2012). Currently, similar Vision Zero policies are in force in a number of other countries, including Finland, Norway, Denmark, the Netherlands, Germany, Poland, the UK (London), Australia, New Zealand, and Canada (see Part 2 of this handbook). While New York was the first city to adopt the policy in the USA (in 2014), many other cities have joined the group since then (Mendoza et al. 2017). So, what is Vision Zero and how does it differ from the safety policies it came to replace?

Vision Zero as a Goal

According to the Swedish government, the long-term goal of road safety is that "no one should be killed or seriously injured as a result of traffic accidents in the road transport system" (Government Offices of Sweden 2016, p. 6). Despite the government's use of the term "vision," it is clear from the preparatory work that Vision Zero is in fact a policy goal that is supposed to guide all road safety work in Sweden (Government Bill 1996/97:137). To reach the goal, which is not temporally specified, substantial adjustments of the road transport system will have to be made over an extended period of time.

As a policy goal, Vision Zero functions not only as a symbolic expression of the government's ambition to reduce the number of fatalities and serious injuries in the road system. The goal also guides and induces action toward achievement of the desired end-state. Using terminology from goal-setting literature, the goal is "achievement-inducing" (Edvardsson and Hansson 2005). As with most policy goals, Vision Zero coordinates action both temporally and between individuals and organizations. Vision Zero can be used by the national transport administration as a departure point for developing and implementing a series of safety measures over time in such a way that the desired end-state can more easily be reached. It can also be used to allocate resources among various sub-agencies or departments to the same effect. Based on Vision Zero, implemented road safety measures can be evaluated and adjusted, and responsibility for insufficient goal achievement can be established. Thus, Vision Zero functions as a normative framework against which road safety measures can be developed, implemented, evaluated, and adjusted (Rosencrantz et al. 2007; see also ► Chap. 1, "Vision Zero and Other Road Safety Targets", by Edvardsson Björnberg, in this handbook). In this effort, Vision Zero posits the fallibility of human beings as a starting point for the design and operation of roads and vehicles (Johansson 2009). But, importantly, Vision Zero is not only a goal but also a strategy.

Vision Zero as a Strategy

Vision Zero is a strategy that relies on both social and technological innovations in the process of approaching the goal of zero fatalities and serious injuries (Belin et al. 2012). Vision Zero differs fundamentally from the traditional approach to road safety management in terms of its "problem formulation, its view on responsibility, its requirement for the safety of road users, and the ultimate objective of road safety work" (Belin et al. 2012, p. 171).

Problem formulation and ultimate objective: In the traditional approach to road safety, traffic accidents were presented as the major problem to be solved, and individual road users were believed to be causally responsible for up to 95% of those accidents (Evans 1996). In contrast, Vision Zero puts focus not on the accidents per se but on the resulting fatalities and serious injuries. The difference between the traditional approach and Vision Zero can be clearly seen from the measures advocated by proponents of the two approaches. In Vision Zero, a road safety measure that leads to an overall decline in fatalities and serious injuries is preferable, even if it involves a greater number of accidents or minor injuries. This is, for instance, the main logic behind the shift from traffic lights to roundabouts in four-way intersections in most Vision Zero-committed countries, such as Sweden and the Netherlands (Mendoza et al. 2017). While roundabouts, as compared to traffic lights, tend to lead to a greater number of crashes, the reduced speed in roundabouts makes the crashes less severe, and the number of fatalities and severe injuries is considerably lower (ibid.). When it comes to road and street design, Vision Zero goes contrary to the traditionally dominant safety strategy of increasing space for vehicles through the construction of wider roads, wider lanes, straighter roads, and larger crossings (Bergh et al. 2003; Johansson 2009). Although these measures facilitate the flow of traffic and reduce the number of crashes, they often have negative effects on safety since "the most predominant effect of creating more space is an increase in driving speed, which means higher levels of kinetic energy in crashes" (Johansson 2009, p. 828).

Two prominent improvements in vehicle technology that have brought huge safety gains in Swedish roads are the introduction of seat belt reminders (SBR) and alcohol interlocks. A study by Krafft et al. (2006) of the driving behavior of 3000 Swedish drivers showed that "in cars without SBR, 82.3 percent of the drivers used the seat belt, while in cars with SBR, the seat belt use was 98.9 percent" (p. 125). Furthermore, "in cars with mild reminders, the use was 93.0 percent" (p. 125). From this, the authors concluded that installing seat belt reminders in all cars would have a dramatic impact on the number of fatal and seriously injured car occupants. Seat belt reminders are a prime example of a measure that aims at reducing the consequences rather than the probability of crashes.

Alcohol interlocks provide another important example of a technological innovation with huge safety benefits. Drunk driving is one of the major factors involved in crashes leading to fatalities and serious injuries. According to the WHO's global status report (WHO 2018), between 5% and 35% of all road fatalities are alcohol-related. In Sweden and many other European countries, alcohol interlocks have been introduced as a remedy to the problem of drunk driving. The technology is now widely employed in professional settings. In 2017, 97% of the busses operating in public transport in Sweden had an alcohol interlock (Sveriges Bussföretag 2018). The technology requires a driver to exhale into the machine and prevents the driver from starting the vehicles if a certain amount of alcohol is detected in their breath. Alcohol interlocks is one of many measures in traffic safety that have positive impacts both on the probability and the severity of crashes. Drunk drivers are more often involved in crashes, and these crashes also tend to lead to more serious injuries.

Vision Zero as New Responsibilities

In the traditional approach to traffic safety, the individual road user was identified as the most important causal factor in traffic accidents. Based on accident investigations, it was reported that road users' behavior was the cause of about 95% of traffic crashes (Evans 1996). Consequently, it was assumed that road users carry almost the whole responsibility for traffic safety, and it was often concluded that safety propaganda, rather than technical improvement, was the best way to deal with the problem.

However, these reports were based on a questionable approach to causality, and the conclusions were largely unhelpful in attempts to improve road safety. Although we usually prefer to think in terms of "the cause" of an accident or other event, the assumption of a single cause is in many cases a gross oversimplification. Events do not typically follow from one single cause. Instead, there are several causal factors, all of which contribute to the effect. Various practical considerations influence which causal factor we tend to call "the cause," for instance, how certain we are of its influence, its conspicuity, whether it could plausibly have been absent, and whether it could have been changed by human action (Hoover 1990). For instance, if you ask a bacteriologist what is the cause of cholera you can expect the answer "the bacterium *Vibrio cholerae*," but a public health expert will probably give an answer referring to the lack of proper sanitation. These causal descriptions are useful for different purposes. In the treatment of cholera patients, the answer mentioning the microorganism may be the most adequate one, whereas the answer referring to sanitary conditions is more useful for disease prevention.

In much the same way, most traffic accidents have causal factors pertaining both to the behavior of the driver and to the construction of the vehicle and the road system. For instance, a driver's decision to drive drunk is often a causal factor contributing to an accident. However, there are also various other causal factors, including the social conditions that led the driver to drinking too much, the lack of resources for treatment of alcoholism, and vehicle-related causal factors such as the lack of an alcohol interlock on the car in question. In discussions on how to reduce traffic accidents involving drunk drivers, the drivers' decisions were previously almost exclusively at focus, whereas the decisions by regulators and manufacturers to allow respectively market cars without alcohol interlocks have not been part of the discussion. The situation was similar for other types of traffic accidents. (On causality and responsibility in road traffic, see also ▶ Chap. 5, "Responsibility in Road Traffic", by Hansson.)

One of the basic insights behind Vision Zero is that it is often inefficient to focus on the causal factors that have traditionally been called "the cause" of various accidents. Instead, the focus should be on the causal factors that are most accessible to interventions that improve safety. It then becomes clear that technological factors such as the construction of vehicles and roads are usually much easier to change than human behavior. This has led to a whole range of new technological solutions that have reduced the number of serious road accidents. Where individual road users fail to act or behave as they are expected to, due to factors such as negligence, incompetence, lack of knowledge, or health issues, the road system can be redesigned so that people do not die or get seriously injured even when mistakes are made. As noted by Johansson (2009, p. 827): "It is true, that 95% of all crashes or collisions depend on human error, but according to Vision Zero philosophy, 95% of the solutions are in changing roads, streets or vehicles."

In consequence, Vision Zero has led to a new focus on the responsibilities of the governmental, regional, and local authorities that are involved in the design of the road environment, as well as the responsibilities of vehicle manufacturers. These two groups are called the system designers, and according to Vision Zero they shared the ultimate responsibility for traffic safety (McAndrews 2013; Government Offices of Sweden 2016). According to Tingvall (1997, p. 41), the road system designers "bear the responsibility to do everything in their power to make the system as safe as possible. . . they are also responsible for meeting the road user demands for road safety in the system."

In part this is an institutional responsibility, carried by the agencies and companies that construct roads and vehicles. However, it also has an important component of professional responsibilities. The engineers and other professionals who perform the actual construction tasks have responsibilities, both individually and collectively, to make the choices that save lives and avert suffering. A comparison can be drawn with healthcare. Governments are responsible for organizing healthcare systems that save lives and preserve health. This is an institutional responsibility. At the same time, physicians, nurses, and other healthcare professionals have a responsibility – again, both individually and collectively – to make the choices that best serve the health and well-being of their patients.

The professional responsibilities in Vision Zero go beyond traditional blame responsibility (often called backward-looking responsibility), which assigns blame for causing a traffic safety problem. The main focus is put on task responsibility, which is concerned with who can do something about the problem. In Vision Zero, the overarching task responsibility falls on the system designers. But unavoidably, blame responsibility can also become involved. System designers can be held responsible for inactivity or misdirected activity that leads to fatalities or serious injuries that could otherwise have been prevented. (On responsibility ascriptions, see also ▶ Chap. 5, "Responsibility in Road Traffic", by Hansson.)

Responsibility is not a zero sum game. In other words, if one group takes on more responsibilities, then this does not mean that some other group has to become less responsible. The fact that system designers assume new responsibilities does not relieve individual road users of their responsibility to drive safely and respect traffic regulations (Tingvall 1997). On the contrary, in Vision Zero, the moral responsibility of road users goes beyond what was traditionally expected of them. In addition to the duty of respecting and abiding by the traffic rules and regulations, the "moral responsibility of road users extends to the health of all road users in all situations–even those not anticipated or defined by the legislative and governing bodies. The moral responsibility of road users also involves making clearly stated and powerful demands on the designers of the system" (Tingvall 1997, p. 42).

Four Central Assumptions of Vision Zero

The above discussion suggests that Vision Zero builds on a set of important but controversial assumptions, all of which are necessary to justify the adoption and promotion of the policy.

Ethical Assumption: "It Can Never Be Ethically Acceptable That People Are Killed or Seriously Injured When Moving Within the Road Transport System"

Vision Zero is based on the ethical assumption that it is morally unacceptable that people get killed or seriously injured due to preventable traffic crashes. For the proponents of Vision Zero, any goal other than zero amounts to voluntarily permitting that people are killed or seriously injured on the road (Tingvall and Haworth 1999). This ethical basis of Vision Zero is the major justification for the adoption of the policy in many Vision Zero-committed countries and cities. Importantly, it has called established practices in safety work and transport decision-making into doubt. For instance, this applies to the use of cost-benefit analysis in road safety planning, since CBA often trades the safety of road users to promote other values. Moreover, monetary valuation of human life and the use of willingness to pay in determining the economic value of traffic safety measures are deemed morally problematic from a Vision Zero perspective (Hokstad and Vatn 2008).

From this point of view, the level of road fatalities and serious injuries is the product of our choices as a political society regarding which values we should prioritize. Fatalities and serious injuries are not deemed to be necessary costs. Instead, they show what price a society is willing to pay for mobility. This is a radical departure from the traditional approach to traffic safety, in which traffic fatalities and injuries are viewed as the necessary costs of using the road system (Belin et al. 2012). Unlike the traditional approach to traffic safety in which safety is usually compromised to promote mobility, Vision Zero considers such a compromise as an unsatisfactory situation that should be changed. According to Tingvall (1997, p. 56):

> It goes without saying that human life cannot be exchanged for some gain. To give an example, if a new road, new car design, new rule etc. is judged as having the potential to save human life, then the opportunity must always be taken, provided that no other more cost-effective action would produce the same safety benefit.

Empirical Assumption: Human Fallibility Is Unavoidable and Therefore Has to be Taken into Account in Traffic Safety Work

There is a long history from industrial safety of attempts to avoid accidents by identifying the workers who cause them and taking measures aiming at these individuals. However, this strategy has been found to be inefficient, since accidents are not limited to the actions of a special category of particularly accident-prone individuals. Therefore, industrial safety instead focuses on making operations "fail-safe," or "inherently safe," which means essentially that the prevalence of human mistakes is accepted and focus is put on minimizing the negative consequences following from such mistakes (Hansson 2010; Hammer 1980; Harpur 1958; Jones et al. 1975). A similar development has taken place in patient safety, where a "blame culture" looking for scapegoats has largely been replaced by a focus on how the probabilities and the consequences of such mistakes can be reduced (Rall et al. 2001).

Vision Zero can be seen as representing the same trend, applied primarily to traffic safety. Traditionally, the mistaken behavior of individual road users was taken to be the dominant cause of safety problems in the road traffic system. Consequently, traffic rules and regulations, education, training, licensing, and other mechanisms for behavioral change were emphasized, with the pronounced intention of promoting the required behavior and adjusting the road user to the road system (Belin et al. 2012). Vision Zero instead focuses on making the road system "fail-safe," so that human mistakes do not lead to serious accidents. This approach is based on the simple observation that, in contrast to human nature, vehicle technology and road infrastructure are accessible to radical change.

Operational Assumption: The Ultimate Responsibility for Traffic Safety Should be Assigned to System Designers

This assumption has largely the same motivation as the previous one. From a Vision Zero perspective, the ultimate cause of accidents is taken to be the "imperfect system." Therefore, it is the system that needs to be adjusted to the needs and capabilities of the individual road users, not the other way around. Since the problem of traffic safety is systemic in nature (Larsson et al. 2010), Vision Zero presumes that responsibility should be shared among the actors that directly or indirectly influence the safety of the system.

Empirical Assumption: Technology Can Solve Most Road Traffic Safety Problems

In most countries that have shown a significant improvement in traffic safety over the past few decades, the role of technology has been significant. The introduction of seat belts, seat belt reminders, airbags, automatic brakes, alcohol interlocks, motorcycle and bicycle helmets, and safer road and street designs have played and continue to play a key role in preventing fatalities and injuries. It is generally believed that further progress can be achieved with new, innovative technologies. However, the use and application of most of the technologies that improve traffic safety has long been questioned and debated due to their impact on economy, freedom, autonomy, and privacy. Nonetheless, in countries committed to Vision Zero, a strong emphasis on the development and implementation of innovative technologies appears to be the next step. The Swedish Vision Zero recommends the use of the best available technology when addressing road safety problems, hence emphasizing the role of technological innovation in promoting traffic safety. In the USA, one of the three major strategies identified in *The Road to Zero: A Vision for Achieving Zero Roadway Deaths by 2050* (Ecola et al. 2018) is to accelerate the production and use of advanced technologies.

Moral Criticism

We will consider six moral arguments against Vision Zero. Four arguments claim that Vision Zero assigns too high priority to serious injuries in road traffic. These arguments are presented in order of decreasing strength of the claims that they make. We discuss the argument that Vision Zero is paternalistic and in section "Vision Zero Goes Contrary to Equity and Social Justice" the argument that it counteracts social justice.

"It Is Morally Misguided to Strive for a World Free from Suffering"

It has been argued that, because Vision Zero aims to achieve zero fatalities and serious injuries through the categorical prioritization of safety and health of road users, it seeks to create a risk-free society, which is considered problematic in various ways. Firstly, there is the argument that creating a risk-free society conflicts with individual liberty, interpreted as the freedom of individuals to choose what risks they wish to expose themselves to (see section "Too Little Responsibility Is Assigned to Drivers"). Ekelund (1999), for instance, criticized Vision Zero for aiming to eliminate all road traffic risks despite the fact that some people are willing to take more risks than others. In the context of public health policy, Fugeli (2006) similarly argued that Vision Zero is a luxurious quest of rich European countries to create a risk-free, perfect society. In his view, Vision Zero seeks to purify life and remove defects and risks, which will lead to undesirable consequences. What these authors seem to argue is that by adopting and pursuing Vision Zero policies society may well reduce suffering in the form of deaths and serious injuries caused by certain activities, such as driving, but it also denies people the opportunities of enjoying life to a fuller extent than what is possible under a Vision Zero regime.

Dekker et al. (2016) locate Vision Zero within the "Western Judeo-Christian salvation narrative," i.e., "the notion that a world without suffering is not only desirable but achievable, and that efforts expended toward the goal are morally right and inherently laudable" (p. 219). This narrative understands human suffering as the result of bad choices made by individuals. Consequently, suffering can be relieved by hard work and better individual choices. This is in line with much traditional safety work, according to which the causal responsibility for accidents is largely attributed to the individual. However, Dekker et al. argue, aiming to relieve suffering by focusing on individual choices invites gaming – both by individuals, who in employment settings may refrain from reporting injuries for fear of being blamed, and managers and CEOs, who may refrain from reporting incidents that may lead to the loss of bonuses – and creates more suffering in the end.

The claim that Vision Zero seeks to achieve a perfect society is not backed up by any evidence. We have found no indication of any such assumption in the written documentation on Vision Zero. On the contrary, a major assumption behind Vision Zero is the recognition that traditional approaches to traffic safety, criticized by Dekker et al. (2016), have failed in their relentless attempts to create a perfect road user. (Cf assumption 2 in section "Four Central Assumptions of Vision Zero") Vision Zero differs from this approach in accepting the occurrence of mistakes, and hence even accidents, as an inevitable fact of life. This speaks strongly against the claim that Vision Zero aims to create a perfect society, free from any suffering. It is difficult to imagine a totally risk-free society, constituted of imperfect individuals who are by their own nature liable to make mistakes and act on the basis of wrong judgments. Furthermore, Vision Zero does not aim at eradicating all accidents and injuries but only those that will lead to "an unacceptable loss of health" (Tingvall and Haworth 1999). Non-serious traffic injuries are outside the scope of Vision Zero. Therefore, as was rightly indicated by Zwetsloot et al. (2013, 2017), the criticism that Vision Zero seeks to create a risk-free society is more of a misconception than a genuine argument against it.

In summary, the argument that Vision Zero errs in trying to create a perfect society is based on a blatantly incorrect description of Vision Zero, and not worth taking seriously. (Therefore, we do not see a need to discuss another assumption underlying this argument, viz., that attempts to move in the direction of a "perfect" state are condemnable.)

"It Is Not Ethically Unjustified That People Die on the Roads"

One of the underlying assumptions behind the adoption and promotion of Vision Zero policies is the claim that it is morally unacceptable that people die and get seriously injured due to predictable and preventable crashes. Therefore, Vision Zero is "presented as a more, or perhaps the only, ethically sound approach" (Elvebakk 2005, p. 18). However, Elvebakk argues, the mere ambition to prevent all fatalities and serious injuries cannot in itself justify the ethical superiority of Vision Zero because "there are not necessarily major differences between wanting to reduce the number of serious accidents as much as possible, and wanting to eradicate them altogether. It would seem that either way, the best one can do is one's best"

(Elvebakk 2005, p. 21). Moreover, "it is not necessarily *in itself* ethically unjustifiable to allow hundreds of people die in traffic every year. [. . .] Death is, after all, a fact of life, and as a society we have to accept that people will die, for one reason or another" (Elvebakk 2005, pp. 24–25).

Elvebakk goes on to present examples of cases of fatalities and serious injuries in different aspects of human life, where the causalities, she argues, are often deemed morally acceptable because of the mere fact that those who died or were injured had voluntarily and knowingly chosen to engage in activities associated with considerable risk. Examples are deaths as a result of suicide, drug overuse, skiing, fishing, swimming, etc. Although these risky activities claim a significant number of lives every year, Elvebakk claims that "there are relatively few calls for regulation, as risk seems to be accepted as an integral part of the activity" (Elvebakk 2005, p. 25). For her, these different areas or activities, including road traffic, belong in the "private space," where individuals often voluntarily and knowingly choose to engage in risky activities and accept responsibility for doing so. Elvebakk comments:

> Proponents of vision zero prefer not to compare road traffic to these areas, but to other professional fields, where fatalities are typically not deemed acceptable. But, arguably, the road traffic system cannot be straightforwardly compared to these professional areas, as they belong to different spaces: road traffic is (for most of the drivers) not a professional space. (Elvebakk 2005, p. 25)

Allsop (2005) advances a quite similar view regarding the nature of the road system and road users' responsibility. For him too, the road system is not a "closed system in which everything can be defined as someone's contractual responsibility, but as part of everyone's day-to-day lives, which they expect to be largely free to lead" (p. 15). Moreover, Allsop identifies an additional similarity between these other risky activities that people often engage in and road traffic: most of them serve the same purpose of fulfilling and giving meaning to human life. Most people who lose their lives due to involvement in one of these risky activities have engaged in it "to meet either social needs, or demands for goods, or desires for fullness of life" (ibid.). Using the roads, he says, serves similar purposes. He concludes that "neither in terms of rational socioeconomic policy nor in terms of human desire for fulfillment is it unacceptable in principle for use of the roads to involve some risk of death or serious injury" (ibid.).

These arguments do not take into account that most of those who are killed and seriously injured in road traffic did not wish to take any risks. They just had no other choice than to travel in the risky traffic system that we have. Furthermore, the assumption that a risk is unproblematic if it comes with a voluntarily chosen activity is quite problematic. On the face of it, humans may seem to choose risk-taking. However, people taking risks do not usually desire the risk per se, but rather something else that it is associated it. For instance, consider a person who chooses to bungee jump. Arguably, what she is looking for is not the risk of dying or being seriously injured, but rather an advantage that it is associated with, namely, the thrill, not the risk. If she had the choice of an otherwise exactly similar jump but with a safer cord, then she would presumably choose the safer alternative (Hansson 2013). The same seems to be the case for dangerous behavior in road traffic, such as speeding and drunk driving. These activities are undertaken for various reasons, including the pursuit of thrill (in the case of speeding). The claim that people drive dangerously because of a wish to increase the probability that they will end up in a wheel chair or a coffin is not borne out by any empirical evidence or plausible argument. To this should of course the observation be added that most dangerous behaviors in road traffic impose risk on other road users. We therefore have good reasons to write off the argument that we might as well let people die on the roads since they have taken the risks themselves.

"Safety Should Not Have Higher Priority than Everything Else"

The adoption of Vision Zero was partly a reaction to the use of cost-benefit analysis (CBA) in transport policy and decision-making. (See Hokstad and Vatn (2008) and Hansson (2007) for elaborate discussions on the moral and philosophical issues associated with use of CBA.) Unlike CBA, Vision Zero does not promote the weighing of safety against other values in the traffic system. Life and health, it is claimed, "can never be exchanged for other benefits within the society" (Tingvall and Haworth 1999, p. 2).

Proponents of Vision Zero have claimed that it rectified a previous double standard for different transport systems. Safety had the highest priority in aviation and rail traffic, where accidents were treated as unacceptable events. In contrast, accidents in the road system were taken to be unavoidable and a price worth paying for mobility (Johnston et al. 2014). The high demands on airplane safety have seldom been criticized, and no attempts seem to have been made to systematically evaluate safety measures in that area with cost-benefit analysis. In contrast, the application of a similarly strict attitude to road traffic, which is promoted as part of Vision Zero, has attracted much criticism. Elvik (1999) maintained that the uncompromising prioritization of safety and health in the road traffic system would divert economic resources from other societal objectives to the promotion of road safety. Since resources are limited, he argued, this would reduce measures against other causes of death and injury in society, leading to an increase in general mortality. For similar reasons, Elvebakk maintained that from a utilitarian point of view, "rather than being a more ethical approach to road safety, vision zero is a less ethically sound basis for policy" (Elvebakk 2005, p. 24). Allsop (2005) argued that "the cold socio-economic logic of the human mind and the warm aspiration of the human spirit join their voices to say: no, they are not paramount, and yes, they can be traded. [. . .] Safety is for living: living is much more than just keeping safe" (p. 15).

Nihlén Fahlquist (2009) argued that Vision Zero could potentially be used to justify radical limitations of freedom of movement and individual autonomy and that it could lead to privacy infringements if inbuilt technologies and safety/surveillance cameras store data on drivers' behavior.

This criticism is based on the assumption that Vision Zero implies that traffic safety always has a higher priority than everything else. That is a misunderstanding. Proponents of Vision Zero accept that it cannot immediately be fully implemented. If traffic safety had higher priority than everything else, then all road traffic would have to be stopped immediately and only be restarted to the extent that it could be undertaken with no risk of fatalities. However, contrary to proponents of CBA, defenders of Vision Zero do not treat trade-offs, for instance, between safety and economy as optimal and satisfactory states. Instead, they treat such trade-offs as temporary compromises that should as soon as possible be superseded by new arrangements ensuring improved safety.

This can be clarified by a comparison with other social goals. There are a large number of policy areas in which society has goals that are subject to compromises with other goals. However, the relationship between goal-setting and compromises is different for different areas. In some areas, the tradition is to work with goals that are believed to be fully attainable. Economic policies illustrate this practice. It would be highly desirable to eradicate unemployment, but economic and labor market policies are not conducted in terms of such goals. Instead, more realistic goals are used, in this case a reduction in unemployment that is considered to be compatible with other goals for economic policies. In other areas, goals are used that represent the most desirable state rather than a compromise. For instance, law enforcement policies do not aim at an economically optimal frequency of manslaughter. Instead, they are based on the assumption that every case of manslaughter is one too much. Similarly, agencies for workplace health and safety are not instructed to try to achieve an economically optimal frequency of fatal accidents on workplaces but to reduce their number as much as possible. The difference between these two approaches is shown in Fig. 2. Either we make compromises and adjustments first and then set the goals (as in economic policies) or we set goals first and make compromises afterward (as in law enforcement and workplace safety). Vision Zero can be seen as an attempt to transfer traffic safety from the first to second of these patterns. This does not mean that the avoidance of traffic fatalities will be the only social goal that is never subject to trade-offs. Instead, it means that Vision Zero will be one of several goals that are given so high priority that any trade-offs will be treated as temporary and unsatisfactory concessions.

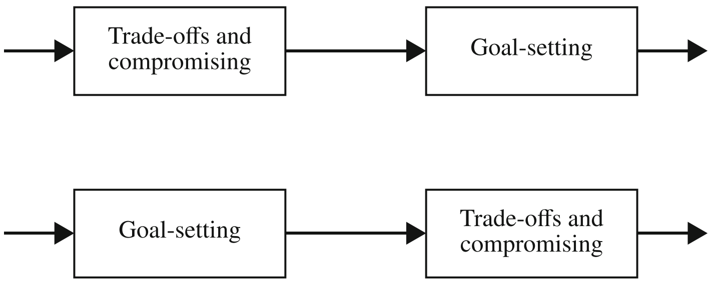

Fig. 2 Two approaches to goal-setting and compromising

In this perspective, the argument that Vision Zero crowds out all other social goals is essentially a straw man argument. However, since the relationship of Vision Zero to other social goals is seldom sufficiently clarified, this is a criticism that has the virtue of giving rise to useful and clarifying discussions.

"It Is Immoral to Focus Only on Fatal and Serious Injuries"

One important point where Vision Zero differs fundamentally from traditional safety approaches is its problem formulation (Belin et al. 2012). As noted above, the traditional goal of road safety was to prevent accidents, regardless of how severe they were. In contrast, Vision Zero accepts that accidents are inevitable in a complex system filled with cognitively fallible individuals. Therefore, it is argued, the road system should be forgiving, and so constructed that predictable crashes do not have severe consequences. Notably, crashes are often not a result of conscious negligence of instituted traffic rules and regulations but of honest and minor errors of judgment (Elvebakk 2007). Another reason for emphasizing fatalities and serious injuries in road safety is, of course, that it is those accidents that bear the largest personal, social, and economic costs.

In a recent book criticizing the Vision Zero approach in Victoria, Australia, Morgan (2018) identifies some debatable aspects of Vision Zero's emphasis on fatal and serious injuries. Singling out and focusing on such crashes, he argues, fails to take into account the magnitude of suffering caused by minor injuries and the economic cost associated with them. He claims that "fatal and serious injury crashes are only a small part of the total road safety/vehicle collision problem" (Morgan 2018, p. 48).

It is fairly easy for a defender of Vision Zero to address this argument. It is generally accepted that saving lives has a much higher priority than preventing accidents that will only lead to temporary impairments of health and mobility. Furthermore, it can be argued that the focus on severe accidents was a crucial factor for making Vision Zero realistic enough to be adopted as a national traffic safety policy in several countries. However, it should also be conceded that the avoidance of minor accidents cannot be given zero priority. Although there does not seem to be a need to give up the strong priority for avoiding fatalities and serious injuries, there is certainly a need to discuss how less serious accidents can be included in preventive work that has a Vision Zero framework as its major driving force.

"Vision Zero Is Paternalistic"

There is a long history of criticism against safety measures in road traffic that are perceived as restricting individual liberty. Legislation against drunk driving has been a major target of such criticism and so have seat belts and bicycle and motorcycle helmets (Jones and Bayer 2007; McKenna 2007). One major argument that is usually presented against the promotion of such safety interventions is that they tend to diminish individual autonomy and pose undue interference in an individual's personal life. Much of this criticism has been couched in anti-paternalist terms (▶ Chap. 6, "Liberty, Paternalism, and Road Safety", by Hansson). It has been argued that as long as no harm is done to others, individuals should be allowed to do what they voluntarily choose to do in road traffic. This type of criticism has repeatedly been directed at Vision Zero. Ekelund (1999) argues that people who so wish should be allowed not to use safety belts, helmets, or other safety technologies. Allsop (2005) maintains that Vision Zero is morally problematic due to the restrictions it imposes on individuals seeking to engage in activities that make their life complete and meaningful, even at the expense of losing their health and safety. Elvebakk (2015) has presented what is probably the most extensive criticism along these lines. She provided two major reasons why road traffic systems operating in accordance with Vision Zero will be problematic from the viewpoint of individual liberty.

The first reason is related to the responsibility ascriptions in Vision Zero. Traditionally, individual road users almost exclusively took the blame for accidents. Moreover, the road system was conceived as a private sphere of individual road users, where they could act and behave as they wanted, so long as they took responsibility for their actions and behavior (Elvebakk 2007). According to Vision Zero, however, it is the responsibility of the system designers to design a road system that takes into account the fallibility and physical vulnerability of road users. Individual road users will still be responsible for respecting traffic rules, but "if they do not live up to these expectations, the system designers must take measures" (Nihlén Fahlquist 2009, p. 391). This, Elvebakk claims, means that contrary to previous systems in which road users themselves could determine the level of risk they wanted to take, in Vision Zero only the system designers determine the level of risk in the system. This argument is obviously fallacious since it is based on the incorrect assumption that road users in a traditional system can choose the level of risk they are exposed to. Many of the people who have been killed on the roads drove as carefully and safely as they could but were hit by another vehicle that suddenly appeared in a place where it should not be. This applies not least to pedestrian and cyclist fatalities.

Elvebakk's second argument is based on the observation that if the intention in Vision Zero is to bring down the number of killed and injured to zero, then system designers cannot allow road users to engage in "high risk activities" in the road traffic system. This observation is correct, and it is also true that proponents of Vision Zero have proposed and partially implemented measures that restrict the liberty to engage in high-risk activities on the road, such as speeding and drunk driving. The use of alcohol interlocks, seat belt locks, and intelligent speed adaptation (ISA) will have a significant impact on the safety of the road system. According to Elvebakk (2015, p. 301):

> Although these technologies only reinforce existing regulation, they do in fact represent a considerable reduction of the individual road user's actual autonomy: while a ban merely adds a legal risk to the existing risk of the action, a coercive technology – if successful –

> physically prevents the individual from carrying out the undesired action. Thus, to the extent that the measures are introduced to protect the road users performing the undesired action, they do take paternalism to a significantly higher level.

When evaluating this criticism, it is important to note that few if any of the measures proposed to implement Vision Zero are in fact paternalistic. For instance, Elvebakk commits a serious conceptual mistake when claiming that the introduction of alcohol interlocks is an expression of paternalism. According to the Global Road Safety Partnership (2007), the presence of even small amounts of alcohol in drivers' blood increases the risk of being involved in crashes. A recent report by the International Transport Forum shows that more than 273,000 annual deaths in the road traffic systems are alcohol-related (Vissers 2017). Obviously, a drunk driver poses a risk not only to her- or himself but also to other users of the road system. For instance, a report by the Centers for Disease Control and Prevention (1997, p. 104) indicates that "approximately one fourth of all traffic deaths among children aged <15 years involved alcohol and that in nearly two thirds of passenger deaths involving a legally drunk driver, the child was in the car driven by the legally drunk driver."

Alcohol interlocks, as well as speed limits that are also essential components of Vision Zero implementation, restrict the freedom of drivers to drive as they wish. However, the issue at play is not:

> My freedom to drive as I like
> versus
> Public measures to protect me.

Instead it is:

> My freedom to drive as I like
> versus
> Public measures to protect others on the roads and pavements.

Thus, criticism against Vision Zero for being paternalistic is largely misdirected. It is not paternalistic to prevent a person from engaging in an activity that exposes others to risks of death. It should be noted that even before Vision Zero, major reductions in the number of road traffic causalities had been achieved with non-paternalistic measures that restrict individual liberty. This includes requirements of licenses, speed limit laws, and drunk driving laws. Technological measures that further reduce the prevalence of speeding and drunk driving, such as alcohol interlocks and automatic speed adapters, certainly infringe on the liberty to behave in certain ways on the roads, but these measures are by no means paternalistic. It may be rhetorically efficient to defend the liberty to put others' lives in danger by labeling countermeasures as paternalistic, but this is certainly not a valid argument.

According to McKenna (2007), an important lesson from the experience with such interventions is that the perceived legitimacy of an activity and the associated intervention determine both the implementation and final success of the intervention. McKenna uses the example of how difficult it was to succeed with interventions against drunk driving in the past, when it was perceived to be a morally acceptable practice, albeit illegal. However, as the public perception of drunk driving shifted from acceptance to considering it to be an antisocial activity, the preconditions for implementing interventions also changed; it became easier for law enforcement bodies to take "active steps to detect and deter drunk driving" (McKenna 2007, p. 2). As this shows, the perceived legitimacy of an activity can change over time. What is considered legitimate at one point in time may not remain so over time. In a study performed in Sweden, Norway, and Denmark, Eriksson and Bjørnskau (2012) investigated the public's acceptance of three ICT-based traffic safety measures that have implications on the privacy and freedom of individual road users. The measures were speed cameras, intelligent speed adaptation (ISA), and event data recorder (EDR). The study indicated that awareness of the problem for which the intervention is used, the belief that one's own actions could contribute to addressing the safety problem, belief in the fairness and effectiveness of the measure, and demographic factors influenced the acceptance of these measures. Generally, the study reported relatively high levels of acceptance for all three measures, despite their impact on privacy and freedom for the drivers concerned.

In summary, the argument that Vision Zero is paternalistic does not get off the ground, since the major restrictions on drivers' behavior that have been proposed to implement Vision Zero are all non-paternalistic. (On paternalism and traffic safety, see also ▶ Chap. 6, "Liberty, Paternalism, and Road Safety", by Hansson.)

"Vision Zero Goes Contrary to Equity and Social Justice"

Globally, the burden of road traffic fatalities and injuries is disproportionately borne by pedestrians, bicyclists, and motorcyclists, who account for more than half of all deaths on the road. It has now been established that road traffic injury is the leading cause of death for children and young adults aged 5–29 years. According to the WHO, a major reason for this is that road safety planning and decision-making usually ignore the interests of these groups (WHO 2018). In many parts of the world, vulnerable road users are forced to use the same roads as vehicles operating at speeds that can lead to fatality or a serious injury if a crash occurs. In addition to the inequitable distribution of risks between different groups of road users, the measures taken to address the problem of road safety can impact differently on different segments of a population. Safety interventions tend to be instituted mainly in areas where people can afford them, which means that investments in safety tend to favor the rich (Elvik 2003). Moreover, when road safety policies are implemented in areas distinguished by large socioeconomic gaps, there is a risk that the policies, rather than addressing the road safety issue equitably, will further exacerbate the unequal state of affairs. While such concerns are almost nonexistent in, for example, a Swedish context, much has been written about traffic-related inequity in the USA, mainly in New York City (NYC).

The most serious of these criticisms are directed against the continued use of intensive policing as a safety intervention in the Vision Zero regime. Lee (2018) argues that Vision Zero has become an essential part of systematic segregation and discrimination in the streets of NYC. In his view, Vision Zero has been repurposed to serve a system of white supremacy that relies heavily on the policing of people of color to create a safe space for rich white people. These observations are made in relation to what he calls Vision Zero apartheid. Much of his criticism is directed toward the New York Police Department (NYPD) and the way they approach electric bike (e-bike) riders. Despite not causing many injuries, Lee argues, the City and NYPD have been using Vision Zero to police and ticket mostly immigrant delivery workers. To take an example, in 2017 over 923 e-bikes were confiscated from immigrant delivery workers and nearly 1800 e-bike criminal court summonses were issued, according to Lee (2018). Criminal court summons is particularly troublesome for immigrant workers, Lee notes, since if they do not show up in court, an arrest warrant will be issued for them.

Vision Zero, as initially developed in Sweden, clearly prioritized the prevention of fatalities and serious injuries and hence excluded minor injuries and noninjury crashes from consideration. The major justification was that it is impossible to avoid all crashes, given the fundamental fact that road users are cognitively fallible. The actual reality on the ground is very different, according to critics of Vision Zero in NYC. The police still target and penalize road users who commit low-level offenses that are not interesting from a Vision Zero point of view. Moreover, in the case of delivery workers on e-bikes, they do so despite lack of credible scientific evidence linking the use of e-bikes by the delivery workers to a serious loss of health (Lee 2018). According to Lee, the targeting of the delivery workers by the police is rather designed to “calm white fears of non-white bodies by using enforcement to impose punitive forms of racial and social control under the guise of public safety” (Lee 2018, p. 186). Thus, he continues, the policing strategy is just an extension and manifestation of systemic discrimination and bias against people of color and immigrants by enforcement agencies.

The enforcement strategies of NYC and NYPD must be understood against the background of the long history of policing in the USA, where a main strategy to prevent bigger criminal offenses has been through the intensive targeting and penalization of minor offenses (Lee 2018; Conner 2016). This policing strategy, called the “broken windows approach,” or “broken taillight policing” when applied in traffic safety enforcement, emphasizes the targeting of minor offenses with the view that this prevents people from engaging in major crimes. According to Conner, the continued use of this strategy has led to a situation:

> where a violation relatively insignificant to safety is aggressively and subjectively enforced. The results are the disparate stopping, ticketing and arresting of drivers and bicyclists in predominantly African-American neighborhoods. Broken taillight policing criminalizes nonviolent and non-criminal behavior, and thus risks creating opposition to enforcement against dangerous driving. Further, because the summonses and arrests that result are tried in a racist criminal justice system, investigatory traffic stops are inherently inequitable. (Conner 2016, p. 16)

Conner further claims that it is impossible to achieve the Vision Zero goal without finding a proper solution to racial biases in police enforcement work and the justice system. This, it is rightly argued, is because the presence of racial discrimination in police enforcement work will lead to the misdirection of scarce public resources, "perpetuating linked cycles of racial bias and ineffective traffic enforcement" (Conner 2016, p. 18).

Connected to the criticism of the disproportionate nature of police enforcement is the issue of procedural justice when it comes to decision-making in road safety work. Critics argue that decision-making on police priorities and strategies is performed in ways that exclude affected parties and their interests. Lugo (2015) identified four major problems that Vision Zero implementation in US cities should address in order to be successful. First, she argued that Vision Zero is a Eurocentric policy, copied from Northern Europe and implemented without taking local realities and voices in the USA into account. Second, Vision Zero's heavy reliance on police enforcement not only fails to consider the history of police violence against people of color in the USA but also opens opportunities for the police to further apply their biases. Lugo stated:

> White people may look to police as allies in making streets safer; people of color may not. . .It really doesn't seem like Vision Zero was designed to admit the problems that are an unfortunate reality for many in this country, a reality that other groups are working very hard to bring to light. It'd be great to see the development of a street safety strategy that starts with a dialogue on what "safety" means and whose safety we have in mind, taking it for granted that we don't all face the same safety problems. (Lugo 2015, p. 3)

The assumption that most people of color would not opt for increased policing as an intervention appears to have some empirical support. A case study on Portland City's Vision Zero equity efforts by the Vision Zero Network shows that community stakeholders and partners who were consulted on the issue of policing were not in favor of "increased penalties and fines for traffic violations" or the use of "checkpoints and saturation patrols to control for DUIs," mainly due to fear of police racial profiling (Vision Zero Network 2018, p. 3).

The third problem with the Vision Zero initiative that Lugo identified is what she calls combative issue framing. The presentation of Vision Zero as "the only ethical choice," Lugo claims, is meant to shame politicians by suggesting that disagreeing with the vision is unethical. However, Lugo urged that this could also have detrimental "silencing effects" on already oppressed people.

> I've seen a worrying tendency among bike advocates to dismiss those who disagree with them as NIMBYs, flattening opposition regardless of whether it comes from community members who lived through the ravages of urban renewal or privileged homeowners concerned about an influx of colored bodies into their suburban sanctum. Vision Zero strategists should show their respect for meaningful inclusion through welcoming intersectional perspectives. (Lugo 2015, p. 2)

Last but not least Lugo criticized Vision Zero proponents' "emphasis on top-down strategy," where the main responsibility to bring about the required change is delegated to policy makers and planners, overshadowing the importance of initial inclusion of other stakeholders in the policy process. According to Lugo, this "creates well-known barriers to participation in agenda setting by the very users the projects... are intended to serve" (Lugo 2015, p. 2).

Similar concerns of exclusion of affected parties from decision-making are aired in Lee's (2018) research on immigrant delivery workers:

> Despite the sizeable presence of delivery cyclists, city officials and bike planners and advocates do not involve delivery cyclists in dialogue about street safety and design. Partly, planning processes typically privilege top-down technocratic decision-making that discounts the embodied knowledge of people and communities particularly marginalized ones. (Lee 2018, p .46)

These criticisms concern the way decisions are made and who is involved in the decision-making processes in Vision Zero. In modern democracies, deliberation by concerned stakeholders on a proposed piece of legislation or policy action is a requirement before the legislation or intervention is put into effect. If there are parties that could be affected by the legislation or action, then involvement and consultation of these parties is an important step that determines not only the legitimacy and acceptability of the legislation or action but also its success.

Generally, when discussing the issues of equity and social justice in Vision Zero, it is important to note, as mentioned briefly earlier, that some countries and cities committed to Vision Zero inherited a road traffic system that is highly characterized by inequitable distribution of benefits and burdens in the road system. These realities have two major implications for Vision Zero when it comes to ensuring the promotion of equity in traffic safety work.

First, it is essential to identify the sources, nature, and extent of past and present inequity and to determine how they now affect the promotion of equity in Vision Zero safety work. For instance, the US General Accounting Office (GAO) in 1983 and the United Church of Christ Commission for Racial Justice in 1987 both confirmed the primary role of race and economy in the distribution of environmental benefits and burdens in the USA. Later studies have also confirmed this to be the case (Bullard 1990; Bullard and Wright 2009). In such sociopolitical environments, it is important for Vision Zero efforts to recognize the impact that race and economy could have on the distribution of benefits and burdens in the road system. Discrimination on the basis of race or economy manifests itself, for instance, through lack of recognition for people's concerns in public decision-making and also through denying them the opportunity to meaningful participation in decision-making processes on issues that affect their lives. Hence, according to social justice scholars (Young 1990; Schlosberg 2007), the correction of distributional inequity calls for consideration and inclusion of these components of justice, which have previously been ignored but are highly important in determining who gets what in a society. Generally, these theorists claim that distributional problems could not be grasped without recognizing other important aspects that determine the processes and outcomes of distribution. For instance, they present recognition and participation as important aspects of justice. It is argued that lack of recognition and exclusion from decision-making processes causes unfair distributive results. These considerations are particularly important in countries and cities where race and economy have a large influence on the distribution of benefits and burdens. Moreover, promoting equity in Vision Zero could also require measures to correct past injustices and unfair distributions through mechanisms such as compensation, or reforming of legal and sociopolitical institutions that could have contributed to the inequitable distribution in the first place. In the USA, for instance, we currently see a growing call for compensating previously neglected areas through increased budgets for traffic safety work. Moreover, there is a similar interest in reforming public institutions such as enforcement agencies that have long and complicated relationships with people of color, minorities, and the economically disadvantaged (Morse 2015). It is also important that Vision Zero proponents design and implement strategies for equity and make sure that current safety work does not result in unfair distribution of benefits and burdens. Conner rightly comments that:

> for all cities adopting Vision Zero, an intersectional and inclusionary equity analysis must permanently guide engineering, education and enforcement along the lines of age, gender, geography and socio-economic condition as well as race. Equity must become a fourth "E," applied in a recurring process of analysis, implementation, and evaluation. Achieving equity in Vision Zero is not only a moral obligation; equity is a tool and tactic requisite to reach our goal. (Conner 2016, p. 18)

To conclude, the criticism against Vision Zero for perpetuating inequalities is valid, although not as a criticism against Vision Zero as such but as a criticism against implementation practices, in particular in places with an entrenched history of discrimination. As we see it, this is a criticism that should be taken seriously. Countries and cities committed to Vision Zero have the double burden of addressing the causes and ill effects of past transportation injustices and making sure that decision-making and policy implementation in the Vision Zero era result in an equitable and fair outcome for all.

Rationality-Based Criticism

A second category of arguments against Vision Zero concerns the rationality (rather than the moral justification) of adopting and pursuing the goal to prevent all fatalities and serious injuries in road traffic. We discuss the argument that Vision Zero is unrealistic and, thus, cannot be used to guide and motivate action toward the desired end-state of no fatalities or serious injuries. After that we discuss the argument that Vision Zero is too imprecise to guide action effectively. Finally, we address the argument that Vision Zero, partly because it is an unrealistic and to some degree imprecise goal, is counterproductive, or self-defeating.

"Vision Zero Is Unrealistic"

A common argument against Vision Zero is that it is a utopian or entirely unrealistic goal: no matter how much we try, we will never be able to able to reach a state where nobody is killed or seriously injured on the roads. When the Swedish government's ministry memorandum on Vision Zero was sent out for referral in the late 1990s, a few of the consultation bodies brought up the issue of achievability. Among those critical to Vision Zero were the county council of Jämtland and Täby municipality, both of which argued that Vision Zero was unrealistic given the extensive economic and administrative resources that would be required to achieve the goal (Government Bill 1996/97:137, section "Accident Statistics Do Not Provide a Reliable Picture of the Safety Level"). A report published by the Swedish National Road and Transport Research Institute (VTI) in 2005 confirmed that similar views were held by local politicians in the mid-2000s (Roos and Nyberg 2005). In this study, in-depth interviews were conducted with 20 municipal politicians responsible for road safety work regarding their views on road safety and the implementation of Vision Zero measures. A core finding was that a majority of politicians considered Vision Zero to be important but unrealistic. However, the practical implications of holding such views were not clear-cut. A few of the interviewed politicians emphasized that it was meaningless to have a vision that was impossible to achieve. Others, however, maintained that Vision Zero was nevertheless the only morally acceptable goal to pursue.

The achievability of Vision Zero has been questioned also in the academic literature. In relation to workplace safety, Long (2012, p. 27) claimed that "absolute goals, regardless of their excuse as aspirations, break the first rule in the fundamentals of the psychology of goal setting – achievability." In Long's view, while adoption of realistic goals typically fosters trust in in the achievability of the goal and primes the agent for success, adoption of overly difficult goals leads to skepticism and instead primes the agent for failure. Similarly, in his criticism of Vision Zero traffic safety policy in the State of Victoria, Australia, Morgan (2018) argued that the goal of zero fatalities and serious injuries is impossible to achieve. Based on case studies on fatal and serious injury crashes in six areas over the period of 2012–2016, Morgan concluded that even when the widespread use of vehicle technology (autonomous braking) is realized, "some 25% to 30% of all fatal and serious crashes are still unlikely to ever go away, even with reduced urban speed limits." However, Morgan does not cite any publications providing details of these studies. In the absence of detailed data, it is not possible to assess to what degree they support his conclusions.

In the goal-setting literature, attainability is often put forward as a rationality criterion for goals (Edvardsson Björnberg 2008). Goals need to be achievable, it is argued, in order to have the capacity to guide and motivate agents toward the desired end-state expressed by the goals. Thus, the SMART criteria, a set of goal criteria commonly referred to in management literature, include the requirement that goals should be attainable. One of the main arguments supporting this conclusion is that goals that are utopian, or very difficult to achieve, risk becoming counterproductive. That is, when the agent realizes that she will not be able to reach the goal, her motivation to pursue it will taper off. Instead of stimulating action toward goal achievement, the goal could make it more difficult to reach or approach the desired end-state (Hansson et al. 2016). (This argument is further discussed in section "Vision Zero Is Counterproductive and Self-Defeating")

There are at least two possible counterarguments to the "anti-utopian objection" raised by Long (2012) and others. Firstly, although empirical evidence supports the conclusion that totally unrealistic goals can have a demotivating impact (see below), a binary categorization of goals as either realistic or unrealistic is too simplistic for most policy purposes. It fails to acknowledge that goal achievability often comes in degrees. A goal that is utopian in the sense of having a very small chance of ever being fully achieved can nevertheless be approached to a meaningful degree. Many of the political goals fought for throughout history, such as equality and freedom, are in fact goals that may never be fully achieved but can still be approached to a meaningful degree. Thus, Rosencrantz et al. (2007, p. 564) write:

> ideological goals like these cannot be achieved once and for all, but will always have to be fought for. This does not prevent social and political movements from using ideals such as freedom and justice as goals. It does not seem constructive to claim that goals like these should never be set, but should be replaced by goals that are known to be fully achievable. The only demand of attainability that seems to be generally required is that goals should be approachable, i.e., it should be possible to increase the degree to which they are achieved.

Highly ambitious goals are commonly adopted, not only by political decision-makers; they also play an important role in private organizations. As an example, Kerr and LePelley (2013) discussed the introduction of "stretch goals" by General Electric's then CEO Jack Welch in the early 1980s. Inspired by Japanese-style management techniques, Welch was convinced that highly ambitious goals should be adopted in order to stimulate creativity, exploratory learning, and "outside-the-box thinking" among the company's employees. Since then, several other companies have introduced a similar approach to goal-setting, among them the US Southwest Airlines and Toyota (Sitkin et al. 2011).

Secondly, as argued in section "It Is Not Ethically Unjustified That People Die on the Roads," there may be ethical reasons why the goal of achieving zero fatalities and serious injuries should be retained, even if it may well be impossible to fully achieve. Some political goals are difficult to adjust without losing their moral appeal. Consider, for instance, the goals to abolish slavery or human trafficking. There are good reasons for arguing that, from an ethical point of view, no number of slaves or trafficking victims above zero is good enough for these societal ambitions. In our view, the same argument applies to Vision Zero. As long as there are measures that can be taken to reduce the number of fatalities and serious injuries in road traffic, Vision Zero can be considered a rational goal.

"Vision Zero Is Too Imprecise"

Goals typically need to be precise in order to have the capacity to guide and coordinate action effectively. Vision Zero has been criticized for failing also on this account. For instance, Lind and Schmidt (2000) argued that the strategy behind Vision Zero is vague and difficult to relate to, especially for actors at regional and local levels, since it has not been operationalized into more concrete targets and measures. One suggested solution to this problem is to introduce subsidiary goals in road safety work. This has been done in some Vision Zero countries, for example, Sweden, where the overall goal of zero fatalities and serious injuries was operationalized into the more precise sub-goal to reduce the number of road traffic fatalities to 220 by 2020. (With 223 dead on Swedish roads in 2019, the country was close to achieving this sub-goal (Transport Styrelsen 2020).)

Elvebakk and Steiro (2009) investigated how the Norwegian Vision Zero was interpreted and perceived among those working with transport and road safety in the country, including politicians, representatives of the National Public Roads Administration and the Council for Road Safety and Police, and NGOs. They concluded that:

> the interpretative flexibility of the vision and relative lack of public debate have created a situation where actors focus on different aspects of the vision, and on different levels, from theoretical questions of ethics to specific practical questions of implementation. On the whole, it seems that the connection between the different levels of the vision are somewhat tenuous, and in this situation actors are relatively free to construct their own interpretation, rather than building one shared vision. (Elvebakk and Steiro 2009, p. 958)

A similar attempt to explore how Vision Zero is conceptualized and instantiated by key actors in Norway was made by Langeland (2009). Among other things, this study investigated how Vision Zero policy documents address the problem of conflicting goals and interests. One of the problems of adopting nonspecific goals, identified by the author, is that responsibility for addressing potential goal conflicts is transferred from the political level (where it arguably ought to be handled) to the administrative level, where different agencies may prioritize differently in the absence of clear political directions:

> By keeping the zero vision on an abstract level, the actors may evade the conflicts that will arise when it is instantiated. The actors might find this beneficiary, as it gives them more leeway. When the zero vision is instantiated, conflicting interests and competing goals come to the fore. This may generate uncertainty for the parties involved. The more the zero vision is instantiated in terms of actual change, the more difficult it will become to ensure implementation. When the zero vision is instantiated through new policies, it will challenge goals competing with road safety. This will probably impede further realization of the zero vision. (Langeland 2009, p. 76)

There can be no doubt that lack of precision can decrease the action-guiding capacity of a goal. Imprecise goals can be difficult to follow. They can also be difficult to evaluate. However, the degree of goal specificity required for a goal to guide and coordinate action effectively depends on the context in which the goal is implemented. For instance, in a context where the implementing agents have fairly good knowledge about what to do in order to reach or approach the goal, the goal does not have to be as precise as when such knowledge is lacking. Furthermore, it is important to recognize that trade-offs may have to be made between the action-guiding and motivating properties of a goal, since a goal that has a high degree of precision may not be particularly motivating and vice versa. In practice, the action-guiding and motivating aspects of goals often have to be balanced in goal-setting processes.

In general, goals that are implemented by another actor than the goal-setter require a greater degree of precision. Edvardsson and Hansson (2005) distinguish between three different types of precision: directional, completive, and temporal precision. A goal is directionally precise if it tells the agent in which direction to go in order to approach the goal. Completive precision means that it is in addition clear to what extent the goal should be reached. A goal is temporally precise if it includes a specified point in time when it should be achieved. Directional imprecision appears to be particularly deleterious, since it leaves the agent without a clear view of what to do in order to approach the goal. In organizational contexts, where goals are adopted and implemented by actors at different levels, imprecision typically also makes it more difficult to evaluate implemented measures and hold those responsible who have impeded goal achievement.

One could argue that the Swedish Vision Zero fulfills two of the three identified aspects of precision (Rosencrantz et al. 2007). Vision Zero is directionally precise, since it clearly states that there should be a reduction in the number of killed and seriously injured people on the road. It has completive precision, since it clearly aims to achieve a total prevention of fatalities and serious injuries. At the same time, the goal lacks in temporal precision; it does not indicate a precise point in time when it is to be fully achieved. However, although Vision Zero has both directional and completive precision, the emphasis on reduction of negative outcomes as an indication of safety has been criticized.

In a study of the formalization of the Swedish system designers' responsibilities between 1997 and 2009, Belin and Tillgren (2012) argued that, although the shift in responsibility ascriptions from individual road users to system designers presented a substantial change in road safety work, the change was nevertheless ambiguous. The reason for this was that it was difficult to get a clear idea of who the system designers were and exactly which of their activities ought to be regulated. Moreover, the authors suggested that, although there was a unanimous consensus on Vision Zero when it was formulated and legally adopted, conflicts of interests emerged during the implementation phase when different actors attempted to translate the vision into concrete action. This was particularly noticeable as perceptions of the costs and benefits of legislating on system designers' responsibility became more real to the stakeholders. These observations point to a fourth type of goal precision not covered by Rosencrantz et al.' (2007) tripartite definition of goal precision, namely, precision in the division of responsibility.

In summary, the empirical evidence indicates that the criticism of imprecision in the formulation of Vision Zero is apposite and also highly constructive. It shows that an overarching goal like Vision Zero is in need of more precise sub-goals that add precision in the dimensions in which the overarching goal is not precise enough for action guidance. In the case of Vision Zero, it is important that such sub-goals specify the temporal component of precision, i.e., clarify when various task should be completed. In many cases, the division of responsibility is also in need of specification in sub-goals.

"Vision Zero Is Counterproductive and Self-Defeating"

Goals are typically adopted in order to achieve (or maintain) certain states of affairs. However, sometimes goals turn out to be self-defeating in the sense that instead of furthering the desired end-states, the goals interfere with progress, making it more difficult to achieve those end-states. As noted by Hansson et al. (2016), various mechanisms can contribute to making a goal self-defeating. We have found two major types of claims that Vision Zero goal is self-defeating, referring to economic and psychological mechanisms, respectively.

Elvik (1999) warned against economic self-defeating mechanisms of Vision Zero. Measures not subjected to cost-benefit calculations would become too expensive, and the policy would end up not only being economically counterproductive but also contributing to increased mortality.

> An objective of eliminating a certain cause of death, like traffic accidents, may be so expensive to realise that it reduces resources available to control other causes of death and thus increases general mortality. (Elvik 1999, p. 265)

One of the basic assumptions underlying Elvik's argument is that there is a causal relationship between income per capita and general mortality, particularly that there is a negative relationship between income and mortality. By disregarding CBA, Elvik argued, proponents of Vision Zero seek to invest in safety measures that do not generate returns on the invested capital, and this leads to a decline in income that would be required to prevent other causes of death in the society. Moreover, Elvik (2003) conducted an investigation into the efficiency of safety policies in Sweden and Norway and claimed to have found that the road safety policies in both countries were inefficient in improving road safety. His recommendation was that making policy priorities on the basis of CBA would lead to greater improvement of safety, than priorities based on Vision Zero.

Elvik's economic criticism is based on a so-called risk-risk analysis, i.e., a comparison between two options, both of which are expressed in terms of risk. Some risk analysts have seen this type of comparison as a way to bypass the common psychological reluctance to value nonmonetary goods in money: "Converting all health outcomes into death-risk equivalents facilitates cost-effectiveness analysis by calculating the cost per statistical life equivalent saved, and it addresses concerns with respect to dollar pricing" (Viscusi et al. 1991, p. 34). The most common way to perform this conversion has been to employ the correlation between health and wealth. Richer people tend to be healthier and live longer. Therefore, "the critical income loss necessary to induce one fatality" (Lutter and Morrall 1994, p. 44) has been calculated and used to translate regulatory costs into fatalities. Elvik's analysis from 1999 is an example of this approach. However, this translation is based on highly uncertain assumptions (Hansson 2017). Since regulations also give rise to business opportunities, costs of regulation cannot be equated with losses in total income. Furthermore, the fact that people tend to live longer in richer societies depends on complex and largely unknown social mechanisms. In particular, there is a strong positive correlation between longevity and income equality. Any conversion of gross national product into gains in longevity is therefore severely misleading (Neumayer and Plümper 2016). There is no ground for assuming that an economic loss anywhere in the economy gives rise to a proportionate increase in total morbidity or mortality.

The second type of self-defeasance identified in the literature relates to the motivational, or behavioral, effects of Vision Zero. As noted above, goals are achievement-inducing not only because they guide and coordinate action toward the desired end-states. Goals can also help us achieve the desired end-states by inducing, or motivating, actions that bring us closer to the goals. This is an important aspect of goal-setting, commonly referred to in psychological and behavioral research. Significant empirical evidence supports the so-called goal-difficulty function, i.e., given certain conditions (such as that the agent has the ability to reach the goal and is committed to it), more ambitious goals will typically induce greater efforts by the agent (Locke and Latham 2002). This holds true up to a certain point where the discrepancy between the goal and the agent's actual performance will be so great that the goal no longer has the capacity to create a corrective motivation to change the agent's behavior toward the goal. If, at that point, the goal gives rise to frustration and resignation instead of inspiration and motivation, then the goal has become motivationally self-defeating (Hansson et al. 2016).

According to some critics, Vision Zero is a good example of a motivationally self-defeating goal. For instance, Long (2012) claimed that pursuing the goal of zero harm in the mining and construction industries has negative motivational consequences that ultimately lead to its own subversion and failure:

> Unachievable goals drive frustration, cynism and negativity; that in themselves diminish effort, energy, resilience and persistence. Absolutes are not achievable with humans, only for machines and gods, and even machines decay and wear out in time. (Long 2012, pp. 24–25)

The stated reason why goals drive such frustration and negativity is that they prime people, in Long's case employees of the mining and construction industry, for failure:

> Zero harm language is not neutral and leaders should be far more aware of how such language 'primes' workers psychologically and culturally [. . .] This is the problem with

> zero harm language, it's non-motivational, noninspirational and counterintuitively primes workers for failure. (Long 2012, pp. 30–31)

Fugeli (2006) similarly claimed that a public health policy based on Vision Zero thinking is problematic because it promises and demands "too much" (p. 268) and eventually leads to a distressed, dangerous, and sick society. He argued that Vision Zero's "obsessive preoccupation with risk" will create a situation where "life becomes surrounded by dangers that the zero missionaries will rescue us from" (p. 268). According to Fugeli, "the Zero-vision demands not merely zero risk, it desires zero deviation from the ideal state of mind and body… Before the Zero-vision a wise furrow, sorrow, shyness, big rump, falling penis—were regarded as natural phenomenon belonging to the mixed state of being human. In the light of the Zero-vision these occurrences become medical deviations claiming restoration by hormones, drugs and knives." In this way, he says, the Zero Vision also contributes to the generation of injustice by dividing and ruling the society for the interest of the educated elites who have "the power to define the golden standards of human life and health and to point derisively at what we will not endure and whom we will not tolerate." However, as far we can see, this is criticism of a straw man. We are not aware of any proponents of Vision Zero who would subscribe to this interpretation of what it means.

There is another way in which Vision Zero has been criticized for being self-defeating, namely, by creating a safety culture within the organizations responsible for implementing the goal that is not conducive to the goal's achievement. Sherratt and Dainty (2017), for instance, argued that Vision Zero, instead of promoting safety, fosters the development of a non-learning culture in which discussions and debates about safety are eliminated. This, they argued, can lead to the "zero paradox," i.e., by adopting and working toward Vision Zero, fatal or serious life-changing accidents actually become more likely. However, judging by the intense and mostly highly constructive debates that Vision Zero has given rise to in traffic safety organizations around the world, it is difficult to see how this could be an impending danger.

In summary, none of the proposed mechanisms that would make Vision Zero counterproductive and self-defeating has been shown to have any impact in practice. Furthermore, the success in many countries of safety work based on Vision Zero speaks against the existence of any strong such mechanisms.

Operational Criticism

We have identified four operational arguments, i.e., arguments concerning the practical methods applied in implementing Vision Zero. The first of these concerns the use of accident statistics and the second the (allegedly insufficient) use of probabilistic information. The last two arguments concern Vision Zero's distribution of responsibilities. According to one line of argument, more responsibility should be assigned to the road users. According to another, responsibility should instead be further shifted toward system designers.

"Accident Statistics Do Not Provide a Reliable Picture of the Safety Level"

In safety work based on Vision Zero, the degree of safety is measured and evaluated in terms in the number of fatalities and serious injuries that occur. Several authors have criticized the use of this measure (Reason 2000; Long 2012; Dekker 2017). According to Long (2012, p. 18):

> Zero harm, if set as a goal is an avoidance goal. One knows goal success by the absence of something rather than the presence of something. Avoidance goals are not only not positive but are not inspirational (Moskowitz and Grant 2009). Avoidance goals tend to be punitive in nature. Performance goals are much more positive and successful. In the framework of understanding motivation and learning leaders should be talking much more in cultural discourse about 'keeping people safe' than 'preventing harm'. Later discussion shows how such discourse 'primes' others. Why does the safety community think that avoidance goals are so inspirational?

We are not aware of any evidence or plausible argument supporting the contention that avoidance goals are not inspirational. Furthermore, it is difficult to find a goal that cannot be expressed in either way. In WW2, the resistance movements in the countries occupied by the Nazis were fighting for the "avoidance goal" not to be under occupation, which could also be described as the "positive goal" to live in a free country. Vision Zero is usually expressed as the "avoidance goal" that no road user should be killed or seriously injured on the road, but it can also be expressed as the "positive goal" that everyone travelling on the roads should travel safely. Ergo, if there is a problem with avoidance goals, then it seems to be solvable with a simple reformulation.

However, there may be more to this. According to Reason (2000, p. 4), the fact that safety is often "defined and measured more by its absence than by its presence" is a safety paradox. He argued that the standard definition of safety, freedom from risks and dangers, fails to take into account the substantial features of safety. For him, safety is better presented if it is positively defined as the ability to deal with risks and hazards so as to avoid damage or losses while still achieving one's goals. However, even more problematic than the way safety is defined, he argued, is that safety is measured in terms of the number of accidents or incidents: "An organisation's safety is commonly assessed by the number and severity of negative outcomes (normalised for exposure) that it experiences over a given period" (p. 5). According to Reason, this is problematic for two reasons. First, it fails to recognize that there is only a weak relationship between an organization's "safety health" and the registered negative outcomes, as chance plays a significant role in the occurrence of accidents.

> As long as hazards, defensive weaknesses and human fallibility continue to co-exist, unhappy chance can combine them in various ways to bring about a bad event. That is the essence of the term 'accident'. Even the most resistant organizations can suffer a bad accident. By the same token, even the most vulnerable systems can evade disaster, at least for a time. Chance does not take sides. It afflicts the deserving and preserves the unworthy. (Reason 2000, p. 5)

Second, he argued, a decrease in accident rates does not necessarily mean that an organization's safety culture is improving. Such a decrease can be the result of instituting mandatory safety technologies or systems that resulted in an early improvement in safety. In most organizations accident rates decline rapidly in the beginning, and "then gradually bottom out to some asymptotic value" (p. 5). Once the asymptote is reached, says Reason, "negative outcome data are a poor indication of its ability to withstand adverse events in the future" (p. 5). He claims that although the presence of high accident rates implies a bad state of safety, low asymptotic values do not necessarily show good safety even though that is how such values have usually been interpreted. Such an erroneous interpretation, he indicates, is the cause of most safety paradoxes and poses practical implications that could negatively impede the promotion of safety.

Similar criticisms have been put forward by Dekker (2017), who also discussed problems associated with defining the goal of Vision Zero in terms of its "dependent variable," i.e., reduced accident outcomes, rather than independent variables that positively or negatively affect the negative accident outcome. According to Dekker, this is one of the reasons why little is known about what activities and mechanisms underlie the reduced negative outcomes achieved by Vision Zero-committed companies. For Dekker, a reduced negative outcome could just be the result of the fraudulent manipulation of the dependent variable (accident statistics), especially if improved statistical outcomes are associated with positive incentives.

> Defining a goal by its dependent variable tends to leave organizations about what to do (which variables to manipulate) to get to that goal. Workers too can become too skeptical about zero sloganeering without evidence of tangible change in local resources or practices. (Dekker 2017, p. 169)

Dekker also claimed that the emphasis on the eradication of accidents often denies the real suffering of the individual workers by inviting data manipulation, stigmatization of workers involved in accidents, and the suppression of bad news. This can result in a work environment that considers mistakes as "shameful lapses, moral failures or failures of character in practice that should aim to be perfect" (Dekker 2017, p. 243). According to Dekker and Pitzer (2016), the reason why many industries face the plateauing of safety performance and, at times, get exposed to surprise fatal accidents is to be found in the very nature of the organizational structure and practices put in place to manage safety. Based on a review of relevant safety literature, they argued that organizational structures characterized by "safety practices associated with compliance, control and quantification" (p. 7) are prone to plateauing and surprise accidents. This, they say, is because in such organizations safety performance close to zero can lead to "a sense of invulnerability," deflection of resources into unproductive or counterproductive initiatives, continued application of obsolete practices, and the suppression of reporting of accidents that actually occurred in the organization.

These authors are right that in general, even if deaths or serious injuries are the main targets, measuring their occurrence may not be the best way to evaluate safety. This is because safety is concerned with the risk of future accidents, which may be of a different type. This is important in industries where rare but very large accidents are the major concern, such as nuclear reactors and many chemical industries. For instance, if day-to-day workplace safety is high in a nuclear reactor – no slippery floors, safe procedures for welding, low radiation exposure, etc. – this does not prove that the risk of a nuclear meltdown is also very low. The measures needed to prevent such an accident are quite different from those needed for more mundane workplace safety issues, and their success is not guaranteed by a low frequency of workplace accidents. The nuclear industry is rather extreme in this respect, but on most workplaces there is a need to carefully analyze the possibility of rare accidents or "surprise accidents." Arguably, this is less important in road traffic than in most other areas of safety work, due to the exceptionally high yearly toll of fatal accidents that provide ample statistical material for priority-setting. However, rare but large accidents such as the collapse of a bridge or a hillside road, or a tunnel fire, surely need to be taken into account even if they do not show up in the accident statistics. Taken as a reminder of this, the criticism referred to above is relevant and should be taken into account in applications of Vision Zero.

"Vision Zero Neglects the Probability of Accidents"

Morgan (2018) argued that Vision Zero is based on a simplistic account of risk because risk is understood solely in terms of the severity of crashes and does not take into account the likelihood that crashes will occur. He writes:

> The safe system approach looks at only half the equation–it does not concern itself with likelihood. . . The safe system premise that safety is everything . . ..inevitably leads to this illogicality: mobility has no value and crash likelihood is not a consideration. . . I think it takes a distorted view of humanity and a messianic view of one's own understanding of life to put the safe system approach to speed management. (Morgan 2018, p. 90)

Not only is Vision Zero based on a flawed definition of what risk is, Morgan argues, it is also a system that does not trust drivers as it seeks to impose a population-wide measure on actions to be committed by one in ten people. In comparison to Vision Zero, speed design principles such as the 85th percentile would render better results since they involve a level of trust in drivers. He claims that "the only benefit of the safe system approach to speed management is that it paves the way for the whole sale proliferation of automated speed cameras, as urged by the safe system manifesto" (Morgan 2018, p. 91).

This criticism is based on the assumption that Vision Zero implementation is focused exclusively on the severity of accidents and does not take their probabilities into account. This assumption is not correct. Many of the measures promoted in Vision Zero have large effects on the probability of accidents. For instance, alcohol interlocks and speed limitations reduce the risks of all kinds of accidents, and roundabouts and central barriers reduce the risk of serious accidents. Probably the most clear examples of measures that reduce the severity of accidents without reducing their probability are seat belts and bicycle helmets, both of which were introduced long before Vision Zero.

"Too Little Responsibility Is Assigned to Drivers"

Ekelund (1999, pp. 44–45) argued that Vision Zero's responsibility ascription is counterproductive, since it puts too great emphasis on the responsibility of system designers. This, he argues, may lead to more reckless behavior by road users. The argument is part of Ekelund's defense of the traditional emphasis on individual responsibility of road users, which he sees as an expression of the freedom of individuals to choose their own goals in life and decide which risks are worth taking:

> By passing a new law for instance about bicycle helmets, instead of leaving the decision to the individual, the responsibility of individuals for their own safety is undermined. This will in practice send a signal: 'You do not need to find out yourself about risks and make your own decisions. We have already found out the risks and made the decisions for you.' By extension, this can induce people to make the assumption that everything that is not forbidden is safe. It will just not be worth the trouble to keep oneself informed about risks, since the government has probably already investigated the conditions of safety. This may very well result in an increased prevalence of careless behavior. (Ekelund 1999, p. 18, authors' translation)

Hence, according to Ekelund, if a government introduces safety legislation against certain dangers, then this will lead the public to be less cautious in relation to other risks. If this were so, then we should, for instance, expect that seat belt legislation has made people more willing to climb dangerous ladders and that the extensive legislation on aviation safety should have induced people to skate on thin ice and swim in strong currents. He provides no evidence of this effect, and we are not aware of any reason to believe that it exists.

However, there are reasons to be concerned that safety legislation can lead to less responsible and more careless behavior *in the specific context* to which the legislation in question applies. For instance, it is much more plausible that measures to increase traffic safety will make drivers feel safer and therefore behave less cautiously, than that these measures will decrease the use of safety equipment in sport activities.

Grill and Nihlén Fahlquist (2012, p. 121) asked if there were "reasons to believe that ascribing responsibility for accident prevention to system designers will in fact make drivers feel less responsible for their driving and so less cautious?" They argued that there are indeed areas where a shared responsibility could mean less responsibility for each party, such as when a certain safety device implanted in a vehicle takes over a task that would have been performed by the driver, had the safety device been absent. They presented examples from aviation where the airplane operator's familiarity with safety devices had led to inattention and complacency (Perrow 1999, pp. 152–154). In road traffic, they argued, similar effects could result from safety devices that take over a certain task from the driver and work continuously through the whole journey, such as a collision avoidance system: "Technical systems that are very sophisticated and where almost all safety hazards are guarded by automatic systems can erode the operator's feeling of responsibility" (Grill and Nihlén Fahlquist 2012, p. 121). In their article, the authors discussed the introduction and application of alcohol interlocks as a manifestation of the responsibility of system designers and refuted the criticism that the use of interlocks will make drivers irresponsible. In their view, the use of alcohol interlocks will not diminish the responsibility of the drivers because the interlock does nothing more than establishing the sobriety of the driver; it merely establishes whether the driver is sober before she can start the engine.

> This test has no direct effect on the driving experience. It does not at all guarantee that the driver is a good one or that the safety of the driver and of other road users is automatically protected. There are many other safety features and conveniences in cars that do make drivers more passive, such as automatic transmission, cruise control and automatic breaking systems. The interlock, on the other hand, only prevents people above a certain degree of intoxication from driving and is itself passive during the journey. (Grill and Nihlén Fahlquist 2012, p. 122)

In conclusion, it seems reasonable to assume that some but not all measures taken to reduce the occurrence of severe injuries in road traffic can have negative effects on drivers' sense of responsibility. This is therefore a criticism that should be taken seriously, as attention to it can improve the efficiency of a Vision Zero strategy.

"Too Little Responsibility Is Assigned to System Designers"

According to Vision Zero, system designers should take the overall responsibility for designing a road system in which fatalities and serious injuries will not occur. Road users are still expected to abide by traffic safety rules and regulation. Failure to follow safety rules and standards could have legal implications. Unlike the individual road users, however, no legal responsibility for safety has been assigned to system designers so far, despite the fact that they have the overall responsibility for the safety of the road system.

Belin and Tillgren (2012) have studied attempts made in Sweden during the years 1997 to 2009 to make system designers formally responsible. Based on evidence collected from official documents, they looked into the progress of the legislative process intended to formalize the responsibility of system designers. They argued that the process of formalizing the designer's responsibility involves a long and complicated process and that there are important factors that limited the government's attempts to realize it. Unlike the initial process that led to the adoption of Vision Zero by the Swedish Parliament, in which the different stakeholders almost unanimously supported the policy, the process of formalizing the responsibility of system designers was characterized by conflicts of interest. These conflicts resulted from the perception that the benefits and costs associated with formalizing the responsibility of system designers were not fairly distributed. This, Belin and Tillgren argued, is in turn a result of a narrow conception of system designers as involving just "the state, the municipalities, and individual road administrators" (p. 94). They argued that "in such a case, we have moved to a position where the benefits are distributed to all road users, while the costs are concentrated among road administrators" (p. 94) and hence resistance against formalizing responsibility among those who perceived that they would receive an unfair share of the burden. The study also identified other factors that prevented the realization of legal responsibility for designers. These included the difficulties associated with changing the traditional responsibility ascription for traffic safety, which is well rooted in both national and international laws, the implementation of other government efforts that had similar effects as that of regulating the responsibility of designers through law, and processes and efforts at other government levels. As an example of the latter, they indicated the positive impact that the process of regulating government agency vehicles and transport services had had on enhancing the responsibility of system designers. The regulation of road administrators' safety responsibility through an EU directive also meant that Swedish road system designers were legally responsible for at least parts of the road network, i.e., the trans-European road network that passes through Sweden. In conclusion, based on the abovementioned reasons, the authors questioned if the attempt at formalizing the responsibility of the system designers was at all necessary. The implementation of other measures that have increased the responsibility of designers shows that "formal legislation is only one policy instrument among others and a formal legislation might not even be the most appropriate way to secure a higher degree of responsibility from the system designers" (p. 100). In fact, the government declined a proposal to introduce formal responsibility. The responsibility of system designers still has no other formal basis than the ethical code of conduct developed in Tingvall (1997).

According to McAndrews (2013), however, the effectiveness of relying only on ethical codes is questionable since a code depends on "the experts' self-regulation" and does not generate any leverage for compliance. A study by Van der Burg and Van Gorp (2005) seems to confirm McAndrews's analysis. These authors investigated how engineers involved in the design of trailers understood their moral responsibilities. They found that the engineers' conception of responsibility was limited to the narrow perspective of respecting the traffic laws and designing an economically efficient and physically strong product. They did not seem to consider themselves responsible for finding technological solutions that would improve traffic safety beyond the legal requirements.

As far as we can see, it is not possible to draw any firm conclusions on whether or not a system of accountability for designers of road traffic systems would contribute

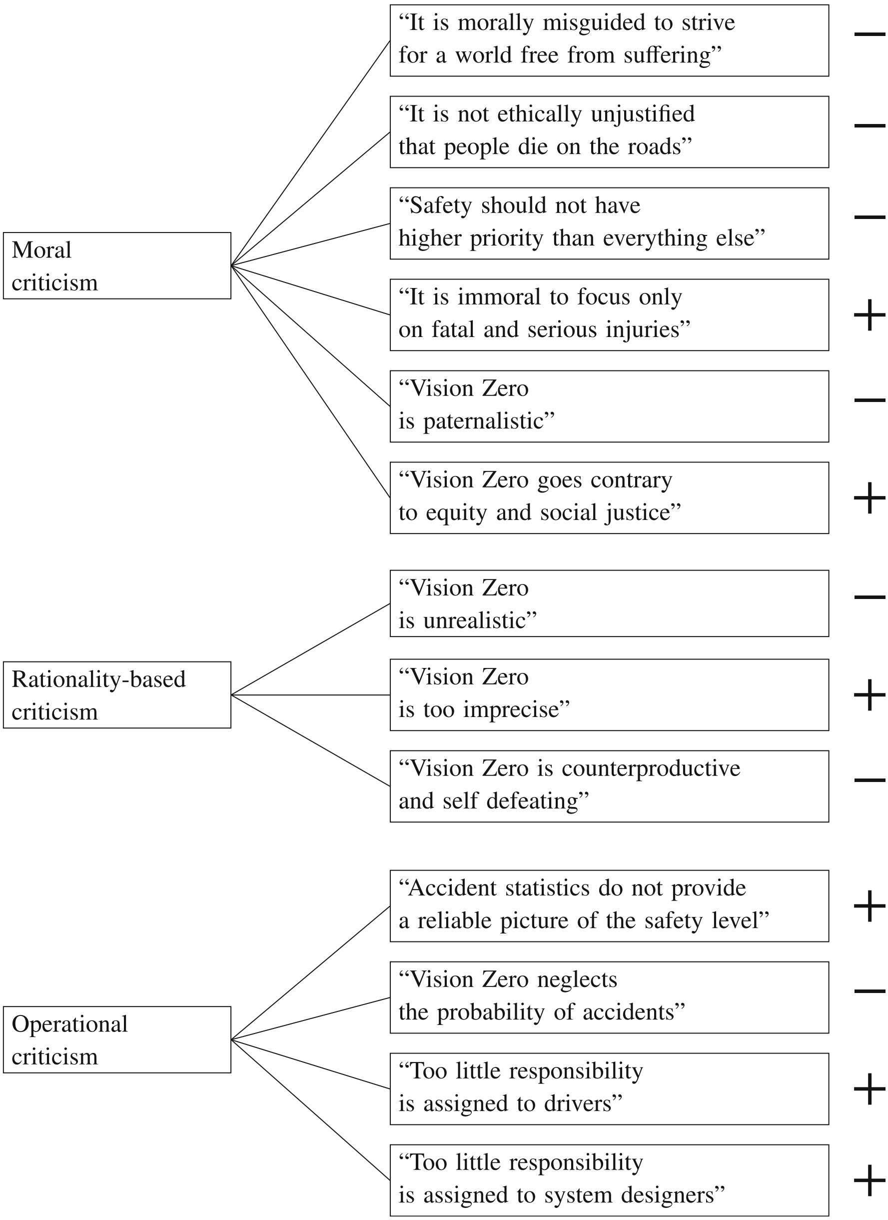

Fig. 3 A summary of our assessments of the arguments discussed in this chapter. The arguments that we found to be useful for a constructive discussion on safety improvements are marked +, whereas the others are marked –

to improved traffic safety. However, the issue is relevant and worth close attention as additional experiences of Vision Zero implementation accumulates. It should definitely be counted as one of the constructive and useful themes of critical discussion.

Conclusion

We have discussed and evaluated 13 arguments. We found that five of them fail because they are based on misrepresentations or misconceptions of Vision Zero (see Fig. 3).

"It is morally misguided to strive for a world free from suffering." – The goals and ambitions of Vision Zero are much more modest than what these critics claim.

"Safety should not have higher priority than everything else." – Vision Zero does not include any such claim of absolute priority.

"Vision Zero is paternalistic." The risk-taking behavior on roads that has to be eliminated according to Vision Zero involves risks for others than the persons who take the risk. Therefore, Vision Zero is not paternalistic.

"Vision Zero is counterproductive and self defeating." None of the proposed mechanisms that would make Vision Zero counterproductive and self-defeating has been shown to have any impact in practice. Furthermore, the many successes of safety work based on Vision Zero speak against this argument.

"Vision Zero neglects the probability of accidents." On the contrary, measures that reduce the probability of accidents have a central role in Vision Zero and its implementation.

Two of the arguments are based on correct descriptions of Vision Zero, but they are nevertheless non sequitur arguments:

"It is not ethically unjustified that people die on the roads." – The proponents of this argument claim that deaths on the roads are acceptable, since people have chosen to risk their lives by travelling on the roads. This argument is fallacious, since most people who are killed on the roads did not wish to take any risks. They just had no other choice than to travel in the risky traffic system that we have.

"Vision Zero is unrealistic." This criticism is based on a too far-reaching requirement on policy goals. In order for a goal to be rational and useful, it has to be approachable, but it does not necessarily have to be realistic in the sense that it is known beforehand that it can be fully realized. Vision Zero is no doubt approachable to a very high degree.

Finally, we found six of the arguments to be at least in part constructive. They should all be further analyzed and taken into account in future traffic safety work:

"It is immoral to focus only on fatal and serious injuries." – There are strong moral reasons to give much higher priority to the elimination of fatalities and severe injuries than to the avoidance of lesser injuries and material damages. However, the critics are right that there is a need to pay more attention to how less serious accidents can be included in safety work that has Vision Zero as its major driving force.

"Vision Zero goes contrary to equity and social justice." Although this does not apply to Vision Zero in general, the proponents of this argument have been able to show that in some places, Vision Zero activities have increased the burdens of transportation injustices. This is, therefore, a criticism that should be taken seriously and leads to careful evaluations of both procedural and distributive justice in Vision Zero activities.

"Vision Zero is too imprecise." The critics are right that Vision Zero usually does not come with a precise time plan for what to do and when. It is necessary to complement it with more precise directives and sub-goals, but this has not always been done.

"Accident statistics do not provide a reliable picture of the safety level." The critics are right that the yearly statistics on deaths in road traffic do not inform us of the risks of rare accidents with many fatalities, such as the collapse of a bridge or a hillside road or a tunnel fire. Traffic safety work based on Vision Zero should pay increased attention to such risks.

"Too little responsibility is assigned to drivers." Judging by the available evidence, some but not all measures taken to reduce severe accidents can have negative effects on drivers' sense of responsibility. The risk of such effects should be included in the evaluation of traffic safety measures aiming to implement Vision Zero.

"Too little responsibility is assigned to system designers." The critics are right that there are currently no means to hold system designers accountable for the design of the road system. It is at present unclear what difference a system of accountability could make or how it should be constructed. However, the issue of accountability should be part of our deliberations on the implementation of Vision Zero.

Cross-References

► Liberty, Paternalism, and Road Safety
► Responsibility in Road Traffic
► Vision Zero and Other Road Safety Targets

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What Is a Vision Zero Policy? Lessons from a Multi-sectoral Perspective

4

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Abstract

Vision Zero is a term mainly connected with road traffic safety and has its roots in the Swedish road safety strategy. It was formally adopted by the Swedish parliament in 1997, and due to the initial success of lowering the number of deaths in traffic crashes significantly, it has become a role model for road safety strategies in countries and cities all over the world. In Sweden, Vision Zero for road safety has also inspired the introduction of Vision Zero policies in other sectors, and this chapter focuses on Vision Zero from a multi-sectoral perspective. The purpose of this chapter is twofold: to present five different cases of Vision Zero policies and to discuss what constitutes a Vision Zero policy based on these five cases. The five cases are found in road traffic safety, fire safety, patient safety, suicide, and workplace safety. Every case has its unique preconditions in terms of laws, actors, scope, etc., but they are also similar in relation to injury prevention and the ambition to decrease the number of deaths and serious injuries. The five Vision Zero policies are summarized by presenting the problem and problem framing, the goal, measures, and solutions as well as leading actors and governing structures. We find that the problem itself is quite self-explanatory in each case but that the problem framing and attribution of responsibility differ. All cases have on paper been inspired by the road safety strategies, but the systems approach, so intimately connected with Vision Zero, is more or less absent in the cases of fire safety and suicide. Furthermore, in the field of fire safety, responsibility is placed on the individual and on the business sector rather than based on a shared responsibility and ultimately on the system designers. In all five cases, there are a set of measures in place, but there are differences in implementation due to temporal factors and also what kind of governing and steering structures are in place. There is also a difference in internal support where the Vision Zero for suicide stands out as having less support among agencies working with the issue. Finally, the monitoring systems differ from case to case. The Vision Zero for road traffic safety stands out as having a monitoring and evaluating system based on specific safety targets ultimately aiming toward zero (management by objectives). Based on the empirical findings, we argue that besides having a clear problem and problem framing, a toolbox of measures, a monitoring system, and a governing structure, a policy based on a visionary approach with an ambition to reach zero needs additional perspectives or criteria in order to be successful: (1) a **scientific** approach to problem framing and solutions, (2) a **comprehensive** approach, (3) a **long-term** commitment, and (4) a system and structure based on **governance**. These criteria do not necessarily have to be in place in order to adopt Vision Zero, but they are a prerequisite for building a system based on Vision Zero.

Keywords

Vision Zero policies · Comparative policy content analysis · Road traffic safety · Suicide · Workplace safety · Fire safety · Patient safety

Introduction

The term Vision Zero has received broad international attention after its launch in Sweden in the end of the 1990s as a road safety measure (c.f. Belin et al. 2012; Belin and Tillgren 2012). Vision Zero for road traffic safety contains a number of ethical and practice-oriented approaches and measures. The term and at least parts of the policy package of Vision Zero have diffused to other countries, cities, and policy areas (c.f. Elvebakk 2007). A quick search on the Internet gives plenty of results from all over the world. Vision Zero is not only discussed in terms of road safety, but as a vision that can be implemented in many policy areas. In Sweden, there are Vision Zero policies in many sectors, such as within healthcare, and there are ongoing discussions about introducing Vision Zero policies in yet more areas, for instance, drowning. Vision Zero approaches are adopted in various spheres, such as public administration, private companies, and organizations.

The questions raised in this chapter depart from an empirical material where five Vision Zero policies within various policy areas in Sweden related to injury prevention are compared. Parts of the empirical material were analyzed from a different perspective in an article from 2018 (Kristianssen et al. 2018). The areas in question are road safety, workplace safety, patient safety, fire safety, and suicide. The Vision Zero for road safety is, in the documents analyzed in the article, described as a role model for the other Vision Zero policies. The policies have at least four elements in common: they are all nationally adopted, they are adopted within one single country (Sweden), they are all related to injuries (a medically reasonably homogenous and well-defined area), and they all present a vision for zero fatalities. What differs is that they are applied in different policy areas which entail variances in the specific preconditions of each policy area, both in terms of actors and structures.

Departing from that empirical material, the purpose of this chapter is twofold: first, to provide a short description of each Vision Zero policy and, second, to scrutinize and discuss what characterizes Vision Zero from a conceptual point of view and what it should contain from a normative perspective to be able to manage a zero approach. This is important because visions are often used directly as, or transformed into, steering tools. The question is if it is always appropriate to use a vision as a tool for implementing policy. It entails both opportunities and risks, and the zero approach has been labeled both paternalistic (Ekelund 1999; Elvebakk 2015), inefficient (Elvik 2003), and unrealistic (Lind and Schmidt 1999). On the other hand, research has also shown that the innovative approach of Vision Zero enables actors and institutions to break away from habits and known patterns of behavior (Belin et al. 2012) and that zero fatalities and serious injuries are not an irrational goal from a conceptual point of view (Rosencrantz et al. 2006). The conceptual perspective of Vision Zero is furthermore important to study as there are several similar approaches, but with clear differences, such as the concept of zero tolerance.

The chapter is divided into five parts starting with this introduction. The second part will explore the use of visions as a steering and governing tool and how visions relate to policy. The third section contains a description of the five Vision Zero policies, and the fourth part is a comparative analysis. The fifth and final section of the chapter is devoted to a discussion about the concept of Vision Zero, related terms, as well as to principles regarding governing by Vision Zero.

Theoretical and Analytical Framework

Controlling adverse occurrences, whether environmental, social, or health-related as in the case of injuries, often constitutes considerable challenges to modern societies since their determinants are rarely confined to single policy domains in reach of traditional top-down governmental initiatives. On the contrary, such problems, often referred to as wicked problems (Rittel and Webber 1973), are complex by nature with determinants rooted across a spectrum of policy areas and sectors, calling for broader collaborative approaches, often referred to as "governance" (c.f. Hedlund and Montin 2009). These problems require a broad set of measures, subject to continuous scrutiny and evaluation, as well as a long-term commitment to finding solutions to the problem. There are a number of models and practices available when working with solutions for these kinds of broader societal problems. They stem from various policy fields and perspectives such as foresight or backcasting models, policy innovation, reforms, strategy management, mission statements, and steering by vision. Research on these topics is performed within many disciplines such as future studies, policy studies, studies in technology development, engineering, business and management studies, etc.

New solutions to major societal problems are thus wrapped in different terms, but the intention to change the current situation and create a different future is the same. Some approaches are focusing on reforming a current system, not necessarily creating a completely new one. Other approaches embrace the idea of a more or less complete overhaul or replacement of the old system. In public administration, reforms are common whether they target small changes or larger transformations. But reforms rarely replace earlier changes, which lead to a layered system (Christensen and Lægreid 2012). This kind of fragmentation has prompted reforms focusing on governance and coordination (c.f. Pollitt 2003). Reforms and policy changes are thus a common part of the everyday routines in both public administration and the private sector, often targeting a specific problem or issue.

Governing by Visions

As mentioned, there are specific tools today for working with comprehensive and complex societal problems, and the ambition of these tools is to have a much broader transformative aim. We will discuss a few of these terms and approaches with a focus on visions as a policy tool. One of those is the use of strategies. A strategy is an "...engine of change, a mechanism to transform the present and mold it in the image of a desired future to come" (Kornberger 2013). Strategies are used in politics, in public administration, in the business sector, and so on, and some are more short term and changeable, while others are long term by nature. The long-term capability of strategies makes it possible to transcend spatial boundaries, temporal restraints, and current challenges. A strategy creates a vision of what the ideal future could look like.

Related to strategies, it is becoming increasingly more common to use visions as a policy and governing tool. In earlier research, visions were often referred to as mission statements (Weiss and Piderit 1999). Using visions as a tool to change the present system entails both opportunities and problems. A vision is intended to inspire and to make people consider new approaches and methods (Hallström and Grafström 2016). A vision does not normally include detailed measures, and that provides flexible opportunities for actors to adapt to the vision (Gioia et al. 2012). A vision is also a long-term commitment with a core message or core image of what the future should look like. On the other hand, as a vision tends to be very broad, the risk is that it turns into nothing but beautiful words. If there is no substance to a vision in the sense that it is translated into specific methods and measures used in order to reach the goal of the vision, then the vision can still inspire, but will not necessarily lead to the intended result. Furthermore, visions sometimes tend to be exclusive rather than inclusive because of the focus on reaching the end goal. Alternative visions or paths to reach a certain goal are excluded in the narrative of the vision (Dignum et al. 2018). On the other hand, for a vision to work, it has to be interpreted and implemented in a comprehensive way reaching as many sectors, actors, and aspects as possible. So, there is duality as the vision needs to be both focused and exclusive in order to focus on and reach a specific goal and at the same time inclusive enough to convince and involve as many relevant aspects and actors as possible. In other words, there has to be dedicated actors driving the transformation process, and the actual problem to be solved has to be well-defined and accepted as a societal problem that needs to be handled with a long-term visionary approach. Dignum et al. (2018) describe the performativity of a vision related to its scope, i.e., reaching beyond what was earlier possible, to its systemic and holistic capability, to its problem description and to its description of the values threatened in the current system, and to its inclusion of a framework for targets and for monitoring the progress. Visions can be studied from various perspectives: (1) as a process, (2) as content, and (3) as output (Dignum et al. 2018). This chapter will concentrate on the content perspective.

Turning Visions into Policies and Goals

The use of visions provides an opportunity to inspire and to think creatively about a societal problem, but there is still a need to present a realistic plan on how to reach that vision. Therefore, we often see a vision complemented by a more specific plan or program for implementation. A vision turned into a more concrete policy program can sometimes be seen or presented as a policy innovation (Belin et al. 2012; Sørensen 2016) where the policy does not only contain specific measures and solutions but clearly draws from visionary aspects for the future. “The content of a policy is innovative to the extent that it offers a new definition of a political problem, provides a new political vision for the political community, and/or proposes a new set of political goals and strategies” (Sørensen 2016:157). The uniqueness of a policy innovation is that it departs from visions and strategies but uses a specific method or approach to work with those goals and strategies.

One such line of methods are goal-related approaches, and one example is management by objectives (MBO), sometimes also called management by results (MBR). This approach was first introduced in the private sector to promote productivity, but came to influence the public sector as well, and was soon incorporated as a core component in what later became known as the New Public Management (NPM) approach (Hood 1991; Lægreid 2011). This development was also driven by a political ambition to save public expenditures by means of privatization and competition among providers. The role of politicians should be restricted to clarifying needs, setting goals, and reviewing results, according to the proponents, while meeting the goals should preferably be left to private providers in competition, when possible and appropriate. In addition, the particular field of accident and injury prevention, especially in industrial settings, was also influenced by parallel industrial developments in quality control, such as quality assurance, total quality management, and the like (Kjellén 2000). The core idea was that undesired outcomes were better controlled by means of proactive identification and control of upstream deviations and determinants, instead of dealing with problems in retrospect. This in turn presupposes a thorough understanding of the underlying causes of adverse outcomes and access to valid measures thereof. These developments found their way to broad public applications as well. Working toward specific goals in relation to a complex societal problem has led to an understanding that there is often a need for broader partnerships between key actors in order to reach that goal.

The zero approach is a vision and a goal with an innovative intent and ethical core. Getting the numbers down to zero, whether it concerns domestic abuse or traffic crashes, is for many a reasonable goal. For some actors it is also a question related to morality and ethics, asking whether it is morally or ethically acceptable that people die due to injuries in, for instance, traffic crashes or fires. The zero approach can also be connected to the so-called improvement principles that are based on some kind of zero perspective although these principles cannot necessarily be incorporated into a model such as Vision Zero (Hansson 2019). As Vision Zero diffuses all over the world, to different levels and to various sectors, it is important to distinguish Vision Zero from other zero perspectives. Based on the summary of each Vision Zero policy, we will in the last section of this chapter discuss and make a distinction between Vision Zero and other zero perspectives. We will use zero tolerance as an example of a zero perspective, but with basically the opposite approach to human behavior. A visionary approach and the concept of zero can be interpreted as a reasonable combination, as both concepts concern long-term commitments. Just as with other visions, the challenge is how to transform Vision Zero into a workable policy tool. The implementation phase is thus crucial for the success or failure of the approach. The Vision Zero for road traffic safety is a policy program targeting a growing societal problem with specific long-term scientific, ethical, and administrative approaches, which we will return to in the next section.

Policy Content as a Framework for Description and Analysis

The next section contains a summary of the earlier mentioned Vision Zero policies. The content of each Vision Zero policy will be summarized using four categories inspired by a model presented in Kristianssen et al. (2018). Although using in part a similar model, this chapter contains a new analysis based on a different purpose and theoretical approach. The analytical framework is also complemeted by the earlier mentioned performative aspects of a visionary approach (Dignum et al. 2018). First, what is the **problem** to be solved in each policy area; second, what is the **goal**; third, what **measures and solutions** will solve the problem; and fourth, what **actors** will solve it. More specifically, in order to solve a major societal problem, it is necessary to understand the nature of the problem, its determinants, and its scope, diffusion, and development within all societal sectors. It is furthermore necessary to have access to a credible toolbox containing measures and solutions for how to deal with the problem. This entails a robust program for systematic implementation and evaluation. These aspects related to problem and measures are dependent on the actual goal and governing structures. As mentioned, goals can be set up in different ways with different ambitions, and the measures and solutions are dependent on that ambition. What actors are involved in deciding, prioritizing, and implementing measures can lead to different results. Using a governance structure with the active involvement of broad networks covering many relevant actors within a specific field can from one perspective alleviate the implementation of important measures and from another create a more fragmented implementation process. Having a strict central steering process risks excluding important actors, but the advantage could be more efficient and/or faster processes.

The descriptions will help us to understand the basic components of each Vision Zero policy. It will furthermore provide information on the conceptual development of Vision Zero, and departing from the descriptive findings, we will analyze the five cases comparatively by using the following questions;

1. What is the scope of the problem framing in each of the five cases and are the problems presented scientifically determined?
2. Is there a functioning monitoring system related to each case and does it have a long-term transformation focus?
3. Do the measures and solutions form a comprehensive policy program for each case with a designated governing structure related to each Vision Zero and if so, is the governing structure centralized or network based?

The interpretation and development of what constitutes a Vision Zero is particularly interesting in the light of its diffusion from road traffic to other sectors. The concept is challenged by the differences in preconditions, and any claims of a generalization of the concept are on the line. In the Discussion section, we will use the findings from the summary and comparative analysis to:

1. Approach the concept of Vision Zero by discussing whether there are discernable determinants for a Vision Zero regardless of policy area and for a successful implementation
2. Discuss whether these determinants have to be in place before adopting a Vision Zero or if structures and system can be created afterward. In other words, is it possible to build a ship while at sea?
3. Distinguish the boundaries between Vision Zero and other zero perspectives

The Five Vision Zero Policies

The descriptions below are based on policy documents related to the actual adoption of the Vision Zero policies and the period leading up to the adoption. We will describe Vision Zero for road safety in more detail as it served as the role model for the other Vision Zero policies described in this chapter. The time period for road safety strategies stretches a bit longer as it served as an example for at least 5–10 years.

Vision Zero for Road Traffic Safety

The Vision Zero for road traffic safety was adopted in 1997 by a parliament decision (Swedish Parliament 1997b; see also Swedish Parliament 1997a; Swedish Government 1997). The decision stated that "no one shall die or be seriously injured in road traffic." The vision was furthermore underpinned by supporting theories regarding the problem description, ethical and strategic perspectives, and a steering and implementation model related to scientific evidence. The intention of the theoretical support was to show a credible policy package aimed at systematically reducing the number of deaths and serious injuries over time.

The adoption of the vision has been described as a paradigm shift in road traffic safety (Tingvall and Haworth 1999; Belin et al. 2012). The most important changes relate to the responsibility of the individual in relation to the responsibility of the system designer (Nihlén Fahlqvist 2006) and what the problem at hand is – the crash or the injury. The previous road safety work was based on the so-called human factor approach, according to which it is the responsibility of the individual to avoid accidents. Vision Zero on the contrary focuses on shared responsibility, where there is a complementary responsibility with the system designers (i.e., road design, vehicle design, etc.), and highlights prevention of injuries rather than prevention of accidents. Injuries are regarded as the major problem, particularly deaths and serious injuries, while damages to properties must be tolerated as they are necessary to shield the human being from injuries. Another key aspect is that human mistakes have to be taken into account in designing the system, as it is part of the human nature to make mistakes.

The ethical foundation is that deaths and serious injuries are not accepted within the transport system. The alternative to tolerate a certain number of deaths or serious injuries is not seen as an option in comparison. There may be a way to calculate a balance between the cost of injuries and the benefit of mobility using cost-benefit analyses, but the development of new technology has a tendency to challenge this balance, by creating new ways of prevention. Therefore, the only reasonable conclusion is to strive for zero even though it might take time. There is a strong connection between this long-term approach and terms that were launched regarding quality development already during the 1970s and 1980s such as "continuous improvements" and the like. These terms have been used in both the private and public sector in order to systematically increase quality.

The scientific or evidence-based approach of Vision Zero is to base the road safety work on scientific results as well as on successful policies and approaches. Injury prevention has since the end of World War II been connected to preventive medicine and public health related to a general prevention of health problems. It concerns preventing or limiting harmful exposure that can be sudden or long term, or counteracting the consequences of such an exposure through protection, rescue, care, or rehabilitation. The details differ depending on what specific risk we are looking at, but the principles are more or less commonly applicable. It means that there is a solid scientific base to rely on when it comes to understanding the preconditions for preventing deaths and serious injury even within a policy area such as road safety. Applied to injuries related to sudden events, there are a number of chronological aspects: to prevent or minimize the negative effect of the event itself, to stop or limit the negative consequences of the injury (the consequence of the event), and to take care of, treat, and rehabilitate the injury. Significant efforts have been made to lessen the consequences of road traffic crashes, often with great success. Vehicles are safer, barriers prevent vehicles from crashing off the road, and poles are folding when hit. These are all safety interventions made to shield the human being from being exposed to potential lethal violence. Speed limits reduce the potential violence but also lessen the risk for crashes by increasing the driver's control of the vehicle. The number and scope of possible measures are comprehensive, and the technological development is constantly producing new possibilities. It is ultimately the responsibility of the system owner to craft the modern and safe transport system design in relation to mobility demands, environmental concerns, and accessibility. The main principle of Vision Zero is that human tolerance for crash violence (Haddon 1968) should guide the design of the transport system.

Finally, the steering model for road traffic rests upon a safe system design where several actors are viewed as system designers. There are numerous actors involved in particularly implementing road safety measures, which in some ways has led to a fragmented governing system. The Swedish Transport Administration has a lead role today in the development of road safety measures, but this has not always been the case during the last 10 years. In order to find an efficient way to work with road safety, several of structures have been set up. Networking is one method to bring actors together. There are various networks discussing and analyzing the current status of road safety in Sweden, a number of them led by the Swedish Transport Administration. Studies show that these networks tend to be set up more for information exchange than focusing on decision-making or raising public awareness (Hysing 2019). Another method used to coordinate efforts is the system of management by objectives. This means continuous measuring of the number of deaths and serious injuries and identifying and monitoring the most important indicators of road safety over time and also giving feedback to the relevant actors.

Vision Zero for Fire Safety

The Vision Zero for fire safety was launched in 2010 by the Swedish Civil Contingencies Agency (MSB). The vision, stated in the national guidelines for fire safety, said that: "no one shall die or be seriously injured due to fire in Sweden" (Swedish Civil Contingencies Agency 2010: 5, our translation). Prior to the adoption of the Vision Zero, national strategies had been discussed for a long time leading to updates in laws and regulations (c.f. Swedish Government 2002). The main problem is that around 100 individuals die every year due to fire and approximately 1000 individuals are seriously injured. The new laws that had been adopted did not lead to a reduction in these numbers, which prompted the introduction of a Vision Zero. According to the national guidelines, the responsibility for fires is placed on the individual and on the business sector, although there is an awareness of the theories regarding human errors and the limitations of placing responsibility solely on the individual. This is a clear break from the systems approach presented in the Vision Zero for road traffic. One explanation is that existing policy and legal frameworks at times create obstacles for implementing measures related to a systemic perspective.

The ultimate goal of zero fatalities is intended to be reached by using interim goals. The results from each time period will be thoroughly evaluated. The first period stretches to 2020. The national guidelines present a number of measures divided into four strategic areas, knowledge and communication, technological solutions, local coordination and collaboration, and evaluation and research. In each of these areas, separate measures were presented such as scrutinizing databases, campaigns, increased collaboration, specific technical innovations, etc. (Swedish Civil Contingencies Agency 2010). These measures were not linked together theoretically in the guidelines, and no coherent steering or governing model was presented to clarify or develop the issue of responsibility to make credible the long-term abilities of the vision.

The Swedish Civil Contingencies Agency has a lead role in evaluating the national guidelines, but the implementation of the Vision Zero falls on several actors, particularly the local authorities. There is a national advisory committee including members from all kinds of societal institutions. But, issues of responsibility and steering are leaning very much on the law regulating fire safety in Sweden (Swedish Law on accident prevention 2003) which places the main responsibility for fire safety on the individual. As the law tends to limit the scope of Vision Zero, there are a number of initiatives today focusing on outlining a system's approach for the area of fire safety (see the ► Chap. 38, "Vision Zero on Fire Safety").

Vision Zero for Patient Safety

The Vision Zero for patient safety was presented in 2013 in a national strategy produced by the National Board of Health and Welfare. This was an assignment from the government and the document stated that "Vision Zero is the image of a future where human beings do not die or are seriously injured within the health or dental care system" (The National Board of Health and Welfare 2013: 8, our translation). The Vision Zero for patient safety was preceded by a number of discussions and initiatives, such as the introduction of a new law on patient safety from 2010 (Swedish Law on Patient Safety 2010: 659; Swedish Government 2007; Swedish Government Official Investigations 2008; Swedish Government 2009).

The main problem presented in the national strategy is that 100,000 individuals are injured every year in the Swedish healthcare system, which means approximately 9% of all patients treated at hospitals. The main reasons for these injuries are poor routines, that regulations are not followed, failures in leadership, and regional differences. The responsibility for reducing injuries and deaths fall on the healthcare system (the National Board of Health and Welfare 2013). The national strategy presents a clear system's approach and the writings have been inspired by the ideas and theories regarding the human factor presented in the Vision Zero for road safety.

In order to reach zero, effect goals have been introduced. They focus on patient safety culture, increasing patient participation, reducing the number of frequent and serious healthcare injuries, and increasing knowledge about effective measures and when to implement these measures. The vision consists of a list of 16 areas where measures are needed but no coherent theoretical framework is presented. On the other hand, the steering model puts the caregiver as responsible for the system, and there is a plan for systematic safety work in line with a continuous improvement approach.

The National Board of Health and Welfare is the lead agency in the sense that it produces reports and acts as a coordinator, but many actors are working within this area. You can find them in both the private and the public sector. One particularly important actor is the Health and Social Care Inspectorate that deals with complaints and irregularities in the healthcare system based on the Patient Safety Law. The inspectorate produces reports and statements regarding the state of the Swedish healthcare system. The vast number of actors working with patients makes it difficult to grasp what is the system to be monitored in accordance with Vision Zero. In addition, Sweden has a considerable number of private actors within the health sector as well as actors on different levels of public administration, which leads to a challenge concerning coordination. One risk and sometimes also a direct consequence are differences in quality, methods, and techniques depending on region, which can make healthcare geographically unequal.

The Vision Zero for Suicide

The Vision Zero for suicide was decided by the Swedish parliament in 2008 after a government proposal. The vision states that “no one should find him- or herself in such an exposed situation that the only conceivable way out is suicide. The government’s vision is that no one should have to end their life” (Swedish Government 2007, our translation). The decision to adopt a Vision Zero for suicide was not based on clear requests from actors working with suicide. On the contrary, the national strategy produced by the National Board of Health and Welfare and the Public Health Agency in 2006 argued against a Vision Zero policy. “The ethical problems related to suicide prevention cannot be completely solved. Therefore, it is not appropriate to formulate a Vision Zero for suicide similar to the Vision Zero for road traffic fatalities. It is possible though to work towards reducing the number of suicides.” (National Board of Health and Welfare and the Public Health Agency 2006: 27, our translation).

The main problem to be solved is that approximately 1500 individuals commit suicide every year. For a long time, this was seen as an individual problem, and one reason for this is that every suicide is complex and cannot be generalized. Vision Zero for suicide added parts of a system’s approach to the policy area by placing the responsibility for suicide prevention on the healthcare system and its work to identify and support individuals in risk of committing suicide (Swedish Government 2007). Also in relation to this policy area, the government has been greatly inspired by the Vision Zero for road traffic safety.

In conjunction with the Vision Zero decision in 2008, the parliament adopted a nine-point program for suicide prevention, which was a mix of both measures and effect goals. These focus on the production of information material particularly for school pupils, on reducing alcohol consumption, on reducing access to lethal means in all kinds of societal contexts, on creating a national function for knowledge assessment, on continuing preventive work within the healthcare system, on gathering and analyzing research results, on initiating campaigns, on improving statistics, and on supporting voluntary organizations in their suicide preventive work (Swedish Government 2007).

These measures and goals did not present a coherent theoretical framework. The parliament decision does not reveal a clear steering and governing model or implementation scheme regarding how the vision will be carried out or who is responsible for what. The Public Health Agency and the National Board of Health and Welfare are key actors in implementing the vision, for setting up measures, and for gathering knowledge and spreading information, but issues of steering are still an ongoing discussion within this field. The critique is still widespread (Tryssel 2018), and the number of actors and levels that constitute the system is considerable, just as in the case of patient safety.

The Vision Zero for Workplace Safety

The Vision Zero for workplace safety was presented in a government proposal in 2016. It says that “No one should have to die as a result of their job. Concrete measures are necessary in order to prevent work-related accidents leading to injury or death" (Swedish Government 2016a, our translation). This was preceded by growing concerns that not all accidents were reported and that workplace safety was becoming more fragmented and harder to monitor. The Swedish parliament therefore urged the government in 2014 to initiate a dialogue concerning fatal accidents, to encourage more research and education within this field, to improve statistics, and to reduce the number of workplace-related incidents such as bullying. The Vision Zero for fatal accidents was one of three parts of the government strategy from 2016 and the other areas focused on a sustainable working life and psychosocial work environment (Swedish Government 2016a, b, c).

The main problems presented by various actors in the field as well as in the government decision were the growing number of accidents in the workplace, but not necessarily fatal accidents. There were also growing concerns regarding the upward trend of longer periods of sick leave. Another problem was the large number of actors with workplace activities in Sweden, making it hard to monitor workplace safety. One cause of these problems was related to the fact that there are more foreign entrepreneurs active in Sweden, not necessarily following or having the knowledge of Swedish workplace law. Another cause is the growing number of short-term employments, increasing migration and movement of people, and more sub-entrepreneurs. These are, for different reasons, risk factors in terms of safety (Swedish Government 2016a).

In relation to the government strategy from 2016, a number of investigations were launched but no long-term strategy for the realization of the vision was presented. The Swedish Work Environment Authority is the lead agency concerning analyzing and evaluating the development of the policy area. The Authority has been given the task to increase supervision and monitoring of both Swedish and foreign companies. The work will also include a gender perspective as well as improvements regarding information and communication. The steering model for workplace safety is called systematic safety work (SAM) (the Swedish Work Environment Authority 2001) and has been in place for a long time. SAM emphasizes that the responsibility for workplace safety rests with the employer and that the employer should work continuously with mapping the workplace risks as well as making the necessary arrangements for preventing accidents and health problems. These tasks are supported by a comprehensive set of rules and regulations as well as an organization of internal safety representatives. The authority responsible for supervising that employers abide by the rules can also initiate legal action when necessary. As the government has launched a number of inquiries related to this area, the foundations of the Vision Zero are under construction rather than being built into the work from the beginning. A number of committees containing experts are presenting reports related to parts of the government decision. It is interesting to note that this and earlier mentioned Vision Zero policies have been inspired by the vision for road safety, but the theoretical and practical foundations have not been in place to a larger degree. One question that will be addressed in the following analysis is whether it is a problem or an opportunity to issue a Vision Zero on that basis.

Analyzing Differences and Similarities in Vision Zero Components

Despite the striking similarities in terms of problems addressed (injuries) and the way the visionary goals are formulated (zero deaths, etc.), it is obvious that the five Vision Zero policies also differ significantly with regard to the preconditions needed to actually influence the development of injuries in the desired direction within each policy area. The differences are manifested in problem framing, in the monitoring of relevant facts, plus, not least, in access to means, strategies, and governing structures.

Problem Framing

Problem framing is always an important foundation for any policy aimed to address a certain problem. The framing should be scientifically anchored, broad-minded, and problem oriented. The framing helps to clarify the nature of the problem at hand, including its spectrum of determinants and potential strategies, and thus creates trust in the theoretical possibility of prevention.

In this respect, the Vision Zero policy for **road traffic** safety can be viewed as a role model. By clarifying the key mechanisms of crash violence, its transmission to human tissues, and potential to harm if human tolerance limits are exceeded, combined with a modeling of theoretically available alternatives to prevent this transfer to human bodies, there is a growing trust in the potential to prevent the problem. The question is no longer *if* the problem can be prevented, but rather in what pace and to what costs. Related to this, emphasizing the distinction between accident and injury is an important contribution. Accidents (crashes) may continue to occur due to system imperfections but do not necessarily need to cause death or severe injury. In contrast to earlier views where accidents were seen as the phenomenon to prevent, Vision Zero points out deaths and serious injuries as the undesired target outcome. Injuries are preventable even if accidents continue to occur.

In comparison, the framing of Vision Zero for **fire** safety appears less elaborated. Fire safety as an academic discipline rests historically on knowledge on fire dynamics in buildings, extinguishing techniques, and rescuing strategies. It is presupposed that a fire becomes increasingly dangerous to humans as it escalates. Recent research, however, shows that many fatalities occur already in the initial stage of a fire before it spreads to the whole dwelling. Smoldering fires in upholstered furniture may generate imminent toxic gases with rapid medical effects, and clothing fires may cause immediate life-threatening burns. Professional learning accumulates from larger fires subjected to callouts, but what kills is usually smaller fires in fabrics and furniture, some of them not even attended by rescue services. In addition, there is an obvious social dimension related to the groups at risk of being killed and seriously injured in fires. Victims typically represent medically and/or socially very vulnerable categories – an aspect of the problem that is highly overlooked in the current profession-based learning system. How the social and medical sides of the fire problem are to be addressed is not well described. To summarize, therefore, important flaws remain in this policy area with regard to problem framing and convincing preventative alternatives.

Patient injuries occur in healthcare contexts and are generally understood and explained as negative health consequences from errors or neglects during medical care in health facilities. Patient safety is seen as an integral part of the quality of care, subjected to managerial efforts in line with general principles for quality improvements. The main responsibility rests with the care provider, while the role of societal bodies is to ensure this accountability through information, advice, and enforcement. The problem framing in patient safety therefore appears comparatively transparent and understandable. But even though the problem here is rather straightforward, other challenges affect the problem framing. For instance, the Health and Social Care Inspectorate (IVO) stated in its yearly report from 2019 that one major problem today for patient safety is that progress is made so fast, concerning, for instance, medical methods and techniques. The healthcare system as a whole does not have the capacity to make sure that the improvements are spread evenly throughout the system or that they are implemented in an appropriate and informed way (IVO 2019).

Suicide is a complex phenomenon with determinants deeply rooted across societal sectors. A suicide incident is by definition self-inflicted in order to terminate life. But suicide cases are often, both practically and scientifically, blurred with adjacent phenomena, such as fatalities without known intention, cases of self-harm without intention to kill, overdose episodes among substance abusers, and the like. Underlying modifiable societal determinants remain largely unexplored. Further, there is theoretical ambiguity among researchers regarding to what degree suicide results from reasoned decision-making or from sudden situational and overwhelming circumstances (“psychological accidents”). The same ambiguity is reflected in different views on preventative strategies, spanning from mental illness identification and treatment to environmental modifications in order to reduce access to lethal means. The problem framing on suicide appears partial as it reflects a medical view of the problem and its solution, mainly, rather than a social one.

Fatal accidents in the **workplace** are, like patient injuries, easy to define without theorizing too much. Fatalities at workplaces result from falls from heights, collapsing structures, incidents with machinery, etc. The spectrum of events is more varied when compared to road traffic, but the injurious mechanisms of uncontrolled “violence” (mechanical, thermal, chemical, etc.) to the human body are similar, as well as the spectrum of measures available to prevent transfer of this harm to human bodies. The basic principle is to minimize deaths and injuries from occupational accidents by technical and organizational measures. The main responsibility rests with the employer, while the role of societal bodies is to ensure this accountability through information, advice, and enforcement. Like patient safety, the problem framing on occupational safety seems fairly transparent and understandable.

Monitoring and Surveillance

Any phenomenon subjected to systematic change should be possible to measure with regard to frequency, distribution across relevant subcategories, and development over time. When policy makers claim that something occurs too often or too rarely, and therefore should decrease or increase, it is already implied that relevant facts exist. If the problem is injuries and deaths, the art of providing such data in a systematic manner is usually called injury surveillance (a sub-discipline of public health surveillance), or simply "injury statistics." Surveillance is a broader term that includes the collection, processing, analysis, and feedback of relevant data to those who need to know in order to take proper actions. Surveillance is aimed to serve as a driver for change. Criteria for good surveillance systems underline issues like accuracy of case definitions and inclusion criteria, validity and reliability aspects, timeliness, as well as the quality of analysis, reporting, and utilization of data. Without access to good data, it is not really possible to say what is wrong, what needs to be done, or to evaluate interventions. The preconditions concerning each of the five Vision Zero policies differ remarkably in this respect.

The policy area of road **traffic** can be seen as a role model also related to this issue. The Swedish Transport Administration has taken the issue of injury surveillance very seriously and clarified operational definitions on fatalities as well as major injuries from road traffic. Validated data collection routines are secured, combining information from the health sector and the police. The data series go back quite far in time which means that analyses on trends can be performed. It is also possible to follow subgroups so that profiled interventions can be prioritized and evaluated. Furthermore, the Vision Zero for road safety has been in place for more than two decades and the actors within the policy area have had quite some time to coordinate and also to establish a specific structure.

In **fire** safety, the situation remains more challenging. The registration of fire fatalities now follows an updated and validated routine combining data from rescue services and the health sector according to a likewise updated case definition of fire fatalities. However, there is still no case definition of major injuries from fire and no regular data collection routine established on major injuries, in spite of the priority these injuries are given in the Vision Zero.

Monitoring **patient** injuries appears even more challenging. Definitional and operational difficulties create barriers for establishing a regular comprehensive surveillance system on patient injuries. Conditions that may have contributed to a patient injury are something that often must be judged by experts in retrospect. Reporting systems based on patient compensation claims or staff reports on managerial deviations highly underestimate the real situation. Valid estimates must be derived from patient record reviews which are time-consuming and expensive. Due to these circumstances, it is currently not possible to give a clear overview of the problem and its development over time and by subcategories.

Data on **suicide** are available from the national cause of death register. Besides confirmed cases of suicide, statistics reported based on data from the register often include cases with unknown intent as well, despite striking differences in terms of demography and fatal mechanism (drowning, suffocation, poisoning, etc.) between the two categories. Adding unknown cases to the confirmed ones inflates the numbers considerably. Data on the so-called suicide attempts, available from national inpatient statistics, include a broad spectrum of injuries from self-harming and self-destructive acts, without information on whether there was an intent to really end life.

Workplace safety, finally, represents longstanding traditions on data collection and analysis for the purpose of prevention. In Sweden, data collection is based on compensation claims to the Swedish public insurance agency, plus, in severe cases, reports directly to the Swedish Work Environment Authority. Triangulation against the national cause of death register ensures reasonable validity on deaths, while underreporting exists among nonfatal cases. Incidents in informal and illegal sectors are probably more extensively underreported.

Means, Programs, and Governing Structures

Finally, we have analyzed the questions of governing and steering structures in relation to specific measures and solutions. We find that steering and governing also presuppose access to effective means, a program clarifying what needs to be done, when and by whom, in addition to a structure on how to govern the program over time in a sustainable manner. Access to means implies that important determinants should be identified and found modifiable through well-known interventions. A program is a plan for action based on grounded assumptions on how various interventions are expected to influence the target outcomes. The program should also clarify priorities over time and an allocation of responsibilities among actors. A governing structure is needed to get the program done, including implementation, coordination, performance analysis, corrective actions, and follow-ups on accountability.

Road traffic safety is a field strongly characterized by its systems approach. Road traffic is part of the transport system, aimed to provide mobility with minimal consequences for safety, health, and the environment. The overall responsibility rests with the system designers and providers, while users are expected to follow rules, pay attention, and heed to other road users. System components include road infrastructure, users, and vehicles. Measures need to be directed toward all three of these components, but priority is given to infrastructure and vehicles in order to compensate for the most unreliable component – the users. Accessibility for broad road user categories is another argument for prioritizing technical and environmental improvements, rather than placing stricter demands on users. The governance of this policy area is delegated from the government to the Swedish Transport Administration and is executed in collaboration with other relevant actors in accordance with a negotiated program where responsibilities and commitments are allocated among actors. As Vision Zero for road safety has been decided upon by the Swedish government and parliament, there is an annual reporting mechanism back to these levels on progression and further needs, intended to maintain political anchoring and support. One specific problem related to the governing of road safety is the fluctuation of the status of road safety in relation to other transport-related issues. There is a risk that this fluctuation in prioritization has effects on long-term transformation. To succeed in bringing the number of deaths down requires coordination and cooperation among many actors. Bringing all these actors together has proven quite a challenge for the Swedish Transport Administration as the lead agency. Networks are set up but the capacity of these networks has not been fully developed.

The policy area of **fire** safety appears less matured and organized. Accountability besides the individual responsibility remains unclear, both legally and in practice. The broader systems approach, like in traffic, is yet to be elaborated and fully mandated for coordination and governance to a designated body. Currently, the policy area of fire safety falls under the jurisdiction of the Swedish Civil Contingencies Agency, an agency with very limited possibilities to influence relevant conditions outside its own restricted sector. Standards for buildings and dwellings fall under other sectors, like other fire-related issues on electrical equipment, furniture, home-based healthcare and nursing, social housing, alcohol, tobacco and drugs, etc. A program is outlined, identifying a set of determinants ("indicators") considered important to modify, but there is no overall steering apparatus established to really implement the program across sectors.

P**atient** safety, however, is another example of a field characterized by a systems approach, at least in writing. System components include professionals, patients, technology, and organization. The overall responsibility rests with the caregiver (organization), while single professionals are expected to comply with standards, keep themselves updated, and report deviations from safe practice. On the other hand, there is a lack of overall monitoring systems and programs allowing for broader overviews and governance. Therefore, the systems approach and the clarity regarding responsibility are issues still largely theoretical, while a concrete management structure is yet to be established. There are several actors with clear mandates to monitor and report, such as the National Board of Health and Welfare, an organization issuing important guidelines for patient safety. The Health and Social Care Inspectorate also has a monitoring role both on a general level but also directly related to patients' complaints. On paper we have an authority providing guidelines that caregivers should follow, and we have a monitoring authority issuing actual advice on improvements, but the system is so vast that the implementation of standards is challenged.

The policy area and Vision Zero for **suicide** shows similarity with fire safety concerning the absence of a broader systems approach and a clear lead agency capable of managing the field in the intended direction. Suicide is a comprehensive societal problem rooted in broad societal developments such as economy, health, labor market, family structures, and housing, all of them conditions out of reach for single actors to change. The National Board of Health and Welfare is appointed by the government to serve as a focal point for this area. The agency has a certain mandate over the healthcare system which means that the program in practice is narrowed down to issues possible to influence through the healthcare system, like identification and treatment of depression. This approach may yield some positive results but will not affect the deeper social determinants of the problem. The critical voices from within the healthcare system and from NGOs and voluntary organizations are continuously pointing toward this narrowing down of the system itself, having clear effects on implementation and problem framing.

Workplace safety, finally, is yet another example of an area with a well-established systems approach and with a clear division of responsibilities. The Work Environment Act (1977) assigns the main responsibility to the employer.

The employer should make sure that all equipment is safe and that employees are properly informed and educated to perform the work in a safe way. The Swedish Work Environment Authority is the lead agency expected to ensure, through information and enforcement that the employer takes on the responsibility for workplace safety in a satisfactory manner. The societal steering is thus performed indirectly by regulation, enforcement, and advice, which in practice limits the possibility to directly affect the development. Recognizing that the actors within this policy area are increasingly working on an international market entailing consequences for safety, wages, and social conditions, this also has consequences for the governing and steering structures related to workplace safety.

Discussion

The analysis of the five cases shows the difficulties and challenges of governing based on a vision and in combination with the zero approach. The Vision Zero role model within road traffic safety was developed in close relation to scientific results on, for instance, crash violence and was also influenced by other events over time in Sweden. Although Vision Zero has continued to develop within this policy area and has been subjected to constant improvement, its foundation appears more solid than the other cases. In this final section of the chapter, we will, based on the empirical findings and comparative analysis, return to three questions raised in the analytical framework:

1. Does a policy have to contain specific criteria in order to be called a Vision Zero policy, and what should we normatively ask of a Vision Zero related to reaching its end goal?
2. Do these criteria have to be in place before the adoption of the Vision Zero policy or can they be developed in a continuous transformation process?
3. In the light of its diffusion all over the world, how can we distinguish Vision Zero from other zero perspectives and why is that important?

Are There Discernable Determinants for a Vision Zero and for It Being Successful?

It is obvious that the compared Vision Zero policies differ in terms of practical feasibility and thereby also in trustworthiness with regard to their possibilities to affect the specific outcomes targeted in each policy. If a policy fails to scientifically frame the problem properly, including determinants and preventability, or fails to measure its problem's frequency and severity across relevant categories and over time, or lacks fundamental instruments for change, it appears problematic to denote it a Vision Zero policy, since there is little or no chance for the policy to fulfill its mission. Doing so may instead erode public trust in Vision Zero policies in general and eventually endanger the whole idea of Vision Zero policies. In our view, it is the visionary image in combination with a trustworthy apparatus for systematic steering toward this vision that legitimates the term Vision Zero. This in turn, with reference to our analytical framework, rests on the model we have used for our comparative analysis, i.e., in short, the Vision Zero policies are based on wicked societal problems and these problems have to be framed properly and consistently in order for the measures and solutions to work efficiently. One crucial framing regards the system itself and particularly its actors and structures. Another key element is a system of monitoring and feedback.

In order to be implementable, a policy has to be clear regarding problem, measures, solutions, and goals, as well as monitoring and governing system. This is very much true for all policies. But using visions as policy tools require additional approaches. The very essence of a vision is its ability to inspire and to affirm important societal values for an extended period of time. To transform a vision into a workable tool requires patience, and adding a zero approach to a vision necessitates coordinated efforts. Visions thus contain both an element of inspiration and an opening for transformation toward implementation in practice. Based on the analysis of the five Vision Zero policies in Sweden, we conclude that there are problems and opportunities with governing by visions. We would like to take the discussion above a bit further by identifying a number of more specific criteria that in our view are necessary in order to work with a vision based on a zero approach in relation to wicked problems within the field of injury prevention. There has to be:

- **Scientifically** determined problems and solutions (in depth and width), including its spectrum of modifiable determinants at individual, technical/environmental, organizational, and societal levels.
- A **comprehensive** approach. For a vision to be successful, it is necessary to view the society in a holistic way. This requires knowledge of what policy measures are effective together and presupposes an analysis (often referred to as "systems analysis") of relevant actors and incentive structures. This process often leads to broader policy programs often studied using the so-called program theory.
- A **long-term** transformation process which has to include measurements and monitoring systems, follow-up and feedback routines, program evaluation. and revision.
- A **governance** structure containing a specific system for goal setting as well as commitment, coordination, and leadership, not only from the appointed authorities but from all actors with a vested interest in solving the problem at hand. Since we are here dealing with complicated problems, not only a governing structure is required but also a governance perspective where all relevant actors work together.

If applying these criteria to our five cases as they were presented when adopted, the analysis can be summarized as following:

	Road safety	Fire safety	Patient safety	Suicide	Workplace safety
Scientific foundation	Broad	Narrow	Broad	Narrow	Broad
Comprehensive approach	Broad	Narrow	Broad	Narrow	Broad
Long-term monitoring system	In place*	Insufficient	Insufficient	Insufficient	In place*
Governance system	In place*	Missing	In place*	Missing	In place*

*"In place" here means that basic functions are in place, while operational quality and effectiveness may differ considerably

Building the Vision Zero Ship at Sea?

We have concluded that the Vision Zero for road traffic safety has a more profound foundation than the other cases in many perspectives. But the question is whether it is problematic to launch a vision without the same kind of foundation. One risk is that the vision remains only on paper and never reaches the implementation stage. On the other hand, having such an ambitious vision can inspire actors to construct methods, models, and above all identifying the system within each area, especially now when there is a role model for Vision Zero. Another problematic aspect is if the methods of the role model turn out to be less effective. The rise of deaths in the road safety statistics in recent years is a concern and adds a dimension to the discussion on having a vision as a steering and governing tool in relation to wicked societal problems. However, there is an alternative way to look at the problem with premature Vision Zero policies. They can also be perceived as challenges, revealing managerial weaknesses, and prompting actions to deal with the fundamental requirements that need to be in place for rational and systematic mitigation of adverse societal outcomes. If following the key components of working with a Vision Zero mentioned above, it should be possible to avoid an empty vision.

A Conceptual Distinction

Reviewing a policy area, intended for a Vision Zero approach, by means of our criteria applied above for policy comparisons, might facilitate the identification of such structural improvement needs. There is yet no ownership or standardization on the Vision Zero concept. But given its popularity and rapid dissemination in combination with an increasing diversity with regard to contents and applications, it might be useful to seek further clarification in order to streamline the uniqueness and theoretical relevance of the concept in contrast to parallel types of policies with similar aims and applications (for an overview of improvement principles, see Hansson 2019).

Among parallel policies and concepts, zero tolerance policies may deserve special attention. Vision Zero and zero tolerance policies are often confused, or referred to interchangeably, in the public debate. The two policies are, however, quite different. The zero tolerance concept was first introduced in crime prevention based on the idea that strict police response to minor offenses would be a way to prevent major crimes. The principles were popularized by Wilson and Kelling (1982) by launching their "broken windows" theory and claiming that indulgence to minor crimes, such as breaking windows and littering, will give way for more severe nuisance and crime (Kelling and Coles 1997). The ideas gained widespread interest and were quickly disseminated to other fields, especially drug prevention. Strict and prompt punishment of any drug involvement, even minor, was expected to deter from more serious involvements. The zero tolerance policy, as applied to crime and drug prevention, has been extensively criticized for being indiscriminate and brutal (Sharkey 2018). It is also blamed for raising barriers between the police and communities (Cox and Wade 1998). In drug prevention, the zero tolerance policy has been criticized for preventing abusers from seeking medical help in critical situations and thereby contributing to unnecessary deaths in overdoses (Tham 1998). As a reaction, the so-called harm reduction strategies are now increasingly advocated as a way to save lives. Drug users are welcomed to clinics where they can get qualified medical assistance and advice without risk of being accused of criminal behavior. The approach is intended to appear forgiving and supportive instead of intolerant and punishing. This helps to clarify the important difference between Vision Zero and zero tolerance policies. While the Vision Zero policy, as first presented in traffic safety, clearly reflects a harm reduction strategy, developed in reaction to the earlier behavior-centered strategy, the zero tolerance approach is directed toward controlling human behavior entirely, moreover by repressive means. According to the Vision Zero philosophy, environments should be designed to tolerate normal deviations in human performance by allocating responsibility to system designers as well, while the zero tolerance approach maintains strict individual responsibility and proclaims intolerance to human failure.

Cross-References

► Vision Zero in Sweden: Streaming Through Problems, Politics, and Policies
► Vision Zero on Fire Safety

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Responsibility in Road Traffic

5

Sven Ove Hansson

Contents

Abstract

Vision Zero requires a new approach to the responsibility for safety. This chapter provides conceptual tools for the description and analysis of this and other responsibility issues. Distinctions between different types of responsibility are introduced, with a particular emphasis on the distinction between blame responsibility and task responsibility. The complex relationship between responsibility and causality is also delineated. This is followed by an analysis of the changes in responsibility assignments that are necessary to implement Visio Zero.

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Introduction

> She ran red lights at high speed and crashed into the helpless cyclist. There can be no doubt that she is responsible for the accident.

> Failing brakes are responsible for numerous accidents on icy roads.

> It is true that the crash was caused by the pedestrian's erratic behavior, which forced several drivers to dangerous maneuvers. But he has a severe mental disorder and is not really responsible for what he did.

> In the last few years, two children have been killed in traffic accidents on their way to this school. The traffic conditions are clearly unacceptable. Something must be done. Who is responsible?

Traffic safety is one of the many social areas in which assignments of responsibility are important and often contested. They have become an even more important topic through Vision Zero, which distributes responsibilities in new ways. But as illustrated in the four examples above, we use the terms "responsible" and "responsibility" in several meanings. This chapter will begin by systematizing the major meanings of the terms. After that we will investigate the complex relationships between responsibility and causality and finally show the bearing that all this has on traffic safety and Vision Zero.

What Is Responsibility?

The most influential classification and clarification of the different meanings of "responsibility" is due to the British legal philosopher H. L. A. Hart (1907–1992). His work is therefore the best point of departure for an analysis of the concept. He identified four major meanings of "responsibility," as the word is used in moral and legal contexts:

- By *liability-responsibility*, he meant, in a legal context, liability for punishment or for paying compensation (Hart 2008, pp. 222, 225). In most cases, liability-responsibility pertains to a person's own actions and their consequences, but there are also cases in which a person is "responsible vicariously or otherwise for harmful outcomes which he had not caused" (ibid., p. 224). In a moral context, liability-responsibility usually means that the person deserves blame, rather than punishment, but in some cases the person is "morally bound to make amends or pay compensation" (ibid., p. 225).

- By *role-responsibility*, Hart meant the "specific duties" a person obtains through occupying "a distinctive place or office in a social organization" (ibid., p. 212). His usage of "role" covers not only professional and official functions but also private roles such as those of a spouse, parent, or host.
- With *causal responsibility*, he referred to cases in which the phrase "is responsible for" can be replaced by "caused" or "produced," without a change in meaning. According to Hart, causal responsibility can be attributed not only to human beings "but also to their actions or omissions, and things, conditions, and events." One of his examples is: "The icy condition of the road was responsible for the accident" (ibid., p. 214).
- By *capacity-responsibility*, he meant capacity to understand, reason, and control one's own actions. This is what we refer to with the phrase "he is responsible for his actions." In order to have capacity-responsibility, the person must have "certain normal capacities," namely, "those of understanding, reasoning, and control of conduct: the ability to understand what conduct legal rules or morality require, to deliberate and reach decisions concerning these requirements, and to conform to decisions when made" (ibid., p. 227).

There are close connections between moral and legal concepts of responsibility, and one may see legal responsibility as a codification of such moral responsibilities that we have agreed to impose upon each other with the force of law. Here, we will focus on moral responsibilities. Let us consider, in turn, each of Hart's four types of responsibility.

As already indicated, Hart was aware that *liability-responsibility* may not be an ideal term in moral discussions. Whereas this form of responsibility is usually strongly connected with liability in legal contexts, in a moral context it is more closely connected with blameworthiness. Therefore, moral philosophers writing about responsibility usually prefer the term "blame responsibility" (Goodin 1987, p. 167). This terminology will be used here as well. However, it should be noted that in addition to deserving blame, a blame-responsible person may also be morally required to compensate negatively affected persons as well as to perform other acts of expiation (Hansson and Peterson 2001).

When we talk about a person as being responsible for something that she has done, we usually focus on the negative consequences of her actions. However, one can also be responsible for laudable acts. The Oxford English Dictionary has a value-neutral definition of the term as "[t]he state or fact of being the cause or originator of something; the credit or blame for something." The European Transport Training Association hands out a yearly Safety Award, which "recognizes those responsible for excellent products or services aimed at improving road safety in the European road transport and logistics industry" (Anon 2013). This usage of the word "responsible" can be termed "praise responsibility." Perhaps it should have a larger social role than what it has – for instance in traffic safety – but for our current purposes it can be left out of the discussion.

Hart's "role responsibility" refers to what one has to do or achieve. Several authors have noted that his terminology tends to obscure the generality of this notion

(Cane 2002, p. 32). The word "role" suits well for legally binding responsibilities, such as those that follow with an employment contract, a marriage, parenthood, or board membership in voluntary organizations. However, it does not suit well for more informal undertakings that are usually considered to confer some responsibility, such as agreements to babysit, water someone's flowers, walk their dog, or feed their aquarium fishes. Some authors have kept Hart's term "role responsibility" but interpret it very widely (Dworkin 1981, p. 29). Others use the term "task responsibility," which has a wider general meaning and obviously covers "duties, jobs or (generically) tasks," including those that originate in informal undertakings and agreements rather than legally binding stipulations or contracts (Goodin 1987, p. 168; Cane 2002, p. 32). Here, "task responsibility" will be used as a general term for responsibility to do or achieve something.

According to Hart, most adults are considered to have *capacity-responsibility*, but it is "lacking where there is mental disorder or immaturity" (Hart 2008, p. 218). We can speak of a person as being responsible for her actions, in this sense, even if we do not know of any particular action that she is responsible for. Therefore, capacity-responsibility should be seen as an ability to be responsible, rather than as a form of responsibility per se. The legal notion of capacity-responsibility is related to the notion in medical ethics of "capacity for autonomous choice" (often also called "decision-making capacity" or "competence"), which marks the limit between those who can respectively cannot give informed consent to a medical intervention (Parker 2001; Stirrat and Gill 2005; Michaud et al. 2015). The term *capacity* (or *capacity to be responsible*) can be used for this notion. Here, we will have relatively little use for it, since issues of capacity (or ability to take responsibility) seldom arise in discussions of traffic safety. Drivers are required to have a driver's license, which is normally only issued to adults with the requisite abilities. The protection of pedestrians lacking in the relevant mental capacities, such as children and people with mental disabilities, is an important issue in traffic safety, but it is usually discussed in terms of the risks they are exposed to rather than their capacity to take responsibility.

The way Hart uses the term *causal responsibility*, it is not entirely clear why he did not instead use the term "causality" for this notion. An icy road can certainly be the cause of an accident, and someone who should have sanded it can then be responsible for the accident, but what is gained by saying that the road itself is responsible? It would seem more clear to reserve the term "responsibility" for agents who can reason and argue and use the term "causality" for inanimate objects.

However, this becomes somewhat more complex in cases when causality is ascribed to humans or to their actions. Consider the following two examples:

Case 1:

Adam was terribly drunk and fell asleep on the kitchen floor. Two of his friends moved him to the floor of an adjacent room, just to keep him out of the way. Susan entered the room without noticing him, stumbled over his legs, fell on a chest of drawers, and broke her nose.

Case 2:

Adam was lying on the floor when Susan entered the room. He stretched out his leg to tease her. She did not notice, stumbled over his leg, fell on a chest of drawers, and broke her nose.

In the first case, Adam caused Susan's broken nose in the same way as it could have been caused by a sack of potatoes, or some other inanimate object. In the second case, his causal role was different, since he made a decision – namely, to stretch out his leg – that had a crucial causal role. This is a role that only an agent can have, and "his, her or its agency serves to explain" the pertinent outcomes, which "can therefore plausibly be treated as part of the agency's impact on the world" (Honoré and Gardner 2010). It is not unreasonable to use the term "causal responsibility" in this case (contrary to the case with the icy road, mentioned above). However, the term "agent causality" will be used here instead. The reason for this terminological choice is that agent causality does not necessarily imply responsibility in any moral or legal sense. If Alyona causes Diego's death while doing her very best to save him from a life-threatening danger, then she is an agent-cause of his death, but not necessarily morally or legally responsible for it.

As summarized in Table 1, we have renamed and adjusted Hart's (mainly legal) terminology to make it more suitable for moral investigations. Notably, only two forms of responsibility remain, namely, blame and task responsibility. We have assigned other names to Hart's other two responsibility concepts, names that do not designate them as forms of responsibility.

This reduction to two forms of responsibility is by no means original; to the contrary it is a common approach in the literature on responsibility. (A notable exception is Gerald Dworkin, who listed three major types of responsibility in an influential article: role responsibility, causal responsibility, and liability responsibility (Dworkin 1981).) However, it is common to use other terms for blame and task responsibility, namely, terms that indicate temporal relationships. Blame responsibility is often called "backwards-looking responsibility," "retrospective responsibility," or "historic responsibility," whereas task responsibility is referred to as "forwards-looking responsibility" or "prospective responsibility" (van de Poel 2011; Duff 1998; Cane 2002, p. 31). Unfortunately, this temporal terminology is somewhat misleading. We can refer in retrospect ("historically") to the task responsibility of medieval physicians to treat patients during an epidemic in spite the grave risks to themselves (Huber and Wynia 2004). Then we have a backwards-looking perspective on a (previous) task responsibility. We can also consider

Table 1 A comparison of terminologies for responsibility-related concepts

Hart's terminology	*Our terminology*
Liability-responsibility	Blame responsibility
Role responsibility	Task responsibility
Capacity-responsibility	Capacity (to be responsible)
Causal responsibility	Agent causality

prospectively whether our actions and omissions will in the future give rise to blame responsibility (Hansson 2007). Then we have a forwards-looking perspective on (future) blame responsibilities. Strangely, the latter but not the former case is called "historical responsibility" in Cane's (2002, p. 31) terminology. The "blame" and "task" terminology does not run into these difficulties, and it will therefore be used here.

Blame and task responsibility are often closely connected to each other. One type of connection between them ensues when a failure to fulfill a task responsibility gives rise to a blame responsibility. If I have promised to water your garden while you are away, then I have a task responsibility to do so. If I fail to do it, then I am blame responsible for this failure. Another type of connection arises when a wrongful action gives rise both to blame responsibility and to a task responsibility to improve one's future behavior. If I disturbed my neighbor's sleep by playing music too loud in the night, then I am not only blame responsible for the disturbance but also task responsible for not repeating it in the future.

However, in more complex social situations, blame and task responsibility do not always follow each other that closely. For instance, suppose that a speeding motorist runs over a child crossing a road on its way to school. In the subsequent trial, the driver will be held (blame) responsible for the act. And of course the driver is (task) responsible for not driving dangerously again. But that is not enough. We also need to prevent the same type of accident from happening again, with other drivers. This is not something that the culpable driver can do. Instead, measures are needed in the traffic system. We may have reasons to introduce traffic lights, speed bumps, or perhaps a pedestrian underpass. The task responsibility for these measures falls to decision-makers such as public authorities. In cases like this, blame and task responsibility part company.

It has sometimes been assumed that the assignment of blame responsibility is some sort of zero-sum game, so that more responsibility for one party must always be linked to less responsibility for someone else. This has often taken the form of a principle of "proportionality," according to which "[a]n agent's moral responsibility for an outcome is proportionate to her actual causal contribution to the outcome" (Bernstein 2017). There are of course cases in which actions that make one agent more blame responsible also reduce the blame responsibility of some other agent(s). However, this does not hold in general. This can perhaps be most clearly seen from cases of overdetermination. If two persons simultaneously shoot a non-threatening victim, and each of them delivers a deadly shot, then this certainly does not mean that each of them is only half as blame responsible as if the other had not pulled the trigger (Bernstein 2017; Moore 1999, p. 10). Similarly, if two motorists drive into a four-way crossing at the same high speed, causing a crash that would also have occurred if only one of them had driven too fast, then neither of them is relieved of his blame responsibility by the other's wrongdoing. Thus, blame responsibility is not a zero-sum game.

A parallel argument applies to task responsibility. There are cases when task responsibilities can be transferred from one person to another. This typically happens when people share a task. For instance, if Erol and Haluk take turns helping their old mother on alternate weeks, then as long as this arrangement lasts, each of them has arguably only half the task responsibility that he would have had if his brother did not help. However, there are other cases in which one person's responsibility does not decrease the responsibility of others. If government takes more responsibility for reducing traffic accidents, for instance by making roads safer, then this does not reduce the responsibility of individual drivers to drive safely. (Instead, it makes it easier for them to fulfill that responsibility.) Although both blame and task responsibility can sometimes be shared, neither of them is in general "like a pie that is to be divided between people that each will have a smaller or larger share" (Verweij and Dawson 2019, p. 100). Our responsibilities are influenced by what other people do and undertake, but often in much more complex ways than that.

Causality

Both task responsibility and blame responsibility are closely connected with causality. Task responsibilities are normally assigned to persons who are presumed to be able to fulfill the task in question successfully. People are held blame responsible for their actions and for outcomes that they have caused or at least causally contributed to (Shaver 1985; Cane 2002; Moore 2009; Mumford 2013; Bernstein 2017, p. 165). However, there are exceptions to this. The law has "pockets of strict liability," by which is meant liability that can be assigned even without any causal contribution (Moore 2009, p. 21n). In many legal systems, owners of a dangerous animal are held blame responsible for injuries inflicted by the animal, and companies are held responsible for defective products, regardless of fault or causality. In a somewhat analogous manner, government ministers and leaders of public companies and other large organizations are often held (morally) blame responsible for wrongdoings by employees.

In moral and legal philosophy, it is often assumed that causality is a well-defined and value-independent phenomenon that can serve as a suitable fact base for value-laden concepts such as responsibility. However, this is a gross oversimplification that does not take into account the complexities of our concept of causality.

The usual approach to causality, applied in moral philosophy as well as in everyday life, takes causality to be constituted of (binary) cause-effect relationships. Such relationships are useful for describing many of the events that we observe around us. For instance, Carina throws a ball at the window, and the window breaks. This is a relationship between two events, a cause and an effect. Her act of throwing the ball is the cause, and the breaking of the window is the effect. In a simple, causally determined world, everything that happened would be the outcome of such cause-effect relationships. But that is not the type of world we are living in. The actual workings of the physical universe deviate from that description in at least two important ways.

The Multiplicity of Causal Factors

The first of these deviations is that instead of a single cause, there are usually several causal factors contributing to an effect. For instance, suppose that Nadja won a game of chess against Boris. We can treat her victory as an effect. What was the cause of this effect? In fact, all of the following can – all at the same time – be reasonable answers to that question:

> It was because of her brilliant queen sacrifice in move 22.
>
> It was because she has carefully studied Rudolf Spielmann's book, *The Art of Sacrifice in Chess*.
>
> It was because Boris made a mistake in move 21 that opened up several winning strategies for her.
>
> It was because Boris had a migraine and did not play at his best.
>
> . . .

This is how it usually is. As was pointed out by John Stuart Mill ([1843] 1996, pp. 327–334), there are normally several causal factors that contribute to the production of an effect. But as he also pointed out, we seldom try do deal with them all on an equal basis. Instead, we tend to select only one of them and call it "the cause." It is not uncommon that different persons choose different causal factors as "the cause." In this case, it would be no surprise if Nadja sees her studies of Spielmann's book as "the cause" of her victory, whereas Boris considers his migraine to be the true cause. If the game is published in a chess magazine, readers can be expected to see either move 21 or move 22 as the cause of her victory.

Our choice of "the cause" among the causal factors that (jointly) lead up to an event depends on our perspective on that event and its antecedents. There is usually no single perspective that is more "right" than the others, and therefore there is no "right answer" to the question what "the cause" of an event is. This can also be seen from a classic example, namely, the cause of cholera. If you ask a bacteriologist what causes that disease, you will probably be told that it is caused by the bacterium *Vibrio cholerae*. If you ask an epidemiologist the same question, you will learn that it is caused by lack of proper sanitation (Rizzi and Pedersen 1992). They are of course both right. Their answers do not reveal a difference in opinion; they just put emphasis on different components in a complex causal process. The two answers can and arguably should coexist since they are useful in different contexts. A physician treating a patient with cholera has reasons to focus on the microbiological cause, whereas the cause mentioned by the epidemiologist should be at focus in preventive work. Attempts to make one of these two causal factors "the cause" for all purposes will render us less capable to solve urgent practical problems. ("Don't worry about sanitation. Cholera is caused by *Vibrio cholera*, nothing else.")

Cause selection is a rather complex process that does not seem to be governed by a single rule. It can be likened to the use of concentrated lighting on a theater stage. With a spotlight, all the light can be put on a small part of the stage. Often, there are several artistically reasonable ways to do this, representing different perspectives on the unfolding drama. Similarly, cause selection can be performed in many different ways.

> We sometimes single out one among all the causes of some event and call it "the" cause, as if there were no others. Or we single out a few as the "causes," calling the rest mere "causal factors" or "causal conditions." Or we speak of the "decisive" or "real" or "principal" cause. We may select the abnormal or extraordinary causes, or those under human control, or those we deem good or bad, or just those we want to talk about. I have nothing to say about these principles of invidious discrimination. (Lewis 1973, pp. 558–559)

The indeterminateness and lack of objective grounds for our choice of "the" cause among the causal factors has often been referred to as a "context sensitivity" of causal claims (Tarnovanu 2015, p. 68). However, it seems to be less a matter of the context than of perspectives and expectations, which may differ within one and the same context. The crucial conclusion we can draw from the multiplicity of causal factors is that our assignments of cause-effect relations depend not only on objective factors in the world but also on our perspectives and expectations.

The Insufficiency of Cause-Effect Relationships

As already indicated, the standard approach to causality, which is based on binary cause-effect relationships, also has another, even more serious problem. The problem is that cause-effect relationships only provide us with an incomplete picture of the world. Obviously, many of the interconnections that hold between different events at different points in time can be adequately accounted for with the cause-effect pattern. However, there are also important interconnections that do not fit into this pattern. In the context of natural science, this was pointed out by Bertrand Russell, who observed that "oddly enough, in advanced sciences such as gravitational astronomy, the word 'cause' never occurs" (Russell 1913, p. 1).

> In the motions of mutually gravitating bodies, there is nothing that can be called a cause, and nothing that can be called an effect; there is merely a formula. Certain differential equations can be found, which hold at every instant for every particle of the system, and which, given the configuration and velocities at one instant, or the configurations at two instants, render the configuration at any other earlier or later instant theoretically calculable. (Russell 1913, p. 14)

Notably, the differential equations that Russell referred to have a central role both in Newtonian mechanics and in the relativity theory that replaced it. In pre-Newtonian mechanics, cause-effect relations were sufficient. This is exemplified by the clockwork universe of René Descartes, in which nature operated in the same way as "the movements of a clock or other automaton follow from the arrangement of its counter-weights and wheels" (Descartes [1632] 1987, p. 873). In Newtonian physics, in contrast, movements emerge from complex interactions between a large number of bodies, all of which influence each other simultaneously.

Modern physics relies even more on mechanisms not describable in terms of binary cause-effect relations than the physics that Russell referred to (Kuhn 1971; Hausman and Woodward 1999). Furthermore, social science has followed physics in adopting models in which the flow of events is determined by simultaneous mutual influences that cannot be adequately described in terms of the stepwise production of effects in a causal chain. This applies for instance to equilibria in economics. Similar complex interactions are also discussed in other areas of social science, such as political and organizational science, although usually not in terms of equation systems (Dent 2003). An account of complex social phenomena that is restricted to binary cause-effect relationships will lack much of the explanatory power of modern social science (Berger 1998, p. 324).

In summary, binary cause-effect relations are not sufficient to describe all the interconnections that there are among objects and events in the world. This makes it necessary to distinguish between two notions of causality. One of them is constituted by binary cause-effect relationships. We can call it *CE-causality*. The other, more general notion of causality refers to the combination of all the various types of interdependencies that obtain among objects and events in the world. We can specify it as consisting of all the connections between different events in the world by which what happens in some points in space-time restrict or partly determine what happens at other points in space-time. We can call this patterns-of-determination causality or *PoD-causality*. It is a feature of the world we are living in. CE-causality is one of the means by which we try to describe it. Newtonian and relativistic mechanics are other such means. Thus, CE-causality is a model of PoD-causality and in fact a rather crude and incomplete model. As always, it is important to distinguish between the real world and the models of it that we have created.

In this section we have made two important observations about CE-causality, which is our common notion of causality: (1) There is no objective ground for our selection of "the cause" of an event among a bundle of causal factors that contribute to it, and (2) binary cause-effect relations are insufficient to account for all the interconnections that prevail among objects and events. In combination, these two insights should be sufficient to caution us against the common assumption that responsibility can be founded on an objective fact base, consisting of cause-effect relationships. Additional reasons to be wary of that assumption will emerge from studying agent causality, the special type of causality that is particularly relevant for ascriptions of responsibility.

Agent Causality

One of the factors that affect our choice of "the cause" among causal factors is a tendency to focus on human actions whenever such actions have contributed to the effect. Therefore, agent causality has a certain priority in our account of causes.

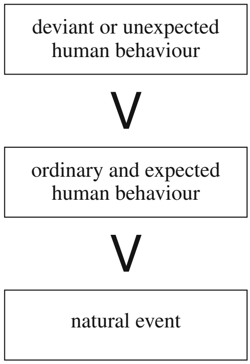

Fig. 1 General tendencies in our choice of "the cause" of an event, among the causal factors that contribute to it. Deviant and unexpected human behavior has the largest chance to be designated "the cause." Ordinary and expected human behavior comes second, followed by natural events

> Where there is only one human causal factor, no matter how small, that factor is potentially significant (and by human causal factor here I am referring to both human action and inaction). If it is also relatively close along the chain of causation that leads to the injury, we are very likely to assign causal responsibility to it. Indeed, even a very small human causal factor may bear causal and therefore moral responsibility if there is no other human causal factor to bear it. (Reiff 2015, p. 393)

Furthermore, if there is a choice among several causal factors exhibiting human actions, then we tend to give priority to actions that stand out as in some respect deviant or unexpected. This should be clear from the following example:

> Lora is driving on a country road in Kent, keeping to the left side of the road. Rose is driving in the opposite direction on the same road, but keeping to the right side. They meet at high speed in a curve and are both severely hurt.

Most of us would say, without doubt, that Rose caused the accident, since she drove on the right side of the road in left-hand traffic. But suppose that exactly the same course of events had taken place on a road in Hauts-de-France, on the other side of the Channel. Then we would have held Lora to have caused the accident, since she drove on the left side in right-hand traffic. Hence, we tend to consider deviant and unexpected behavior, rather than ordinary and "normal" conduct, as "the cause" of an event. These priorities are summarized in Fig. 1.

Causes with Moral Foundations

One of the ways in which human behavior can be deviant, or diverge from our expectations, is by departing from our moral norms. Perhaps surprisingly, moral aberrations often have a crucial role in determining our choice of "the cause" among a set of causal factors. There is a considerable amount of psychological research showing the role of norms in causality ascriptions (Willemsen and Kirfel 2019). For our present purposes, it is probably more useful to show this with the help of a couple of illustrative examples.

> Due to massive rainfalls, a segment of the river bank has been undermined, and anyone entering the area runs the risk of being drawn into the dangerous rapids.
>
> *Case 1*: Charles is well aware that a large part of the foundations of the river bank has been swept away. In spite of this, he recommends Andrew to go all the way down to the river to look for fish. The bank collapses, and Andrew drowns in the rapids.
>
> *Case 2*: Charles has no means of knowing that the river bank is damaged. He recommends Andrew to go all the way down to the river to look for fish. The bank collapses, and Andrew drowns in the rapids. (Hansson 2022)

In the first case, it seems reasonable to claim that Charles's ill-considered advice was "the cause" of Andrew's death. We would probably not hesitate to say that Charles "caused" the accident. In the second case, such a statement would appear much more problematic. Although Charles's advice is a causal factor in both cases (presumably, the accident would not have happened without it), we are much more hesitant to call it "the cause" of the accident in the second case. The crucial difference seems to be that we consider him morally culpable in the first but not in the second case.

> Despite her parents' advice to the contrary, Anne goes for a long walk on an unusually cold winter day, wearing only thin summer clothes and no coat or jacket. Three hours later she calls her parents from a hospital, where she is treated for severely frostbitten toes. "It's so unfair", she sobs. "Why should this happen to me of all the thousands of people who were out there in the streets?"
>
> "But dear Anne", says her mother. "I am sure they all had much warmer clothes than you. In this weather it is almost certain that you will have a cold injury if you dress like you did. No doubt, your way of dressing was the cause of your injury." (Hansson 2022)

What Anne's mother says makes sense and would be fairly uncontroversial. In this case, there are two obvious causal factors: the cold weather and Anne's decision to take a long walk in thin clothes. The first of these is a natural event, whereas the second is a consciously chosen human activity. As indicated above, we have a strong tendency to prefer human actions to natural events as "the cause" of something that happens.

> Despite her parents' advice to the contrary, Anne goes for a long walk in the late summer evening, wearing an unusually skimpy dress. Three hours later she enters a police station, weeping incessantly, to report a rape.
>
> In the trial three month's later, the defendant's attorney says: "There were thousands of women out in the streets that evening. In all probability, Anne was the only one who wore such an unusually revealing dress. We have just heard my client telling us that this is what made him approach her – admittedly in a somewhat pushy manner – rather than someone else. Given what we know about young men in this city I am convinced that if he had not approached her in this manner, then someone else would have done so. It is therefore obvious that her dress was the dominant causal factor that led up to the interactions that we are here to clarify. I do not hesitate to say that her way of dressing was the cause of what happened." (Hansson 2022)

This example is in some respects similar to the previous one, but there is a crucial difference: the most obvious alternative to characterizing Anne's behavior as "the cause" is to assign that role to the actions of the rapist. The reason why we find the attorney's causal claim to be preposterous is that the rapist's actions are by all standards incomparably more morally reprehensible than any choice of clothes that a person could make. Again, our moral appraisal determines our choice of "the cause" of what happens.

Let us now consider a couple of examples from road traffic.

> *Case 1*: A man steps out into a motorway where no pedestrian access is allowed. The driver of an approaching car tries but fails to stop, and the man is killed.
>
> *Case 2*: A man walks out into the street on a pedestrian crossing. The driver of an approaching car tries but fails to stop, and the man is killed.

Even if what happens physically is exactly the same in the two cases, we are much less willing in case 2 than in case 1 to describe the pedestrian's behavior as "the cause" of the accident. The reason for this is of course that he is morally less at fault in the latter case.

> A drunk driver loses control of the car, which hits and kills a woman walking on the pavement.

In this case, we would typically describe the drunk driving as "the cause" without even considering other causal factors. But there are at least two other causal factors at play. One of them is the pedestrian's choice of a place to walk. This accident would not have happened if she had been somewhere else at this moment. However, since her action is morally unassailable, it is a much less plausible candidate for "the cause" than that of the driver.

The other factor that we should consider in this case is a technical feature of the car, namely, that it was so constructed that an inebriated person could start and drive it (since it had no alcohol interlock). If we treat this as just a physical fact, then it cannot compete with the driver's behavior for the position as "the cause" of the accident. However, the car is not just a physical object but also a designed product, and decisions have been made on what safety features it should and should not be provided with. If we shift our perspective from this particular accident to the large number of accidents that involve drunk driving as an essential component, then these decisions might very well be a plausible choice for "the cause" (Cf. Grill and Fahlquist 2012).

All these examples contribute to making it clear that agent causality is strongly connected with moral assessments of actions. This was observed already by Ludwig Wittgenstein, who said: "Calling something 'the cause' is like pointing and saying: 'He's to blame!'" (Wittgenstein 1976, p. 410).

For good reasons, we want to separate our discussions and deliberations on facts as far as possible from our moral beliefs (Hansson 2018). This, however, does not seem to be fully achievable since, as we have seen in the above examples, moral concerns are often decisive for what we choose to call "the cause" of an event. This is a most undesirable conclusion, since it appears to entail that we are stuck in a kind of moral morass with no means to reach a stable factual ground. It does not seem possible to systematize our moral thoughts in a precise and well-ordered manner if our factual statements about human action are inextricably coalesced with our moral assessments. It should therefore be no surprise that many philosophers have toned down the influence of moral appraisals on causal claims or maintained (unrealistically) that our everyday concept of causality can be purged of its moral contents. (See Reiff (2015) and Tarnovanu (2015) for unusually clear statements of the issue and good selections of references.)

But there is another way out, which becomes obvious once we have realized that CE-causality is only a model for describing factual connections in the world. The problems that we encountered in the above examples were all connected with attempts to identify "the cause" in an objective way. The failure of attempts to do so does not show that we have no means of separating factual and moral assertions from each other; it only shows that the highly simplified single-cause variant of CE-causality (which is usually presumed in moral discussions) does not provide us with means to make such a separation. The chances of achieving the separation will be much better if we replace the search for single causes by attempts to identify multiple causal factors or even, when necessary, turn to models of simultaneous interactions that go beyond what can be described in terms of binary cause-effect relations (Hansson 2010). This should come as much less of a surprise to accident analysts than to moral philosophers. Accident analysis has a long tradition of searching for multiple causal factors rather than a single cause. The focus is usually on causal factors whose elimination is predicted to be feasible and to reduce the risks of future accidents. Such causal factors are usually called "root causes" (Parry 1991; Rooney and Vanden Heuvel 2004; Boyd 2015). This is arguably a somewhat misleading terminology. "Target causes" would be a better term, since the "root causes" are selected to be targeted in subsequent safety work.

The Politics of Causality

The strong connection between causality and responsibility has important consequences for political discourse and action. If the public conceives an activity as the cause of something undesirable, then chances are high that they will hold those who perform that activity responsible and require changes in their behavior. This gives rise to a "politics of causality," i.e., attempts by different actors to influence public perceptions of causality.

The most common strategy in causality politics can be called *backgrounding*. It consists in attempts to move, in the public's perception, a causal factor as far into the presumably unalterable background as possible. Backgrounding is usually performed on behalf of social actors whose activities give rise to a causal factor for some socially undesirable outcome. They try to turn away the public's attention from their own contribution, often by pointing at some other causal factor for which someone else can be blamed. Organizations that contribute to health risks and other dangers are particularly active in backgrounding. Tobacco companies are a prime example. Most of their victims became addicted before reaching the age of majority. In order to disclaim responsibility for the massive lethal effects of their products, these companies claim that "the cause" that a person smokes is a free and voluntary choice by herself.

The opposite of backgrounding is *foregrounding*, the process of attracting attention to causal factors that were previously parts of the unheeded background. Foregrounding is a strategy often adopted by social critics who wish to put causal factors on the agenda that were previously treated as unalterable parts of the social structure. One important example is the changed attitude to workplace health and safety that was achieved in the late nineteenth century by trade unions and public health activists. Previously, dangerous working conditions were treated as unavoidable, and workplace accidents were blamed on the victims. It is now generally accepted that workplace accidents are caused by dangerous working conditions, which employers are responsible for eliminating. Currently, foregrounding is an important part of public health efforts aimed at risk factors such as smoking, malnutrition, and obesity. In these cases, foregrounding consists in looking beyond the choices of affected individuals and addressing the "background" conditions under which these so-called lifestyle choices are made.

To illustrate the politics of causality, let us consider one hypothetical and one actual example. The hypothetical example is as follows:

> A manufacturer of chain saws sells a model with a very strong motor. The user regulates the speed of the chain by pressing a handle. If the handle is pressed to the bottom, then the chain will move so fast that the user cannot control the saw, and there are grave risks both to the user her- or himself and to people in the vicinity. The saw has an instrument on which users can see if they press the handle too hard, and it is legally prohibited to pass certain marks on that instrument. But in spite of this, accidents are common, and hundreds of people die every year due to chainsaws being run at too high speeds. (Hansson 2022)

I have presented this example in various lectures and discussions and as yet never encountered a person who claimed that these accidents were caused by careless users of the saw. We seem all to agree that these accidents should be causally attributed to the dangerous construction of the saw. This causal attribution supports the standpoint that the manufacturer is responsible for the accidents and should therefore urgently provide the saws with a speed limiter that prevents them from being run at too high speeds.

Let us now turn to the actual example:

> A manufacturer of motor vehicles sells a model with a very strong motor. The user regulates the speed of the vehicle by pressing a pedal. If the pedal is pressed to the bottom, then the vehicle will move so fast that the user cannot control it, and there are grave risks both to the user her- or himself and to people in the vicinity. The vehicle has an instrument on which users can see if they press the pedal too hard, and it is legally prohibited to pass certain marks on that instrument. But in spite of this, accidents are common, and hundreds of thousands of people die every year due to motor vehicles being run at too high speeds.

In this case, we tend to consider the accidents to be caused by the users (drivers), and consequently, the consumers rather than the manufacturer are held responsible for the accidents. Therefore, as noted by Christer Hydén, "[t]he most obvious measure to treat non-compliance of speed rules – the vehicle speed limiter – is not on the agenda yet" (Hydén 2019, p. 4). Estimates based on experiments with speed limiting devices indicate that obligatory speed limiters have the potential to reduce road fatalities by about 25–50% (ibid., p. 5). However, such a measure would not be uncontroversial. In 2019, an automobile manufacturer announced that it will block speeds above 180 km/h on all their new cars, except emergency vehicles. This is a high limit that will have no impact whatsoever on non-criminal driving, but nevertheless a motor journalist made a failed attempt to start a campaign against the decision (Nilsson 2020a, b).

Notably, there is no "objective" or mechanical difference between chain saws and motor vehicles that justifies the difference between our assignments of causality in the two cases. Instead, the contrast between our judgments in the two cases reflects our customs and conventions concerning two types of technological devices. It is the politics of causality, rather than the causal structures themselves, that differs between the two cases.

Responsibility in Road Traffic

In this final section, we are going to apply what we have found out in the previous sections about responsibility and causality to safety in road traffic.

The Traditional Approach

The approach to responsibility for road safety that prevailed throughout the twentieth century has been well described as follows:

> Historically, road accidents have been treated as isolated incidents caused by bad drivers and as an unfortunate side effect of increased mobility. Consequently, responsibility has been ascribed to individual road users whose behavior government responses have sought to influence through education, regulation, and control. (Hysing 2021)

This approach may have psychological advantages. According to Elaine Walster, it can be reassuring to categorize a serious accident as the victim's fault, since we can then "assure ourselves that we are a different kind of person from the victim, or that we would behave differently under similar circumstances, and we feel protected from catastrophe" (Walster 1966, p. 74). However that may be, this approach has a most serious disadvantage: its exclusive focus on mistakes by individual road users tends to block considerations of efficient measures that would reduce injuries and fatalities.

Well into the 1960s, it was generally accepted that traffic safety was all about *crash avoidance*. Governments, automobile manufacturers, insurance companies, and motorist organizations all agreed that it was the drivers' responsibility to avoid all collisions. The manufacturers' responsibility was limited to making this possible by delivering vehicles with adequate mechanisms for steering and braking that were reliable enough to make sure that the driver would not suddenly lose control.

Similarly, the responsibility of road managers was limited to providing a reasonably smooth road without undetectable obstacles. Even in cases when a crash could be linked to a mechanical failure, the blame was often put on the driver for lacking maintenance (Wetmore 2004, pp. 380–382).

In the 1960s, after considerable struggles, the crash avoidance approach was supplemented with requirements of *crashworthiness*. Since crashes were unavoidable – and rising in numbers – manufacturers were now held responsible for reducing the consequences of crashes. This led to the introduction of seat belts, crumple zones, and other life-saving technologies (Wetmore 2004, pp. 383–389). Today, after more than half a century of improvements in crashworthiness, cars are much safer than they once were.

However, the demands of crashworthiness did not lead to a shift in the ascription of responsibility for crashes and their consequences. True, the responsibilities of manufacturers were extended. They now had to deliver cars equipped not only with reliable mechanisms for steering and braking but also with equally dependable crashworthiness features such as seat belts. However, it seemed – and still seems – to be assumed that the vehicle manufacturer has satisfied all its responsibilities when it has delivered a vehicle that satisfies all the legal safety requirements. For what happens after delivery, road users are still held almost exclusively responsible, even if improved or additional safety features could have prevented deaths or injuries.

An interesting example of this can be found in an article from 1978 by two British psychologists (Howarth and Repetto-Wright 1978). They reported a pattern that they had found in official documents about accidents involving child pedestrians: Such accidents were usually considered to be caused by the child's behavior. In police reports, the most common explanation of these accidents was that the child "ran heedlessly into the road." Courts tended to conclude that "in the circumstances there was nothing the driver could do," and consequently the driver was acquitted and considered blameless (ibid., p. 10). The same approach was implicitly taken by road safety experts, who advocated training of children as the most important countermeasure against these accidents.

However, the two authors had made observations of children crossing roads and found that the description of their behavior as "heedless" was far from accurate. Children were typically highly aware of the traffic, and often afraid of crossing roads, but they sometimes made mistakes such as misjudging the speed of a vehicle or not noticing a vehicle because of their close attention to another vehicle. In the moments before an accident, the situation was "surprisingly symmetrical. The child can see the danger but makes the wrong judgement: the driver can see the child but misjudges what the child will do. In these circumstances," the authors said, "it is rather odd and indeed discreditable to absolve the driver from responsibility for his misjudgement but to blame the child" (ibid., p. 10). Noting "how difficult it is to change the behaviour of children on the roads" (ibid., p. 11), they proposed that drivers "must be regarded as at least equally responsible for these accidents, and we must now ask what could be achieved by altering their behaviour" (ibid., p. 12). It was necessary to "*redefine* the responsibility of drivers for pedestrian accidents," for the simple reason that drivers "have the greatest power to reduce these accidents" (ibid., p. 13).

This shift of responsibility from children to adults was clearly a step forward, but interestingly, the two authors explicitly dismissed proposals to reform the traffic system in order to protect children against accidents. They noted that there were people who wanted to place "our chief reliance on engineering measures to keep pedestrians and vehicles apart," either by constructing "controlled crossings, bridges or underpasses" or by adult accompaniment or the provision of school buses. They considered all these proposals to be unrealistically costly, but they also rejected them on more principled grounds. These proposals were, as they saw it, based on the assumption that "neither pedestrian nor driver are [sic] at fault," a standpoint that they equated with the view that "no-one is to blame." They expressed relief that "[f]ortunately most people in this country are not willing to take up such an extreme ideological point of view" (ibid., p. 11). Remarkably, they did not mention lowered speed limits in this context. (However, in a later article, the main author mentioned that driver education should include the advice to slow down when one sees a child wishing to cross the road; Howarth 1985, p. 176.)

The focus on the road user's individual responsibility is still remarkably strong in the traffic safety literature. That literature is still replete with claims that the vast majority of traffic accidents, typically around 90%, are caused by human failures (Algora-Buenafé et al. 2017, p. 240; Santosa et al. 2017; Harantová et al. 2019). This claim is also prevalent in the (remarkably small) ethical literature on traffic safety. For instance, Meshi Ori writes:

> It is well established in traffic safety literature that human factors are the predominant causes of traffic crashes. Obviously there are physical, and probably social and cultural aspects that count as contributing factors to the causes of traffic crashes, but those are marginal and depend on the way the driver/rider is influenced by them. (Ori 2014, p. 356)

However, as we saw above, no one can establish what the "predominant causes" of traffic accidents are, for the simple reason that the designation of some causal factors as "causes" or as "predominant" cannot be done in an objective way. In accident investigations performed under the assumption that vehicles complying with the legal regulations are beyond criticism, human failures will be the predominant causal factors. If we instead assume that human mistakes are inevitable, and investigate how the technology reacts to such mistakes, then the causal analysis will have a different outcome.

In addition, the ethical literature on traffic safety contains standpoints that go even further than the technical traffic safety literature in assigning responsibility to individual road users. In his often-quoted 2004 paper on traffic accidents, Douglas Husak observes that "personal vehicles cause tremendous amounts of harm" and adds that "much of this harm is caused culpably" (Husak 2004, p. 351). Without even considering other options, he assigns this culpability entirely to individual drivers and proceeds to discuss "*moral* questions about the use of personal motor vehicles." In doing this, he goes beyond "the trivial observation that many motor vehicle accidents result from speeding, alcohol impairment, or some other kind of unlawful mode of operation" (ibid., p. 351). In his view, even careful and law-abiding driving involves so large risks for other persons that driving "for frivolous purposes" is immoral (ibid., p. 362). This would include "traveling across town to patronize a new bar or restaurant," going "from one outlet to another" to find a cheaper product, as well as all forms of "purely recreational" driving. He also finds it culpable that "[m]any persons elect to live [at] great distances from their place of employment" so that they have to travel longer than necessary to work (ibid., p. 361).

Husak himself recognizes the crucial weakness of assigning, as he does, causality and responsibility for traffic accidents exclusively to the individual road users.

> I have no illusions that the general public will be receptive to my proposals. Pleas to curb driving are likely to be met with ridicule and hostility. (Husak 2004, p. 370)

He is not alone in this insight. The limitations to what can be achieved by attempts to change road users' behavior were a major factor leading to a new approach that aims for radical improvement of the traffic system.

Vision Zero

This new approach received its first official formulation in 1997 when the Swedish Parliament adopted Vision Zero as the overarching framework for road traffic safety in the country (Rosencrantz et al. 2007; Belin et al. 2012). The basic assumption of Vision Zero is that "from an ethical standpoint, it is not acceptable that any people die or are seriously injured when utilizing the road transportation system" (Government Bill, 1996/1997:137, p. 15). All serious accidents are considered to be unacceptable, and efforts to reduce the number of fatalities and serious injuries must continue assiduously as long as accidents still occur. This cannot be achieved with the traditional approach that assigns almost the whole burden of responsibility to drivers and other road users. Therefore, Vision Zero makes the designers and implementers of the transport system responsible for eliminating human deaths and injuries. In the terminology introduced above, the movement for Vision Zero is an unusually clear example of a movement for the foregrounding of previously backgrounded causal factors.

The Vision Zero approach to responsibility is new, and in a sense revolutionary, in traffic safety. However, it is certainly not without forerunners in other areas of safety. In a sense, it can be seen as the implementation in traffic safety of a general outlook that has long been taken for self-evident in workplace safety. In stark contrast to the traditional focus on individual fault and culpability in traffic safety, workplace safety has a strong and well-established focus on technological and organizational causal factors that can be eliminated or curtailed in order to reduce the prevalence of injuries. Since these factors are almost invariably in the employer's control, it follows from this approach that the employer, rather than the employees, has the primary responsibility for safety on the workplace.

An interesting comparison can be made between the approaches to two types of traffic accidents, namely, road traffic accidents and accidents with forklift trucks on workplaces. As we have just noted, the road traffic literature still standardly looks for "the cause" of accidents and categorizes most accidents as caused by road users. In contrast, at least since the 1970s, the literature on forklift truck safety has refrained from looking for culprits and instead investigated the various types of forklift accidents with the purpose of "[p]rescribing the remedy (design improvement) to minimize the hazard and lower the risk" (MacCollum 1978, p. 145; cf. Stout-Wiegand 1987; Larsson and Rechnitzer 1994). One of the effects of Vision Zero is that the view of causality and responsibility that has since long been applied to forklifts, as well as to other dangerous machines on workplaces, is now increasingly applied to motor vehicles on public roads.

Self-Driving Cars

Self-driving cars have been discussed and to some extent developed at least since the 1950s, but it is only in the twenty-first century that they have become a realistic possibility. One of the several ethical issues that their potential introduction gives rise to is that of responsibility, in particular blame responsibility. Self-driving cars are predicted to be involved in fewer accidents than conventional cars, but there will still be accidents. Who should be held responsible for such accidents?

There are four reasonably plausible answers to this question. Blame responsibility for accidents can be assigned to:

- The car itself, or more precisely to the *artificial intelligence* built into it
- The *users* who travel in the cars
- *No one* at all, just like no one is held responsible for the occurrence of natural disasters
- *Other persons* than the users

Let us consider each of these options in turn. Concerning the first, it is important to distinguish between the question whether the artificial intelligence in self-driving cars can be held responsible for accidents and the much more general question whether any artificial intelligence can at all be held responsible in the same way as we hold human beings responsible for their doings (Nyholm 2018a, pp. 1209–1210). The answer to the latter question seems to depend crucially on what types of artificial intelligence humans will encounter in the future. We can think of hypothetical future intelligences that will exhibit beliefs and desires and communicate with humans about moral issues in much the same way that we humans communicate with each other. It is fairly plausible that we, or future humans, would be disposed to assign blame (and task) responsibilities to such artificial agents, if and when we encounter them. However, this is not the type of artificial intelligence that will be installed in self-driving cars. Instead, these vehicles will be provided with software that is constructed to execute the orders given by humans and to do so in accordance with guidelines and restrictions devised by their human designers. Therefore, it seems highly unlikely that we will treat them as agents that can be culpable or held responsible (Brey 2013; Purves et al. 2015; Coeckelbergh 2016; Nyholm 2018b).

Our second option is to hold the users of self-driving cars blame responsible for whatever damage the car is deemed to cause. Concerning this option, it is important to distinguish between semi-automated and fully automated vehicles. A semi-automated vehicle still has a “driver,” who is passively but constantly following the driving and prepared to intervene immediately whenever necessary. With this arrangement, it does not appear unreasonable to assign blame responsibility to a (standby) driver who did not take over and solve a situation that the system could not solve. A fully automated vehicle does not require a standby driver. Such a car can navigate on the roads without any human driver or passenger or when everyone onboard is asleep. It is difficult to see how blame responsibility for an accident could be assigned to the occupants of a vehicle under such circumstances.

The third option is to refrain from assigning blame responsibility for an accident to anyone at all. This is how we often react to natural events. We do not assign blame responsibility to anyone for the occurrence of hurricanes or tsunamis (although we often assign blame to people who have failed to prepare properly for such events). However, this is not how we react to machines or other technological devices that are causal factors in an accident. As noted above, we have a strong tendency to focus on causal factors that involve human actions, whenever there are any such factors. For example, automated train systems have been introduced in many parts of the world, mostly in metro networks and airport transit systems (Wang et al. 2016). Automated trains are subject to extensive safety management. Accidents are certainly not treated in the same way as unevadable natural disasters. Instead, they are treated in the same way as accidents in other, less automated technological systems, namely, as avoidable failings for which human beings are responsible (Seng et al. 2009). There is no reason to believe that accidents in automated systems on roads will be treated differently.

This leaves us with the fourth option, namely, to assign blame responsibility for accidents to some other persons than the users of the automatic vehicles. There are strong reasons to assume that this is what is going to happen. The obvious candidates for undertaking responsibility are the system designers and system owners, i.e., those who are responsible for the construction of the vehicles and the construction, maintenance, and management of the roads and the communication systems that these vehicles will operate with. This is how we assign responsibilities for other automated systems, such as the automated trains just mentioned. Importantly, this is also how the first serious accidents involving self-driving cars have been dealt with. In media and in public discussions, the responsibility of the car manufacturers has been taken for granted. There are also clear signs that the automobile industry is planning to assume that responsibility (Atiyeh 2015; Nyholm 2018b).

In conclusion, we have strong reasons to expect that the blame responsibility for accidents implicating self-driving cars will be assigned to designers and owners of the automated traffic system. But that is only part of the answer to our question. Our future traffic systems will have many designers and owners. If two self-driving cars of different brands collide, then responsibilities may have to distributed among two automobile companies, the organization responsible for maintenance of the road, the organization(s) running the electronic communication system(s) that guided and coordinated the two vehicles, and various subcontractors of these companies and organizations. The automobile industry has a history of protracted blame games (Noggle and Palmer 2005), and neither legal battles nor public relations campaigns over these responsibilities should come as a surprise. Instead of the philosophically fascinating, but probably unrealistic, issue whether we can assign responsibility to the self-driving cars themselves, we may have to deal with more mundane conflicts between companies trying to avoid financial and reputational losses.

Institutional and Professional Responsibility

Much of the discussion above boils down to the unavoidable conclusion that in order to improve traffic safety, it is not sufficient to remind road users of their responsibilities. First and foremost, we have to assign important task responsibilities to those who have the resources and the power to bring about such improvements, namely, the system designers. This will not always be easy. Road traffic has no single responsible authority corresponding to the employer on a workplace. Instead, it has a large and rather heterogeneous collection of system designers.

> Who then are the system designers? In the Swedish VZ policy, the concept embraces all actors—public and private—who, in their professional capacity, influence the design and function of the road system. . . Three groups of designers were singled out as particularly important: road administrators (state, municipalities, and private), the automotive industry, and actors procuring or providing transport services (taxi, bus, and freight). Other identified system designers are actors responsible for various support systems, such as the police (monitoring and enforcement), driving schools (education), and emergency services, health care, and rehabilitation professionals. (Hysing 2021)

As yet, the responsibility of system designers is largely informal. Those working in the public sector are of course required to implement the government's policy, but the involvement of the automotive industry and other private sector companies and organizations is voluntary. Furthermore, there is no liability associated with these responsibilities. This can be compared to the employer's responsibility for workplace safety, which is in most jurisdictions fairly far-reaching and subject to legal sanctions. As discussed in Abebe et al. (2022), the lack of legal liability for system designers has been the object of some criticism, but it is not clear whether the introduction of such liability would lead to improvements in safety.

Importantly, the system designers' responsibility is a matter of both institutional and professional responsibility. The institutional responsibility is carried out by government agencies and private companies. The professional responsibility is carried out by the traffic safety experts who work in these institutions.

The notion of specific professional responsibilities goes back at least to the Greek physician Hippocrates (c. 460–c. 370 BCE), whose oath for physicians made it clear that a physician, when acting as a professional, has special duties and responsibilities that differ from those of citizens in general. In the Hippocratic tradition, the physician had to act for the benefit of the ill, keep silent about what he learnt about patients and their families, and treat all patients alike irrespective of whether they were men or women, rich or poor, free or slaves. If needed he should offer his service for free to the poor (Jouanna 1999, pp. 112–126; Askitopoulou and Vgontzas 2018). These are still parts of the ethics of the medical profession. However, there is also an important difference: Whereas the Hippocratic physician acted alone, physicians in the modern world work together with others. Instead of the single physician visiting patients in their homes, healthcare is now mainly performed in teams consisting of physicians and other healthcare personnel with different specializations (Heubel 2015).

What makes medical ethics *professional* is that it puts focus on certain values for which members of the profession have a special responsibility. For instance, according to the Hippocratic oath, the physician should always be of service to the ill. Therefore, he could not undertake to kill or hurt a person with a poison or suggest to others how to do so (Jouanna 1999, pp. 128–131). Interestingly, this was recognized by Plato, who considered it a more serious crime for a physician than for a layperson to poison a person. (Plato, *Laws*, Chap. 11, p. 933d.) Still today, all major organizations in the medical profession disallow their members to contribute in any way to capital punishment (Anon 2005; Litton 2013). In this context, the American Medical Association has made it very clear that professional ethics is distinct from personal moral judgments:

> An individual's opinion on capital punishment is the personal moral decision of the individual. A physician, as a member of a profession dedicated to preserving life when there is hope of doing so, should not be a participant in an execution. (American Medical Association 2019)

Much later than physicians, other professions have developed professional identities, responsibilities, and ethical principles of their own. Lawyers, accountants, and engineers are among the most prominent examples. For instance, since the late nineteenth century, the engineering profession has developed ethical codes and delineated specific responsibilities that follow with the profession of an engineer. The value that has most often been associated with engineering professionalism is that of safety. Just as the ethical codes of physicians prevent them from undertaking to poison or otherwise hurt a person (even if it is legal to do so), the ethical codes of engineers prevent them from accepting assignments to make unsafe or dangerous constructions. Importantly, the ethical requirement not to compromise on safety is considered to override contractual obligations towards employers and customers.

Road safety has not yet been established as a profession like those of medicine and engineering, but the professionals whose work determines the risks we all run as road users can easily be identified. Although the overarching responsibilities for traffic safety has to be assigned to the organizations that make and maintain roads and vehicles, the practical day-to-day implementation of these responsibilities will require the direct engagement of those who actually do the work. It is difficult to see how patient safety could be achieved in a hospital solely through directives from the top, without authorizing competent professionals to independently promote safety in their daily work. Road safety may not be very different from patient safety in this respect.

Cross-References

- ► Arguments Against Vision Zero: A Literature Review
- ► ISO 39001 Road Traffic Safety Management System, Performance Recording, and Reporting
- ► Saving Lives Beyond 2020: The Next Steps
- ► Vision Zero in Sweden: Streaming Through Problems, Politics, and Policies
- ► Vision Zero: How It All Started

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Liberty, Paternalism, and Road Safety

6

Sven Ove Hansson

Contents

Abstract

Traffic safety measures such as seat belts, helmets, and speed limits have often been opposed by people claiming that these measures infringe on their liberty. Safety measures are often described as paternalistic, i.e., as protecting people against their own will. This chapter provides a historical account of such criticism of safety measures, beginning with nineteenth-century opposition to sanitation

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measures, which were claimed to threaten the freedom to drink dirty water. The historical analysis has a surprising conclusion: Opposition to safety measures does not seem to have much to do with paternalism. Some measures that would typically be described as paternalistic, such as seat belts in commercial aviation and hard hats on construction sites, have met with no significant opposition. In contrast, some of the most vehemently opposed measures, such as speed limits and the prohibition of drunk driving, cannot with any vestige of credibility be described as paternalistic. This is followed by an analysis showing that due to our tendency to follow examples set by others (herd effects), purely self-affecting behavior is much less common than what has usually been assumed. Most of the opposition to safety measures in road traffic seem to result from some individuals' desires to engage in activities that endanger other people's lives. The social need to restrain the satisfaction of such desires is obvious.

Keywords

Acceptance of safety measures · Herd effects · Liberty · Paternalism · Traffic safety · Vision Zero

Introduction

In April 1985, the Senate of the State of Washington discussed a proposal to make the use of seat belts mandatory. Arguing against the proposal, Senator Kent Pullen (R) conceded that seat belts would save lives, but in his view, that was not reason enough to make them mandatory. "There is something more important than life itself," he said, "and that's freedom" (Leichter 1991, p. 12). This is a type of argument that traffic safety has met with throughout its history, and it is still in very active use. Currently, a Missouri law-maker, Eric Burlison (R), is working hard to repeal the motorcycle helmet law in his state. Like Pullen, he recognizes that his policies will lead to more deaths, but that does not deter him. "At the end of the day," he says, "it's about individual responsibility and individual freedom. I want my neighbor to stay safe and healthy, but it's not my business to force those decisions upon my neighbor" (Huguelet 2020).

We hear similar messages in many other contexts. The American Enterprise Institute campaigns against the "spirit of anti-smoking paternalism" that has given us smoke-free bars and restaurants, and they deplore attempts by legislators to remove unhealthy components such as trans-fats from food, calling all this "a remarkable confiscation of freedom" (White 2006). The owner of a British pub who was criticized by the authorities for deficient hygiene complained about "our modern nanny state's requirements for sterile and salubrious certification" (Woolfson 2016). Anti-vaccination campaigners call themselves "freedom keepers," and claim that parent's rights not to have their children vaccinated is a matter of "civil rights" (Mays 2019). And in 2017, an Australian parliamentarian declared the prevention of such measures to be his main aim in politics.

> When our most basic rights and freedoms are being chipped away at on a daily basis through nanny-state regulations and big-government paternalism, with smoking indoors banned, irrespective of what the owner of the property thinks; with bicycle helmets mandatory, despite the rest of the world agreeing that they are really not worth the effort; and with e-cigarettes, a potentially life-saving alternative pathway to quitting smoking, practically banned, I will be there, making the case for personal choice and personal responsibility. (Stonehouse 2017)

What is all this about? Of course we want freedom, but we also want traffic safety, healthy food, and protection against deadly diseases. How severe is the conflict between safety and liberty? Can we have safety on the roads in a free society, or do we have to choose between freedom and safety?

Paternalism and Liberty

At the center of this discussion is the concept of *paternalism*, protecting someone against her or his will. The critics of government interventions – or at least the more thoughtful among them – accept government interventions to prevent people from harming others, but they reject interventions intended to prevent us from harming ourselves. The latter type of regulation, they say, treats adults as if they were children. That is why it is called paternalistic.

Defining the Term

The word "paternalism" is derived from "paternal," which means fatherly. In the late nineteenth century, it was often used in a positive sense, in particular about employers who cared for their employees. Today it is almost universally used in a negative sense. In the scholarly discussion, Gerald Dworkin's definition of paternalism is widely accepted. In its latest variant it says:

> Paternalism is the interference of a state or an individual with another person, against their will, and defended or motivated by a claim that the person interfered with will be better off or protected from harm. (Dworkin 2020)

Three major components of this definition should be noticed: (1) a person is interfered with, (2) the person in question does not desire that intervention, and (3) the interference has the purpose to benefit this person (Wilson 2015).

A small modification and some clarification of the definition will be useful. To begin with the modification, Dworkin only mentions that "a state or an individual" can interfere with a person, but certainly so can also a company or some other type of organization. For instance, a company that performs construction work may choose to fence in the worksite for no other reason than a desire to protect the public from danger. Similarly, a manufacturer may choose to voluntarily withdraw a product because of problems with its quality or safety, although some consumers still want the product. A company that takes such actions behaves paternalistically in the same sense as a government that makes the same type of decisions for the same type of reasons. In these and other cases, an action affecting a group of persons can be paternalistic towards some but not all of its members, depending on whether or not they oppose the action (Grill 2018).

Dworkin's term "interfere with" is in need of clarification, and indeed he provides such a clarification later on in the text, when he specifies that the paternalist "interferes with the liberty or autonomy" of the targeted person (Dworkin 2020). This is an important clarification, since otherwise the list of paternalistic actions would grow to enormous proportions. In private life and in work-life we often find ourselves doing something for the benefit of a person who does not appreciate it. And unavoidably, political decisions intended to benefit large groups of people are not always appreciated by all of them. Some writers have used the term "paternalism" for all sorts of political decisions that are intended to benefit the population, including government funding of healthcare, education, public broadcasting, museums and theaters, tax deductions for pension savings, and subsidies of leisure activities and healthy food (Le Grand and New 2015, pp. 12, 52–54, 65–66, and 153; Conly 2017, p. 208). With such a wide definition, the building and maintenance of roads is also paternalistic, and so most certainly is law enforcement, which – just like publicly funded art museums – is intended to benefit all, but unfortunately is not appreciated by all. If we call all of this paternalism, we risk losing sight of the much more limited range of cases that have been at the focus of debates on paternalism, such as seat belts, motorcycle helmets, and vaccination. These cases all have in common that they satisfy Dworkin's criterion of interfering with the liberty or autonomy of the targeted person (Cf. also Dworkin 1972, p. 67). Another way to express this is that they limit the person's choices by removing an option, making an option less accessible, or reducing her ability to choose.

In definitions and more principled discussions of paternalism it is assumed that a person has a right to harm or risk her own health and well-being, but it is not assumed that she also has a right to harm her family members or expose them to risk. However, in political discussions, and even in some academic texts, the latter assumption is made as well. Even Giubilini and Savulescu (2019, p. 241), who commendably advocate universal vaccination programs, describe this as a matter of "how much weight we want to give to paternalism compared to individual freedom, and particularly the freedom to decide what kind of risks to take on oneself or on one's children." Shiffrin (2000, p. 217) takes this even further, suggesting that a park ranger behaves paternalistically if he prevents a person from making a dangerous mountain climb, not at all out of concern for the person himself or herself but for the person's spouse who would be left grief-stricken in the case of a fatal accident. As noted by Dworkin (2015, p. 26), according to how paternalism is usually defined, this case rather exemplifies "precisely the contrast class to paternalism."

Non-paternalistic measures to promote safety and public health have a long tradition. For instance, free vaccinations were an important part of infection control throughout the nineteenth century, and they still are (Rigau-Pérez 1989, p. 400; Daker et al. 1893, p. 217; Anon 1894). In order to encourage traffic behavior that reduces the risk of crashes, stop lines have been painted on roads since 1907, and centerlines and pedestrian crossings since 1911 (Petroski 2016). The strategy behind these and other similar measures for health and safety was summarized in 1976 by the American public health scholar Nancy Milio:

> The point is that most human beings, professional or nonprofessional, provider or consumer, make the easiest choices available to them most of the time, and not necessarily because of what they know is most healthful. Thus, if it is agreed that health-promoting life patterns are a good thing, then the focus for changing behavior should be on the problem of how to make health-generating choices more easy, and how to make health-damaging choices more difficult. . .
>
> In order then for life-style patterns to alter among individuals in numbers sufficient to affect the incidence of major diseases, new, health-promoting options must be available, and more readily so than health-damaging options, i.e., in such a way as to be less costly in dollar and other costs. (Milio 1976, pp. 435 and 437)

In 2008, the term "nudge" was introduced in a book promoting this approach (Thaler and Sunstein 2008). Neither this nor most other texts on "nudge" acknowledges the long tradition of similar ideas in public health. This was pointed out by Signild Vallgårda (2012), who also noted that "while renaming an activity has the benefit of creating enthusiasm and new energy and providing the encouraging feeling of being part of something new, it also has a drawback: it could lead to a neglect of insights generated by the pursuance of similar policies in the past." In their book, Thaler and Sunstein used the term "libertarian paternalism" about the "nudge" approach. As already mentioned, this is a usage that, if applied consistently, would lead us to classify a large part of the benevolent activities that take place in society as "paternalistic." It should be recognized, though, that some of the actions that are "libertarian paternalistic" according to Thaler and Sunstein, but not paternalistic according to traditional definitions, are problematic in other ways, for instance, by being manipulative (Mols et al. 2015; Dworkin 2020). This was also noted by Dworkin, who said:

> Their definition of Paternalism is very weak in the sense that it allows many more acts to count as paternalistic than would be under almost all traditional definitions of paternalism. (Dworkin 2020)

In order to avoid thinning out the concept, I will use the term "paternalism" only for interventions that satisfy Dworkin's definition, as explicated above. This is the terminology that appears to be most in line with the tradition, at least in philosophy. Of course, a different terminology could have been chosen. We could choose to use the term "paternalistic" about all measures that have the purpose to benefit a person against that person's will, or without her consent. Then, however, we would have to introduce a new term for what is called "paternalism" here.

How Bad Is Benevolence?

Dworkin's definition of paternalism has a peculiar feature, which it apparently shares with all other definitions of the term. This is his third criterion, which says that a paternalistic action is "defended or motivated by a claim that the person interfered with will be better off or protected from harm." We can call this the criterion of benevolence.

Something seems to be wrong here. That an action affecting another person is benevolent towards that person is surely a morally good feature of that action. But paternalism is presumably bad. So how can a good feature of an action be a necessary requirement for the action to belong to a category of bad actions?

The mystery deepens if we consider how benevolence is usually assessed from a moral point of view. Consider the following example (which happens to be based on an actual occurrence):

> After spreading thawing salt (road salt) on the asphalt outside his own house, Ahmad walked over to his elderly neighbor's house and strewed some salt on her entrance stairs. When she noticed this a couple of hours later, she was much annoyed since she believes that thawing salt will cause the stairs to crack.
>
> *Case A*: Ahmad did this because he was worried that she might otherwise slip and break her leg.
>
> *Case B*: Ahmad did this because his wife had told him that another neighbor wanted him to sprinkle salt over her stairs, but he mistakenly went to the wrong neighbor's house.
>
> *Case C*: Ahmad did this because he wanted to wreck her stairs.

In case A, Ahmad's action is benevolent. In case C it is malevolent. In case B it is neither benevolent nor malevolent; we can call it neutral in that case.

It can, I believe, be safely assumed that most of us would agree that Ahmad's action is morally better in case B than in case C, and even better in case A. Wanting to help your neighbor seems to be a better excuse than confusing her with someone else. Case A is the case in which Ahmad's action was benevolent. Apparently, this example confirms the supposition that benevolence contributes to making actions good, rather than to making them bad.

But perhaps this example is untypical since it concerns actions by individuals, rather than actions by governments or organizations? Let us consider such examples, and begin with an example of a business organization.

> Liliana owns the only hardware store in town. She has stopped selling a particular brand of electric jigsaws, although several customers would still like to buy one.
>
> *Case A*: Liliana did this because the protection of the user's hands on this particular saw is inferior to that of other brands, and she did not want her customers to be hurt.
>
> *Case B*: Liliana did this because her supplier did not offer this particular saw any more, and she did not take the trouble to look for someone else who can supply it.

In case A, Liliana's purpose is clearly benevolent towards the customers whom she has deprived of the option to buy this particular saw. Furthermore, according to standard usage of the term, her decision in this case is paternalistic. In case B, in contrast, her action is neither benevolent nor paternalistic. It is just an ordinary business decision. The decision in case A is clearly praiseworthy from a moral point of view, and we might even use it as an example of corporate social responsibility on a small scale. In case B, her decision does not seem to be particularly praiseworthy from a moral point of view. So is paternalism better than business as usual? Then it cannot be terribly bad, or can it?

Let us consider a similar example where the government is involved:

> Liliana had to stop selling the power jigsaw. It would have been illegal to sell it since the government did not prolong its type approval.
>
> *Case A*: The government decided not to prolong the type approval because the jigsaw did not have a satisfactory protection of the user's hands.
>
> *Case B*: The reason why the type approval was not prolonged was that a government official failed to include this brand on a list of electric tools for routine prolongation of the type approval. Due to procedural rules introduced by a previous government, it will take a full year to correct the mistake.

In case A, the motive of the decision was benevolent, and it can also be described as paternalistic. And again, the paternalistically motivated version of the decision would appear to be the morally best version.

Thus, it seems as if benevolence cannot make an action or a decision worse than what it would otherwise have been. Then how can benevolence be a defining characteristic of an undesirable feature of an action, namely, that it is paternalistic? Can the notion of paternalism at all be saved from this conundrum?

Yes, there is in fact a fairly satisfactory solution to this, but it requires a small change in the definition: The definition should not refer to the presence of paternalistic justifications of the action, but rather to the absence of sufficient non-paternalistic justifications. This is also what Dworkin indicates. When he elaborates his benevolence criterion more in detail, the crucial phrase is:

> *X* does so *only because X* believes *Z* will improve the welfare of *Y* (Dworkin 2020; emphasis added)

(*X* is the agent who behaves paternalistically, *Z* the paternalistic action, and *Y* the person who is the target of the paternalistic action.)

In other words, a sensible anti-paternalist cannot maintain that it is wrong to have paternalistic motives or justifications for one's actions. (The terminology is somewhat intricate. A motive or justification for an intervention affecting a person is commonly called "paternalistic" if it is benevolent towards that person, irrespectively of whether or not the intervention infringes on that person's liberty. This usage will be followed here.) The wrong will have to be identified as that of not having sufficient non-paternalistic motives or justifications. Let us consider an example that illustrates this:

> For many years Stephen has earned his living by travelling around with a pendulum ride, which he sets up on various festivals and fairs. One day he is visited by a safety inspector

from a government agency. After discovering a serious fault in the machine, the inspector issues an injunction prohibiting Stephen from offering any more rides on it.

Case A: The inspector does this because of a serious risk that the attendant, that is Stephen himself, can be killed in an accident. Riders are not at risk.

Case B: The inspector does this because of a serious risk of an accident in which both the riders and the attendant can get killed.

Case C: The inspector does this because of a serious risk that the riders can be killed in an accident. The attendant is not at risk.

Stephen, we may assume, is a fervent anti-paternalist. In case A, he can legitimately claim that the inspector has acted against him on purely paternalistic grounds. Such a claim would not be tenable in the other two cases, since the risk to the riders is reason enough for the inspector's decision. But would it be reasonable for Stephen to claim that the inspector's argument for closing down his machine is weaker in case B than in case C, since a concern for Stephen's own well-being is involved in the former case but not in the latter?

INSPECTOR: I have decided to close down your machine because there is a large risk that riders can get killed if you continue to operate it.
STEPHEN: I fully respect your decision.
INSPECTOR: I appreciate that. I should also tell you that you would probably be killed yourself in such an accident, and of course that contributed to my decision.
STEPHEN: What are you saying? Are you a paternalist wanting to protect me? Then I cannot respect your decision any longer. Are you really sure that it is necessary to close down the machine immediately?

It would not be absurd to claim that a paternalist argument has no weight at all. (This would mean that the inspector's injunction is justified to the same degree in cases B and C.) However, as this example shows, it would be utterly absurd to maintain that a paternalist argument carries a negative weight. There may of course be anti-paternalists who maintain that it is blameworthy to harbor concerns for other people's well-being. I am not claiming that such a position is impossible or non-existent, only that is a morally absurd position that is not worth taking seriously. This is written during the Covid-19 epidemic in 2020. Among the many statements that have been made on what governments should and should not do in relation to this health crisis, I have as yet not heard a claim that governments have no business to be concerned with the population's health. (This would mean that the injunction is less well justified in case B than in case C.) This confirms the limit to sensible anti-paternalism that was proposed above: It has to be concerned with the absence of sufficient non-paternalistic motives or justifications, not with the presence of paternalistic ones. This also means that the legitimate concerns of anti-paternalism are concerns about infringements of liberty, not about other people's benevolence. Wilson (2015, p. 212) reached a similar conclusion. Several authors have pointed at the difficulties involved in judging an action by a government or an institution by its intention (e.g., Dworkin 1972, p. 65). Participants in a decision may differ in their intentions, and it is far from clear how their intentions can be aggregated (Preyer et al. 2014; O'Madagain 2014; Salice 2015). I will give the last word to the safety inspector:

> INSPECTOR: Look here, Stephen. I have full respect for your strong views on personal liberty. I certainly cherish the idea of a free society myself. But there is an imminent risk to your customers, and that is reason enough to close down the ride. The freedom that I believe in is not a freedom to hurt others. And if you don't like that I care for your safety, then let me just tell you one thing: I am in my right to do so. How can you bother about your own liberty without accepting my liberty to care and worry about other people? Would you now please close down the ride?

What Options Can We Forbear?

We have identified the bad that anti-paternalists legitimately worry about as infringements in liberty. Liberty consists in being able to choose between different options. We can therefore express this as a concern that people are deprived of options that they could otherwise have chosen among. This is clearly an important concern. Everyone's right to make their own decisions and to choose their own way of life is a crucial part of what it means to live in a free society.

Living in a society with other people comes with a wealth of options that an eremite living in the wilderness does not have. (Just think of what you have been doing today, before reading this. How much of that could you have done without the combined effects of the actions of innumerable other humans, of present and past generations?) As our societies develop, some options are lost while others are added. Some options have been lost due to commercial decisions; for instance, you cannot buy a new car with a 20 hp engine any more. (That was the power of the Ford Model T motor.) Other options have been lost due to government decisions; you cannot spray DDT on your garden roses to get rid of insects. (This use of the pesticide was still recommended by the US Department of Agriculture in 1967, 5 years after Rachel Carson's book Silent Spring (1962) was published (Smith 1967, pp. 6 and 9–12).) Both these are examples of lost options that few would wish to regain. They illustrate that not all losses of options are regrettable. In the case of DDT, there was considerable resistance to the change (Krupke et al. 2007), but that reaction has since long abated. Let us have a look at some examples of safety-related infringements of liberty, what reactions they have encountered and how those reactions have developed.

Sanitation

Our first example is a classic issue in public health, namely, clean water and hygienic sewage systems. The British Public Health Act, adopted in 1848, authorized local authorities to take control over water supply, sewerage, and other facilities needed to ensure hygienic living conditions. The new law was strongly supported by those whose living conditions it would improve, as well as by philanthropists and radicals in higher social strata, but it also met with considerable resistance (Roberts 1958, 1979, pp. 200 and 258–259; Wiggins 1987; Porter 1999, pp. 119–120).

Speaking in the House of Commons, the Tory MP Charles Newdegate (1816–1887) described the law as “a departure from the free principles of the British Constitution.” His liberal colleague George Muntz (1794–1857) considered the whole issue of sanitation to be “grossly exaggerated,” and denounced the legislation as unnecessary since “[t]he people were clever enough to manage their own affairs” (House of Commons 1847, cc. 729 and 750). Another liberal MP, Edward Divett (1797–1864), warned against “the constant meddling and dictation” that he expected from the government authority overseeing the legislation. “The electors did not object, it was true,” he said, “to sanitary improvement; but they did not choose to be ordered how to set about it.” (House of Commons 1848, c. 725) The most prominent opponent of the law was the influential conservative MP David Urquhart (1805–1877), who opposed the bill because it placed “despotic powers” in the hands of the Government. Government had already too much power, he said, and he was determined to do whatever he could “not merely to prevent any increase to that power, but to reduce the amount of it which the Government at present enjoyed.” (House of Commons 1848, cc. 712 and 715)

The most vociferous critics could be found in the Tory papers. For instance, the London journal *Morning Herold* argued that “[a] little dirt and freedom may after all be more desirable than no dirt at all and slavery” (Roberts 1979, p. 200). However, the prevalence of such sentiments receded in the coming decades, and today we do not hear much talk about the importance of being free to drink contaminated water or walk on filthy streets.

Workplace Safety

The legal approach to workplace health and safety underwent large changes in the late nineteenth and early twentieth centuries. According to the old tradition, male workers were responsible for their own safety, and any attempt to lay responsibility on the employer was conceived as an infringement on the workmen’s freedom of contract. For instance, in 1880 a liberal government in Britain introduced new legislation that gave workers right to compensation from the employer for injuries incurred on the workplace. The Tories vehemently opposed this measure. In Parliament, the conservative member Thomas Knowles (1824–1883), who had business interests in coal mining, warned that the new legislation would be disastrous for mine owners, whose companies in his view had so many accidents that the law would in practice “confiscate their property.” He also told Parliament that due to the new liability legislation, he estimated that his own assets in coal mines had only half the value that they had had a week ago (Knowles 1880, cc. 1100–1101. Cf. Green 1995, p. 73.). There was also considerable resistance against the law within the liberal party (Green 1995, p. 75). The prominent left liberal philosopher Thomas Hill Green (1836–1882), who supported the legislation, summarized the most prominent argument of his opponents as follows:

> "The workman," it was argued, "should be left to take care of himself by the terms of his agreement with the employer. It is not for the state to step in and say, as by the new act it says, that when a workman is hurt in carrying out the instructions of the employer or his foreman, the employer, in the absence of a special agreement to the contrary, shall be liable for compensation. If the law thus takes to protecting men, whether tenant-farmers, or pitmen, or railway servants, who ought to be able to protect themselves, it tends to weaken their self-reliance, and thus, in unwisely seeking to do them good, it lowers them in the scale of moral beings." (Green 1888 [1881], p. 365)

Crossley (1999, p. 292) quotes this passage, but removes Green's four quotation marks as well as the phrase "it was argued". He correctly attributes the text to Green, but omits the crucial information that Green described his opponents' views, and incorrectly describes the text as written by "[o]ne opponent of the Act". This, said Green, was an argument "which many of us, without being convinced by it, may have found it difficult to answer." (Green, p. 365) But he had an answer:

> When we speak of freedom as something to be so highly prized, we mean a positive power or capacity of doing or enjoying something worth doing or enjoying, and that, too, something that we do or enjoy in common with others. We mean by it a power which each man exercises through the help or security given him by his fellow-men, and which he in turn helps to secure for them. . . If the ideal of true freedom is the maximum of power for all members of human society alike to make the best of themselves, we are right in refusing to ascribe the glory of freedom to a state in which the apparent elevation of the few is founded on the degradation of the many, and in ranking modern society, founded as it is on free industry, with all its confusion and ignorant licence and waste of effort, above the most splendid of ancient republics. (ibid., pp. 371–372)

A contract in which someone "bargains to work under conditions fatal to health" could not, in his view, be defended in the name of freedom since it was "an impediment to the general freedom," preventing the workers from making the best of themselves (ibid., p. 373). At the core of his argument was his assertion that the freedom to take a dangerous job, without even a right to compensation in the case of an accident, was simply not a freedom worth having. This was also the general viewpoint among workers, and it was therefore Thomas Knowles and other opponents of this "paternalist" legislation, rather than its proponents, who claimed to know better than the workers what their interests were. With the exception of marginal mavericks, the anti-paternalist argument against workplace safety regulations and workers' compensation is since long a historical phenomenon. (See Spurgin (2006) for a refutation of anti-paternalist argumentation for unsafe workplaces.)

Seat Belts

The seat belt was invented by the English engineer George Cayley (1773–1857), who intended it for use in airplanes. In aviation, the use of seat belts was uncontroversial from the very beginning. For instance, the very first aircraft of the US army, delivered by the Wright brothers in 1910, came with seat belts. From the beginning of commercial aviation traffic, passenger seats were provided with seat belts. In the US, the first government regulation requiring passenger seat belts went into force in 1926. The use of seat belts has continued to be uncontested in air traffic. Flight attendants asking passengers to buckle up are seldom met with negative reactions. In spite of the standard phrase "for your own safety" used in the safety announcements, airlines do not seem to be accused of being instruments of the "nanny state." In short, no one seems to demand the right to travel in an airplane without using a seat belt (Johannessen 1984; Vivoda and Eby 2011).

Already in 1885, seat belts could be found on some horse carriages. They were also used in racing cars as early as in 1922. However, the automobile industry did not equip their vehicles with belts. In the 1930s, physicians with experience of treating victims of automobile accidents started to advocate the mounting and use of seat belts in motor vehicles. However, not much happened until the 1950s, when designers developed safer and more convenient seat belts for cars. In the beginning, their constructions were largely based on the belts used in airplanes. In 1959, the Swedish engineer Nils Bohlin (1930–2002), who had a background in constructing ejection seats for airplanes, invented the three-point seat belt for cars. In the 1960s, more and more countries required all new cars to be equipped with seat belts, and car manufacturers started to include them as a standard (Johannessen 1984; Vivoda and Eby 2011).

In 1970, the Australian state Victoria adopted the first law making the use of seat belts mandatory (but only for drivers and front seat passengers). This was followed in the 1970s, 1980s, and 1990s by more and more countries. Today, the use of seat belts is mandatory in front seats in most countries, but many countries still do not require the use of belts in rear seats. In the beginning, considerable anti-paternalist resistance was mobilized against seat belt legislation. It was described as an infringement on liberty. For instance, one American opponent claimed that such legislation "violates the right to bodily privacy and self-control" of the drivers and passengers, and that it treated them in a "coercive, demeaning manner" (Solan 1986). The critics did not hesitate to oppose seat belt legislation for children. For instance, in a debate in the British parliament in 1988, the Conservative MP Gary Waller said that it "would be going too far" to require that parents refrain from driving more children in the car than there are belts for. He favored a noncompulsory approach and argued that "we should consider carefully whether a regulation is necessary or whether it would be better for advice to be given in the highway code, and for persuasion rather than compulsion to be exercised to ensure that children are carried in cars as safely as possible" (Waller 1988, cc. 591–598).

As seat belt laws have been introduced and enforced, this type of reaction has become increasingly uncommon. As Elvebakk (2015, p. 298) noted, opposition to obligatory seat belts is now "long forgotten in Europe." In 2019, two ethicists summarized the situation as follows:

> Within a few years, wearing seat belts became widely accepted and indeed endorsed in most countries. It became not only a legal, but also a social norm precisely because it was made compulsory and people started buckling up. . .

> As often happens, people simply get used to and comply with new legal requirements even when they are initially opposed to them, and in the long run they see it simply as a social norm. (Giubilini and Savulescu 2019, pp. 237–238 and 243)

This appears to be an accurate description of the general picture, although there are still a few people, both in politics and in academia, who oppose mandatory seat belt legislation (Solomon 2010; Flanigan 2017).

Helmets

Helmets have been worn by soldiers for at least four and a half millennia (Gabriel 2007, pp. xiv and 80). There does not seem to have been any uproar or mutinies against orders to wear protective headgear on the battlefield.

In 1917, the US Navy provided workers in shipyards with hard hats to protect them from falling objects. In the early 1930s, some construction workers used homemade hard hats for the same purpose, whereas others used surplus WW1 helmets provided by their trade union. The Golden Gate Bridge in San Francisco, built in 1933 to 1937, seems to have been the first major construction workplace where the employer provided helmets to all workers and made their use mandatory. Advertisements from the 1930s onwards for helmets of different shapes and materials show that there was a demand for protective headgear (Snell 2018; Rosenberg and Levenstein 2010). Although some individual workers found hard hats uncomfortable, there does not seem to have been any ideological or organized resistance, and their use is now undisputed on construction sites and other workplaces with risks of head injuries. The requirement to wear them is seldom questioned, or as two researchers on occupational safety wrote:

> Hard hats are different from other forms of P[ersonal] P[rotective] E[quipment]; people wear them even when they don't need to. There is no compliance issue with hard hats. They're cool. (Rosenberg and Levenstein 2010, p. 240)

The first motorcycle helmet seems to have been constructed by the English physician Eric Gardner. It was used for the first time in a race on the Isle of Man in 1914. After the race, Dr. Gardner received the following message from a colleague: "Every year the humdrum of medical practice in the Isle of Man is relieved by interesting concussion cases in our hospital from the Tourist Trophy Race; this year, thanks to your damned helmet, we have had none." (Gardner 1941) In the inter-war period, motorcycle helmets seem to have been used on racetracks but not much on roads.

In 1939, the Australian-British neurologist Hugh Cairns (1896–1952) started to work with brain-injured WW2 soldiers. Many of them were military motorcycle messengers. After studying their injuries, he emphatically proposed "for all motorcyclists, civilians and fighting Forces alike, the use of a crash helmet of the type worn by racing motor-cyclists" (Cairns 1941, p. 466). Following his advice, both the Army and the Air Force provided all their motorcyclists with helmets, which they were required to use (Lanska 2009). This initiative seems to have been well received by the motorcyclists themselves. Cairns wrote:

> When we began to treat Army motor-cyclists at [a military hospital in] Oxford, we naturally got to know their comrades—keen motor-cyclists in the Army Training Schools, Royal Corps of Signals, and other units, who were very much alive to the wastage of their man-power from accidents, and they needed little encouragement to become enthusiastic advocates of compulsory use of crash helmets. (Cairns 1946, p. 322)

Summing up his work after the war, Cairns wrote:

> From these experiences there can be little doubt that adoption of a crash helmet as standard wear by all civilian motor-cyclists would result in considerable saving of life, working time, and the time of the hospitals. (Cairns 1946, p. 323)

After the war, motorcycle helmets were probably more common than before, and much improved helmets reached the market. However, a large number of motorcyclists continued to ride unprotected. This was changed through political decisions. During the period when seat belts became mandatory in country after country, motorcycle helmets also became mandatory (but often somewhat later than seat belts). Currently, motorcycle helmets are obligatory almost everywhere in the world, except in the US (https://apps.who.int/gho/data/view.main.51427. Accessed April 9, 2020).

In 1977, all but a handful states in the US had mandatory helmet laws that applied to all riders. However, there was considerable resistance from an active anti-helmet lobby, whose anti-paternalistic message appealed to Conservative and Libertarian lawmakers. In consequence, several states rescinded their helmet laws or weakened them to apply only to teenage drivers. In 1995, Congress repealed the federal legislation that had incentivized states to uphold the helmet requirement. This led to an avalanche of revocations of state laws (Jones and Bayer 2007). At the time of writing (2020), only 19 states and the District of Columbia have universal helmet laws (https://www.iihs.org/topics/motorcycles. Accessed April 9, 2020).

Just like motorcycle helmets, bicycle helmets protect efficiently against severe brain damage and fatalities that may result from cycling accidents. In bicycle sport, a minority of riders have used helmets at least since the 1950s, and helmets became much more common in the 1990s. They became obligatory in 2003 (https://web.archive.org/web/20160304110024/ http://oldsite.uci.ch/english/news/news_2002/20030502i_comm.htm. Accessed April 9, 2020.). In the 1970s, a small minority of non-racing (transportational and recreational) cyclists began to use helmets, and a few companies sold helmets intended specifically for cycling. Standards were adopted, and helmets satisfying the standards were designed. In Victoria (Australia), helmet promotion activities led up to the introduction of a law in 1990 that made helmets mandatory for all cyclists (Cameron et al. 1994). The other Australian states have followed suit, and universal helmet laws have also been adopted in New Zealand and Argentina. Some other countries have made helmets mandatory only for children, but still in 2020, most countries have no legislation requiring the use of bicycle helmets.

Ice hockey has been played since the late nineteenth century. It is a sport with many head injuries, but up till and through the 1950s, almost no player ever used a helmet or any other type of head or face protection. This was much due to a "culture of toughness" that led players to view injuries as a part of the sport, which one had to endure. In the 1960s, the major hockey organizations introduced obligatory helmets for youth players. In 1979, the National Hockey League made helmets obligatory for professional players (with an exemption for older players, who were allowed to continue playing without a helmet). Helmets are now an uncontroversial part of the equipment of hockey players, and there is no sign that players crave for playing without them (Bachynski 2012).

Drunk Driving

Patricia Waller has described the attitudes to drunk driving that still prevailed in many countries in the 1970s:

> Drunk driving was considered more or less a "folk crime," almost a rite of passage for young males. Most adults in the United States used alcohol, and most of them, at some point, drove after doing so. This is not to say that they drove drunk, but many of them undoubtedly drove when they were somewhat impaired. Although the law provided for fairly harsh penalties, they were rarely applied. Upon arraignment, defendants would ask for a jury trial, and because drinking and driving was so widespread, juries almost invariably acquitted the defendant, thinking, "There but for the grace of God go I." (Waller 2001, p. 3)

Writing in 2001, she noted that "[r]emarkable progress has been made" (ibid., p. 4). This would not have been possible without the convincing data produced by the research community, she said, but another contribution was at least as important:

> It was citizen action groups that provided the impetus for major changes in public policy governing drinking and driving. Their activities generated public support for enforcement of existing laws and enactment of new ones. (Waller 2001, p. 3)

Particularly in the 1980s, activist groups changed the focus of the discussion from the drivers to the victims, not least children (Williams 2006). As emphasized by Leonard Evans (1991, p. 352), "the most important factor was the widespread serious discussion of the tragic dimension of the problem in the media, with the consequent deglamorizing of the drunk as a likeable humorous character."

A few contrary voices have been heard. In 1994, a philosopher published a journal article in which he claimed that drunk driving is not a serious offense. As an alternative to preventing drunk driving he proposed the removal of roadside trees, which are the "most commonly struck objects" by drunk drivers, as well as the introduction of airbags, which "would make drunk driving much less risky" (Husak 1994, p. 68). As late as in 2011, a major libertarian magazine in the US published an article describing the prohibition of drunk driving as "nanny state" legislation. The author claimed, incorrectly, that "[e]xperienced drinkers" differ from less experienced ones in that they "can function relatively normally with a B[lood] A[lcohol] C[ontent] at or above the legal threshold." He used this as an argument for entirely "repealing drunk driving laws" so that a drunk person should be allowed to drive unless he is "violating road rules or causing an accident" (Balko 2011). However, in experiments with driving simulators, heavy ("experienced") drinkers did not perform better under the influence of alcohol than unexperienced drinkers (Marczinski and Fillmore 2009; Fell and Voas 2014).

Today it is difficult to defend drunk driving in public. In some countries, opponents of efficiently enforced drunk driving laws have instead turned against the means of enforcement, for instance, claiming that random sobriety checks on the roads (sobriety checkpoints) are an unbearable infringement of the liberty of drivers. In Australia, activists working for the introduction of random breath testing found themselves opposed by "the alcohol industry and its supporters, notably civil libertarians and anti-nanny state proponents," who claimed that this would be an infringement on individual freedom (Howat et al. 1992, p. 20). One American legal scholar described this method of law enforcement as "[f]ascist-like sobriety checkpoints" (Miller 1993, p. 174). This argumentation has not been without success; in several states in the US the police are not allowed to perform random sobriety checks (Fell et al. 2004; Vissing 2014).

In the 1990s, a reliable method to prevent drunk driving was introduced in the form of alcohol interlocks (breath alcohol ignition interlock devices). Currently available technology requires the driver to provide a breath sample prior to starting the vehicle (and usually also at random times when driving, to prevent the use of another person's exhalation air). Ongoing research aims at obtaining the same result without a breath sample – either through analysis of the driver's normal exhalations or by measuring blood alcohol levels noninvasively with infrared light directed at the driver's fingertips (https://www.dadss.org. Accessed 10 April 2020.). In a large number of countries as well as all states in the US, courts can order convicted drunken drivers to install alcohol interlocks in their cars, as a means to prevent repeat offence. In 2005, the Swedish (social democratic) government announced a coming bill that would make alcohol interlocks mandatory in new cars by 2012. However, the new (conservative) government that entered office after the general election in 2006 decided not to go forward with the legislation, and since then there has not been a political majority for the measure (Grill and Nihlén Fahlquist 2012).

As yet, there does not seem to be much resistance against alcohol interlocks. That may be because their current use has the effect of increasing the automotive freedom of convicted drunk drivers. By installing the alcolock, they can keep or regain their driver's license, which they would otherwise have lost. However, it is plausible that proposals to introduce breathalyzers in all motor vehicles can give rise to counter-reactions of the same types that we have seen against laws mandating seat belts and motorcycle helmets. In 2019, the European Union announced plans to require all new cars from 2022 to be technically prepared for easy installation of alcohol interlocks. This will facilitate later installation of interlocks if the driver is convicted of drunk driving, or chooses to mount an interlock for other reasons (such as, possibly, a future tax reduction for those who do so). It will of course also simplify any future decision to make alcohol interlocks obligatory. This latter possibility was keenly observed by a conservative motorist organization in the US, the National Motorists Association (NMA). In one of their newsletters, they first criticized other safety features mandated in Europe, such as advanced emergency braking systems (AEBS) and systems that warn a driver who gets drowsy. They continued:

> The other mandatory element that is problematic: Every new car would include an alcohol interlock installation facilitation. The driver's blood alcohol content could potentially be checked by breathalyzer or by tactile sensors. The mandate would mean no driver could start a car without passing the electronic testing... Vision Zero proponents want to rein in irresponsible, that is, all (in their minds) motorists by literally limiting speed, choice, privacy and personal responsibility. The war on cars and on drivers is heating up. (National Motorists Association 2019)

Speeding

It was known long before the introduction of the modern automobile that high speed increases the risk of accidents involving vehicles. The oldest speed limit on record seems to be a regulation that was passed in Newport, Rhode Island, in 1678, forbidding horse-riders to "gallop or to run speed" in the streets. In Boston in 1757, carriages were limited to "foot pace" on Sundays to protect church visitors. The first speed limit referring to an exact velocity was probably the legislation passed in Britain in 1865 for steam carriages on highroads, which were limited to at most 4 mph (6 km/h). In the early twentieth century, many countries introduced speed limits for automobiles, often with different velocities for different kinds of roads (Elston 1971, pp. 21–22). This was "a time when motorists were in the minority and unpopular" (Tripp 1928, p. 535), and judging by articles in the newspapers at the time, there was considerable public support for these restrictions. In 1907, the American magazine *Harper's Weekly* published an article about "speed mania," describing the perpetrators as follows:

> [I]n every case their mania arises from an overweening sense of their own importance, accompanied by very slight capacity for self-restraint. The type of man who motors at dangerous speed is the same type that speculates in more stocks than he is able to carry, eats and drinks more than he can assimilate, covers himself with gaudy jewels, makes an objectionable exhibition of himself on every possible occasion. The strong arm of the law is the only effective curb for this species. . . (Underwood 1907)

In contrast, "[a] decent regard for the safety of mankind will always preserve the normal man from giving way to speed mania" (ibid.). It did not take long before motorists started to strike back. In 1911, the Automobile Club of America demanded that "all speed limitations should be omitted from the law," for the somewhat curious reason that "no matter what the limit is, the majority of drivers will try to exceed it."

They did however emphasize that “[c]areful driving” should be enforced (Dorrian 1911).

Speeding continues to be a major factor contributing to the prevalence and severity of road traffic accidents (Farmer 2017; de Bellis et al. 2018). Cavalier attitudes to the dangers of speeding are perpetuated by widespread and entrenched myths such as “a general belief that speeding slightly in excess of the limit (up to at least 5 km/h, perhaps as much as 10 km/h) is not associated with increased crash risk if the driver is otherwise driving safely” (Delaney et al. 2005b, p. 23). A Swedish writer who obviously believed in this myth claimed that speed limits are a form of “collective punishment” in order to solve the problem with “those who do not manage reasonably safe” at higher speeds (Eberhard 2006, p. 291).

Speed cameras, which have been introduced throughout the world since the 1970s, have met with considerable resistance. The experiences reported from an Australian speed camera program appear to be typical:

> As the speed camera program expanded in 2001 and lower speeds over the limit were targeted, various controversies came to the fore and had high public profile. These included the notions that the program was established principally to raise revenue for the government (fine money goes to consolidated government revenue), that camera locations included those where it was “safe” to speed, that overt operation of cameras was most appropriate if the aim was to deter speeders at unsafe locations, that exceeding the speed limit by only a small amount was safe, that there was no opportunity afforded to explain the circumstances of the event, and that the reliability of cameras and speedometers came into doubt when the tolerance was perceived to be only about 3 km/h (1.9 mi/h) above the speed limit. (Delaney et al. 2005a, p. 408)

This is a long list of complaints, but interestingly, it does not contain any clear anti-paternalist or “nanny state” argumentation. In Britain around the year 2000, resistance to speed cameras was even more outspoken and active than in Australia, but the argumentation was about the same (Pilkington 2003). Even the clandestine organization Motorists Against Detection (MAD), which claimed to have destroyed 600 speed cameras, justified their activities by claiming that the real purpose of the cameras was to collect speeding fines for the government (Chancellor 2003). Speed cameras are still vandalized in many countries (Max 2019; Robinson 2019). In summary, there are people who hate speed cameras so intensely that they go to the extreme of vandalizing them, but they do not usually invoke anti-paternalist arguments to justify their opinions or their actions.

Speed control can be taken to a new level with Intelligent Speed Adaptation (ISA), i.e., a system that keeps track of the speed limit where the car is driven and relates it to the actual speed. ISA systems can be either passive or active. A passive system warns the driver, whereas an active system reduces the speed to the legal limit (possibly with an option for the driver to override the system). Active ISA systems (speed limiters) have been predicted to drastically reduce the number of fatalities in road traffic (Carsten and Tateb 2005). Based on this, a strong moral argument can be made in favor of making active ISA obligatory (Hansson 2014, p. 373; Smids 2018). However, several studies indicate that drivers’ willingness to install and use such a system is low (Fu et al. 2020). Numerous newspaper articles describe speed limiters as an entrance gate to the "nanny state" (e.g., Mowat 2019). A Canadian truck-driver who had been ordered to use a speed limiter went to court, arguing that this order infringed on his freedom (Nyholm and Smids 2020). Although he lost his case, this indicates that the introduction of automatic speed adaptation can lead to a clash between traffic safety objectives and strongly felt anti-paternalistic sentiments.

Conclusions

Summing up the above, we have studied quite a few examples of legal requirements and mandatory practices that can be said to reduce the freedom of choice of individuals in some way or other. We can classify them in three main categories. The first category consists of *uncontested restrictions*, i.e., restrictions in liberty or freedom of choice that have never encountered significant ideological or organized opposition:

- helmets in the military
- seat belts in airplanes
- helmets in motorcycle racing
- helmets on construction workplaces
- alcohol interlocks for convicted drunk drivers

These examples have somewhat different backgrounds. Soldiers have been ordered to wear helmets since ancient times, and no one seems have come up with the idea of accusing their commanders of thereby restricting the soldiers' liberty, or freedom of choice.

Seat belts were mounted on passenger airplanes from the beginning of commercial aviation (at a time when flights were much more shaky than today), and today their use is an entrenched habit, which no one seems to put in question. They are just one of a large number of safety arrangements that we take for granted without thinking much about them. To see how common and how generally accepted such arrangements are, let us suppose that you try to avoid them. Suppose that you go to a household appliances store and look for a microwave oven that can emit microwaves when the lid is open. You will be told that no such ovens are made. If you go to the hardware store and look for power tools with uncovered live electrical parts, you will be equally disappointed. All the power tools on sale have sturdy protective shields to keep the user safe from electric shocks. Next, you go to an auto glass shop in order to have the cracked windshield of your car replaced. You want a windshield of common inexpensive window glass, instead of the expensive laminated safety glass that you are offered. "I am sorry," says the repairman, "but all windshields are made of laminated glass."

What has happened? Has the nanny state invaded the shops and stopped them from providing the articles you asked for? Yes, in a sense it has, since there are (in most countries) regulations enforcing safety standards for microwave ovens, power tools, windshields, and a myriad of other products. However, even in the absence of such regulations, it is much to be doubted whether any of the articles you asked for would be manufactured, or whether, if they were made, anyone would buy them. No one seems to care for the liberty to avail themselves of such products. And similarly, no one seems to ask for the liberty of remaining unbelted in an aircraft during take-off or landing. In fact, few would even care to know if it is the government, the airline, or perhaps some international aviation organization that decided that we all have to use a safety belt onboard.

The last three examples in this group differ from airplane seat belts in having been introduced as a new practice in an existing activity. Motorcycle racing and construction work were originally performed without helmets. The protective headgear was introduced without any ideological or organized opposition. Similarly, in-car breathalizers for convicted drunk drivers were introduced without resistance.

Our second major category consists of *previously contested* restrictions in liberties and freedom of choice that are now generally accepted:

- clean water and hygienic treatment of sewage
- employer's responsibility for safe workplaces
- seat belts in cars (in most countries)
- helmets in ice hockey
- prohibition of drunk driving

There have been days when fervent campaigners fought for the liberty to forgo modern sanitation, to work in extremely dangerous mines (or rather, to hire others to do so), to drive drunk, and to play ice hockey without helmets. Today, no one (with the possible exception of a few eccentrics) propagates these standpoints, for the simple reason that desires to exercise these liberties are no longer considered to be reasonable or worth supporting. The same is now, in most countries, true of desires to travel without seat belts in motorcars. This means, for instance, that hockey helmets are now equally uncontroversial on the ice rink as hard hats on the construction site. Notably, in all these cases, the transition has been gradual, and it has been accomplished by activists concerned about other people's health and safety.

Our third and final category contains the *currently contested* restrictions in liberties and freedom of choice. These are the practices that encounter significant ideological or organized resistance:

- motorcycle helmets on roads
- bicycle helmets
- universal alcohol interlocks
- speed cameras
- speed limiters in cars

Judging by the historical experience, some of these practices may in the future find their way into the second category. For instance, in countries such as Sweden, motorcycle helmets seem to be at a rather late stage in that process. However, this is not a transition that can be taken for granted. Vaccination belongs to this third category. It has remained contested for more than two centuries, despite its tremendous contributions to public health (Meyer and Reiter 2004).

At least four important conclusions can be drawn from this résumé of uncontested, previously contested, and currently contested infringements on liberty. First, *some but far from all restrictions of individual liberties are at all contested, and over time, there are large changes in what restrictions are contested.* We saw this clearly in the discussion of the second category (previously contested).

Secondly, *which restrictions are contested has very little to do with the distinction between paternalistic and non-paternalistic constraints on liberty.* Some of the most passionately opposed restrictions cannot with any vestige of credibility be described as paternalistic. This applies, for instance, to prohibition of drunk driving, as well as speed cameras and speed limiters. On the other hand, some of the restrictions that have encountered little or no opposition are commonly considered to be paternalistic. This includes seat belts in airplanes and hard hats in the building industry.

Thirdly, *we accept restrictions more easily if we encounter them in situations where we are accustomed to do as we are instructed.* This goes a long way towards explaining why helmets have been accepted in armies and on workplaces, as well as – after some initial opposition – in organized sport activities, where directives from referees and coaches have to be followed (Bachynski 2012).

Fourthly and finally, *we are less prone to accept restrictions if they require changes in our entrenched habits.* This seems to have been an important factor in resistance to several safety measures in road traffic, such as seat belts, helmets, sobriety, and reduced speed. As a corollary, we can expect restrictions to encounter little opposition if they are introduced from the beginning in a new activity (e.g., seat belts in airplanes). Habits also seem to have a role when previously disputed restrictions gain acceptance. For instance, seat belt laws induced law-biding people to buckle up. This became a habit – the “new normal” – and habituation to this convenient and well-justified routine appears to have led to its acceptance (Boughton 1984, p. 187).

Seen in this perspective, many of the issues that have been depicted as conflicts between paternalism and anti-paternalism are in fact largely fought along other – no less important – conflict lines, such as that between one person’s freedom and other persons’ safety. However, this does not imply that the issue of paternalism is irrelevant. In the next section we are going to have a close look at the scope of anti-paternalist arguments.

The Significance of Human Connectedness

The purpose of anti-paternalism is to protect everyone’s right to make and follow her own choices in matters that only concern herself and nobody else. Therefore, the scope and importance of anti-paternalism depends on what types of situations there are that answer to that description.

Obviously, there are many choices that only concern the person who makes them. This includes many of the liberties we have in private life. The color of my coat, what books I read, what furniture I buy (if I can afford it and I live alone) are under normal circumstances nobody else's business, and these are only a few of the many liberties that we should all have. There are also many liberties that we should all have, although our exercise of them can have large impact on others; this includes the political liberties of democracy. However, many of the allegedly private actions that have been at focus in discussions on paternalism are not as unconnected to other people's lives as they have often been claimed to be. This, as we will see, can have considerable impact on the scope and strength of anti-paternalist arguments.

Some discussions of liberty give the impression that we humans are rational atoms, each with her own, individually chosen, goals, and with no other obligations to each other than to avoid colliding when we follow our chosen trajectories in the huge space of possibilities. But this is not a true picture of human life. To the contrary, we are all bound to each other in innumerable ways, and no one can reach very far without the – past or present, willing or unwilling, intended or unintended – actions by others. Sometimes this interdependence is hidden from us, and sometimes we prefer to see it as an unchangeable background, like the mountains and the seas. But that is an illusion. Almost everything we do connects us with other human beings.

This interdependence is reciprocal, which means that it goes in two directions. On the one hand, the choices and decisions that we make are far less individual than what we tend to believe, and much more co-determined by others. On the other hand, our actions have effects on others, effects that we are often not aware of. Both these aspects of our social interdependence have important moral implications, not least for the scope and applicability of anti-paternalist arguments. Let us begin with the first of them.

Combined Causes and Extended Anti-paternalism

The causality of human actions is much more complex than what we usually think (► Chap. 5, "Responsibility in Road Traffic"). Most of the actions that we ascribe to a single person do in fact depend on the combined actions of many persons (sometimes acting at different points in time). In a discussion on paternalism, we have reason to apply this insight in particular to self-harming actions, or more generally, actions that go against the interests of the person who performs them. (There are of course many cases in which it is impossible to determine univocally what goes against a person's interests and what does not. For our present purpose, we can leave such cases aside.) In many cases when we talk of a person as harming herself, or acting against her own interests, others have made choices and taken actions without which the self-harm would not have been possible:

- *A drug addict harms herself by buying addictive drugs that destroys her health.*
  This would not have been possible without drug dealers who choose to sell products that havoc the health and the lives of most of the people who use them.

- *A smoker harms her own health by smoking cigarettes.*
  This would not have been possible without the cigarette companies that have chosen to sell and aggressively market products that kill about half of the people who use them.
- *A cyclist rides to work on a dangerous road among cars and trucks driving at high speed.*
  This would not have happened if the road authorities had arranged a separate bicycle lane.
- *A motorist drives without a seat belt.*
  In the vast majority of cases, she would have fastened the seat belt if the manufacturer had equipped the car with a seat belt reminder.
- *A motorist drives at an excessively high speed on the expressway, endangering both her own life and that of others.*
  This would not have happened if the manufacturer had installed a speed limiter making it impossible to drive the car at speeds at which it cannot be controlled.

These are all cases of "mixed" causality, in which harm to a person is caused by a combination of her own actions and actions by others. In such cases, the causal role of the others is often downplayed, and the action is described as purely self-harming. For instance, the drug dealer is sure to claim that "it was her own decision to buy the drug" and "if I hadn't sold it to her, then someone else would have done so." (For a discussion of responsibility ascriptions in such cases, see Hansson (▶ Chap. 5, "Responsibility in Road Traffic").)

Anti-paternalism, properly speaking, defends a person's right to harm herself. From such a right it does not follow that others have a right to harm her, or to contribute to harming her. However, attempts have often been made to extend the "green light of liberty" that anti-paternalism bestows on self-harming actions to other-harming actions by others that contribute to the same harm. One of the most remarkable examples of this is the argumentation of the tobacco industry. This is an industry with a long and still on-going record of aggressively marketing massively death-bringing products. For instance, in three decades, the 1970s to 1990s, tobacco companies focused disproportionately large resources on areas in American big cities with predominantly African American residents. They distributed free cigarettes in the streets, and focused particularly on what they called the "starter market," i.e., new smokers, mostly minors. These marketing activities led to a considerable increase in smoking among Afroamericans. One of the consequences of this was that the prevalence of lung cancer among black men, which had previously been lower than among white men, rose to levels higher than those among white men (Yerger et al. 2007). This is only one of many examples of the decisive impact that marketing and propaganda has on smoking. However, the tobacco industry spends considerable efforts on describing smoking as depending exclusively on the smokers' own free decisions, claiming, for instance, that "the growing intrusion of government in the lives of adult smokers is a threat to the freedoms of all citizens" (Katz 2005, p. ii33. Cf: Cardador et al. 1995; Apollonio and Bero 2007; Schneider and Glantz 2008; Fallin et al. 2014). With these campaigns they try two achieve two results: First, they try to attribute smoking entirely to the individual smoker's decision. They have been remarkably successful in promoting this rather obvious fallacy. For instance, in a book published in 2006, a Swedish physician (!) ridiculed lung cancer patients who sued tobacco companies, claiming that these plaintiffs professed "not to know that it was dangerous to smoke" (Eberhard 2006, p. 313). Secondly, by appealing to anti-paternalism on behalf of the smokers, they try to ensure that anti-paternalism also protects their own, massively other-harming, activities.

This is an extreme example, but the same pattern of thought can be found in many other contexts where anti-paternalism is invoked to protect other-harming actions. But how valid is this type of argument? If anti-paternalism protects my right to drink so much that I am unable to walk home, does it also absolve the publican who serves me that much liquor? If anti-paternalism allows me to eat food with toxic mold or pesticide residues, does it also acquit the food industry or my grocer for selling such food (properly labeled) to me? If anti-paternalism lets me ride a motor-cycle without a helmet, does it also exonerate the rental agency that rents out a motorbike to me without including a helmet in the rental? And if it permits me to drive a car without a seat belt, does it also condone a carmaker who refrains from mounting a seat belt reminder as standard equipment?

The general issue illustrated in these examples is that of *extended anti-paternalism*, by which is meant the use of anti-paternalist arguments to justify actions or activities that harm (consenting) others, usually in combination with self-harming actions or decisions by the persons in question. The term "extended anti-paternalism" was introduced in Hansson (2005). In the literature on paternalism, the distinction between anti-paternalism in the proper sense and this extension has usually not been made. Authors who observed the distinction, or some variant of it, have usually not made much of it (Mill (1977 [1859], pp. 296–299; Dworkin 1972, pp. 67–68; Dworkin 2020, Sect. 2.4; Feinberg 1986, pp. 9–11; Schramme 2015).

From a logical point of view, it is obvious that a right to harm oneself does not imply a right to harm consenting others or to facilitate or contribute to their self-harming activities. But logic alone cannot tell us if it is reasonable to extend anti-paternalism in this way. That is a moral question, and it has to be discussed in terms of moral principles. We can approach this moral issue by first reminding ourselves of how we deal with it in private life. What moral attitudes do we usually have to the combined effects on a person of actions by herself and actions performed by others? It does not take much reflection to see that this depends on the nature of the combined effect.

We are at liberty to do many things that are presumed to have a positive value. For instance, suppose that you have a friend who likes to read books. We would normally see it as not only allowed, but also commendable, to help her to exert that liberty, for instance, by picking up books at the library for her or recommending her books that she might like. We also see it as positive if (commercial or nonprofit) services, such as bookshops, libraries, and reading groups, are available for her and others wishing to exert this liberty. The same applies to a multitude of other activities that people are at liberty to perform, and which we presume to have predominantly positive effects on the well-being of those who choose them. This is how we usually perceive actions that help people to exert their liberties.

But there are also liberties that are endorsed per se (for the sake of liberty as such), rather than for any positive effects of realizing them. Liberties to harm oneself belong to this category. In private life, helping others to harm themselves is usually held to be morally misguided, if not outright wrong. Suppose that your neighbor has the unusual obsession of burning small scars on his body with a burning glass. This action is presumably not illegal, and neither do we tend to morally condemn it. (On what grounds could we condemn it, and of what use would it be to do so?) Let us assume that we take an anti-paternalist position to this activity; in other words we consider it to be a form of self-harm that he is at liberty to perform, and which we have no right to prevent him from. Is it then reasonable to augment our anti-paternalism in this case to extended anti-paternalism? In other words: Is it morally allowable to help him by holding the burning glass over his back so that he can get scars there as well? Is it OK to recommend him a stronger burning-glass, or buy one for him? And if he becomes an Internet celebrity and attracts followers burning scars into their own skins, is it good business ethics to produce and market "scar burners," specially adapted to the purpose?

The obvious answer to all these questions is "no." In private life, morality requires that we care for other people, and doing so is not compatible with encouraging or helping them to harm themselves, or even with looking the other way when they do so. The morally laudable reaction to his burning obsession would be to try to help him: talk to him about why he does it and what could to make him stop, find ways to help him break the habit, perhaps find a psychiatrist who can help him.

The example is unusual, but it illustrates how we usually react to clear examples of self-harming activities when we encounter them in our private lives: Instead of contributing to other people's self-harm, we try to help them out of it. We do not praise those who buy liquor to the alcoholic, emetics to the bulimic, or poison to the depressed and suicidal friend. Instead, we praise those who try to make them change their minds and develop more positive thoughts and habits. Extended anti-paternalism does not work in our everyday lives. Empathy and care do.

This insight can also be applied on a larger social scale, in discussions about what communities, organizations, companies, and governments should do. By breaking up the false inference from anti-paternalism to extended anti-paternalism, we open up for a more efficient strategy to promote safety and public health. Such a strategy should actively prevent the exploitation of self-harming action. This includes, for instance, effective curtailment of the pathogenic activities of tobacco companies. Instead of blaming each other for dangerous and self-destructive behavior, we should make our society and the options it offers less dangerous. This is the approach that has been applied for more than a century in occupational safety, with considerable success. Instead of admonishing workers not to put their fingers into the press machine, the employer installs a machine that does not move unless both hands are in safe places. If this approach was ever criticized for being paternalistic, then that criticism is long since forgotten. Applying it in road traffic would mean to ensure that vehicles and the road system are so constructed that self- and other-harming activities on the road, such as speeding, driving drunk or on the wrong lane, are technically impossible. This, by the way, is a large part of what Vision Zero is all about.

Herd Effects: How We All Influence Each Other

In the discussion on paternalism in public health, it has often been pointed out that many activities that seem to be “pure self-harm” with no effect on others do in fact have significant impact on others than the person who exposes herself to a harm or risk. An unbelted back seat passenger can become a projectile in the event of a crash, and injure or even kill front seat occupants. This effect is surprisingly large; according to one study, the risk for a belted driver or front seat passenger to die in a crash increases almost fivefold if she has an unbelted passenger behind her on a rear seat (Ichikawa et al. 2002). Psychological costs to bystanders who witness a deadly crash have also been mentioned, and should most certainly be taken seriously (Feinberg 1986, pp. 139–141). An even more serious concern is the suffering of family members: children who lose a parent and spouses who have to care for a seriously injured accident victim, or mourn the loss of their partner (McKenna 2007). The risk of making one’s children father- or motherless is probably an important consideration in many private discussions and deliberations. It was also discussed in the newspapers after the death of a female climber, the mother of two small children, in a descent from the summit of K2 in 1995 (Barnard 2002). However, it does not seem to have been much discussed in connection with accidents in road traffic such as the around 2000 unhelmeted motorcyclists who die on American roads every year, many of whom are sure to be parents (NHTSA 2019, p. 11). Arguments referring to the economic costs have had a more prominent role. They concern the costs of hospital care, rehabilitation, a future life in a nursing home, and subsistence for family members (Hundley et al. 2004). In some of the American states that allow unhelmeted motorcycling, unhelmeted riders are required to have an extra insurance to cover personal injuries (Langland-Orban and Flint 2011). Obviously, if these psychological, social, and economic costs of injuries and fatalities on the road are taken into account, then the common anti-paternalist argumentation against measures to improve traffic safety will lose almost all its bite.

However, arguably the most important reason why anti-paternalism cannot be applied to actions such as helmetless motorcycling has been absent from these discussions, namely, what I propose to call the *herd effects* of individual behavior. Many authors have provided what appears to be intended as a complete list of effects of helmetless motorcycling that anti-paternalism cannot legitimize, without mentioning herd effects (Schonsheck 1994, pp. 107–141; Camerer et al. 2003; de Marneffe 2006, pp. 82–83; Thaler and Sunstein 2008, pp. 232–233; Nolte et al. 2017).

Herd effects a rise because in almost all our decisions, we humans tend to follow the examples of others. This has been known for long. Already Julian of Eclanum (c.386-c.455) wrote about the “contagion of sin” (Barclift 1991, p. 14), and his contemporary John Chrysostom (c.349–407) strongly emphasized the positive side of this, namely, the importance of being a good example to others (Chrystostomus 1836, p. 788, c.1D). The concept of behavioral or social contagion was introduced into social science by the French scientist Gustave Le Bon (1841–1931). Today there is an extensive literature on how all kinds of human behavior is propagated in populations through our tendency to copy or imitate the behavior of others (Lehmann and Ahn 2018).

This applies not least to behaviors relevant to public health, such as smoking, drinking, substance abuse, and physical exercise (Christakis and Fowler 2013). There is also ample evidence of strong contagion effects on both the following and the breach of safety rules on workplaces (Liang et al. 2018; Liang and Zhang 2019). In road traffic, social contagion has a large role in creating a "culture of driving." An important study in the early 1990s showed that "drivers are sensitive to the influence of others and... that a small shift in the behavior of few can be amplified, through the interaction between individuals and their collectives, to a larger effect, resulting in a changed social environment or a modified 'culture of driving'" (Zaidel 1992, p. 585). Other studies have confirmed that drivers have a strong tendency to adapt to the prevailing speed pattern (Connolly and Åberg 1993; Edwards et al. 2014). There is also evidence of similar effects on risky pedestrian behavior McGhie et al. 2012).

Unusually clear evidence of social contagion has been found in those states in the US that replaced a law requiring all motorcyclists to carry a helmet by a law that only required this of young riders. In these states, large numbers of young riders chose not to use a helmet when they saw older riders riding helmetless. In Florida, the number of motorcycle fatalities among riders younger than 21 nearly tripled after the helmet law was downgraded in this way in 2000 (Bachynski 2012, p. 2216. Cf. Nolte et al. 2017). A group of public health researchers have pointed out that a similar effect can be expected for bicycle helmets:

> We also conjecture that by applying the [bicycle helmet] law to children but not adults we would encourage a "rite of passage" effect (much as happens with cigarette smoking), whereby older children abandoned helmets to signify their maturity. This perverse effect would subvert an explicit, if secondary, policy aim of making helmets compulsory for children, which is to encourage adults to adopt helmets in order to set an example without compromise to adults' legal liberty and moral autonomy. (Sheikh et al. 2004, p. 264)

These results put what seemed to be purely self-affecting decisions, such as whether or not to use a seat belt or a helmet, in an important, previously neglected, perspective, namely, that of how our actions influence other people's actions. We humans are not mental solitarians who make decisions and choices independently of each other. To the contrary, we are herd creatures. We all observe what others do, and we usually follow trends, in particular trends among people whom we feel akin to. If you speed, others will feel encouraged to do the same. If you use a bicycle helmet, then that can have a considerable influence on people whom you know, and it can also have a smaller influence on a larger number of people, namely, those who see you riding with the helmet.

Do these herd effects have any moral relevance? Do we have a moral obligation to behave in ways that give rise to positive rather than negative effects on our fellow beings? Or are these effects just byproducts of our actions and choices, for which we have no responsibility? I can see no reason to treat herd effects differently than other consequences of human action. In other words, they are morally relevant. This means that we are morally accountable for the foreseeable effects of the examples we set. It is morally blameworthy to set bad examples, for instance, by taking foolish risks to no avail, and it is morally praiseworthy to set good examples, for instance, by following safety rules and using protective equipment. This is not a new or original standpoint; presumably it has never been a highly esteemed conduct to drink oneself into a stupor or play dangerously with knives in the sight of children or adolescents. But apparently we need to be reminded that the same moral principles apply to many behaviors that have been considered protected by anti-paternalism.

A useful comparison can be made with another type of contagion, namely, infectious contagion. There are two reasons why you should take vaccinations against infections that threaten public health. First, vaccination protects your own health. Secondly, vaccination protects other people, since if you do not get the disease you will not spread it to others. This is particularly important for vulnerable people who cannot, for medical reasons, take the vaccine. For instance, vaccination against measles, a potentially deadly childhood disease, cannot be given to babies. Their only protection is herd immunity in the population, which is obtained when those who can take the vaccine do so. This means that vaccination is not just a personal matter, and consequently refusal to vaccinate is by no means protected by anti-paternalism. There are strong reasons to regard vaccination against diseases that threaten the community as a moral obligation (Jamrozik et al. 2016; Pierik 2018).

This is written during the Covid-19 pandemic in 2020, which has led to drastic measures all over the planet to contain the infection, including lockdowns and social distancing. The same reasons for these measures apply as for vaccination: You do this in order to protect yourself against the disease, but also to avoid spreading it to others. In this case, vulnerable, mostly elderly, people are most at risk, and they depend for their protection on the willingness of others to take the measures necessary to avoid contracting and spreading the disease.

Unfortunately, there is in both cases, vaccination and social distancing, a minority of people who either have not understood that the recommended measures are needed to protect others than themselves, or just do not care. We can call this the *Bolsonaro fallacy* after the Brazilian president Jair Bolsonaro who has flagrantly and defiantly violated the directives of his own administration to reduce the spread of Covid-19, with the justification "If I have got myself infected, so OK? Look, that is my responsibility, no one has anything to do with this." ("Se eu me contaminei, tá certo? Olha, isso é responsabilidade minha, ninguém tem nada a ver com isso." From an interview on March 16, 2020. Last accessed 14 April 2020 on https://www.youtube.com/watch?v=M0za8MSoO64&feature=youtu.be. At 6:58–7:02.)

This example provides a useful background for the moral appraisal of how we contribute to social contagion, which is no less a formidable force in society. The mechanisms through which our behaviors impact on those of others can be even more imperceptible than viruses and bacteria, but they are just as real. A motorcyclist who wears a helmet contributes to creating a culture, or social environment, in which helmets are an unquestioned part of motorcycling, just as hard hats are worn routinely on construction sites. A motorcyclist who refrains from using a helmet contributes, to the contrary, to maintaining or creating a social environment in which it is normal, perhaps even "tough" or "cool," to ride unhelmeted. The analogy with taking vaccines and complying with social distancing in times of an epidemic is obvious. The vaccine shot that you receive reduces the risk of contracting the disease by a small amount for each of the persons who could potentially be infected by you, and the sum of all these small amounts matters morally. Similarly, the helmet on your own head encourages others to do the same, thereby contributing to making wearing a helmet the normal and expected thing to do. Social contagion is just as real, just as unavoidable, and just as morally important, as infectious contagion.

For both social and infectious contagion, what matters is the sum of a large number of small effects. But in both cases, we can see from the sums that these effects are real. Countries with high vaccination rates are almost unaffected by diseases that have devastating effects in unprotected populations. And in countries like Sweden, where young people may never have seen an unhelmeted motorcyclist, the question of riding helmetless does not even arise. In neither case does the fact that each of the many small individual effects cannot be perceived make them morally irrelevant (Hansson 1999). Therefore, a motorcyclist who refrains from wearing a helmet, claiming that this concerns no one but herself, makes the same mistake as the vaccine refuser and the organizer of crowds in a pandemic, namely, the Bolsonaro fallacy.

Putting this more positively, the fact that we are so much influenced by each other is a reason to put more weight on the old but sometimes forgotten moral value – and moral imperative – of setting good rather than bad examples. Asking a person to use a helmet, or to fasten her seat belt, is not a meddlesome intrusion into her private life. It is an invitation to take part in a joint effort to create or maintain a custom that protects us all. It is for obvious reasons better if such customs can be achieved and preserved without the force of law. This is how ice hockey helmets were introduced. However, if this does not work, then we should not forget what we have governments and laws for. We certainly need them when children contract potentially life-threatening diseases due to adults' vaccine refusal, or when older bikers inspire teenagers to risk their lives by riding without a helmet.

Driver Assistance and Self-driving Cars

Vehicle technology is in a process of increasing automation. Modern cars have a whole set of driver assistance functions that reduce the risk or the severity of accidents: anti-lock braking systems, cruise control, lane departure warning systems, driver attention monitors, collision warning and automatic brake systems, etc. This began with systems that merely warn the driver, but increasingly, functions are introduced that take control of the car if the driver does not heed a serious warning, for instance, automatic braking to avoid a head-on collision or mitigate its effects. There does not seem to have been much opposition to these systems. This may be because they have been constructed not to reduce the driver's feeling of control in normal driving.

However, it does not follow from these experiences that fully automatic, self-driving cars will easily be accepted. As it now seems, autonomous vehicles will not be introduced, at least not on a large scale, until and unless they are far much safer than manually driven cars. We tend to be less willing to accept machine errors than errors made by human beings. Our tolerance for safety-critical malfunctions in cars is already low. Vehicles are recalled for repair even of faults that have a comparatively low probability of giving rise to injuries or fatalities. Occasionally, car manufacturers have refrained from recalls that they deemed too costly in relation to the gains in safety, but that led to strong negative reactions from the public (Smith 2017). Some authors have worried that a large number of avoidable fatalities and severe injuries will ensue if the introduction of autonomous vehicles is delayed by safety requirements that are inordinately high as compared to those applied to conventional vehicles (Brooks 2017; Hicks 2018, p. 67).

To the extent that automated vehicles run a smaller risk of crashes than humanly driven vehicles, there may be a movement towards relaxing safety measures such as the use of seat belts. Already in 2006, a year when more than 300 persons were killed in Swedish road traffic and around 9000 were injured, a Swedish physician (!) asked: "Do we even need the seat belts any more, now that the cars have become better?" (Eberhard 2006, p. 321) The answer to that question depends, of course, on your attitude to human death and suffering. Needless to say, less safe behavior by car occupants can at least partly offset the gains in safety obtainable with the new technology. Since no driver is needed, children can presumably travel alone in a self-driving car, and so can a company of severely inebriated persons. This can have consequences for occupant behavior. This means that questions about safety culture and how we influence each other's behavior will continue to be pertinent in automated vehicles.

In a traffic system with automated vehicles that are much safer than human-driven cars, questions may arise about the legitimacy of the latter. Proposals have already been made to prohibit human driving on at least parts of the road net (Nyholm and Smids 2020). This can surely meet with ardent resistance, since driving is a major source of pleasure and pride for many people (Edensor 2004; Moor 2016; Borenstein et al. 2019, p. 392). However, such conflicts can possibly be avoided if future human-driven cars are equipped with advanced assistive technology, including an emergency autopilot function that takes over in extreme cases when this is necessary to avoid a crash.

Some authors have maintained that human moral agency is in some way stymied by technology that reduces the risk of injuries or other adverse effects of human failures. These authors call such technology "techno-regulation" (Brownsword 2005) or "technology paternalism" (Spiekermann and Pallas 2006). Examples that have been used include automated entrance barriers at railway and metro stations (to prevent fare dodging) (Yeung 2011, p. 22), alcohol interlocks (Spiekermann and Pallas 2006, p. 10), and – of course – self-driving cars (Brownsword 2005, pp. 16 and 18). Roger Brownsword maintains that these technologies have a problem in common:

> When regulators design people, products, or places in such a way that regulatees have no choice but to act in whatever way is judged to be appropriate, we cannot meaningfully speak

> about them being morally responsible agents, to be credited with acts that respect others and to be blamed where they fall short of moral requirements. (Brownsword 2005, p. 18)

Similarly, Karen Yeung writes:

> Although an isolated techno-regulatory measure may appear benign, the *cumulative* effect of techno-regulatory action by a range of regulators acting independently across a variety of social contexts might ultimately lead to such a significant erosion of moral freedom that meaningful moral agency can no longer be sustained. (Yeung 2011, p. 27)

These arguments are based on an extremely one-sided selection of technological innovations. All through human history, technology and social arrangements have shifted in ways that have both created and closed down options for moral decision-making. New weapons have given rise to moral issues on when they could legitimately be used. Would it have been a disadvantage if weapons of mass destruction were not available, so that no one could exercise their moral agency by deciding (hopefully) not to use them? New means of food production have reduced the burden of deciding how to distribute food in times of famine. Would it have been better if there was even more scarcity of food so that more people could flourish as moral agents by distributing it rightfully? Technological devices, such as fences, locks, safes, and alarm systems have made burglary next to impossible in some places. Would it be preferable to ensure that all jewelry shops and bank vaults (and your home) have doors that are easy to force open, so that prospective burglars have ample opportunity to make virtuous decisions not to break in?

Arguably, these examples are sufficient to show the absurdity of valuing options for moral deliberation higher than the avoidance of human suffering. But it may nevertheless be of some interest to ask: Are these authors right in contending that modern technology, as a general tendency, removes moral choices and thereby moral agency from us humans? That is extremely difficult to determine, since examples pointing in both directions are easily found. Notably, the Internet as well as social media have given rise to a host of new moral issues that concern our private lives, information on climate change has put air travel in a new moral perspective, and environmental concerns have added moral aspects to our choices of foodstuff and other consumer products. This may very well add up to outweigh a potential reduction in the need for moral choices in road traffic.

In Conclusion: Vision Zero

Vision Zero has not been much mentioned in this chapter, but in a sense it has been all about Vision Zero. Questions about personal freedom and how we influence each other's behavior are central for the choice of a traffic safety strategy, and many of the differences between Vision Zero and previous road safety policies are closely connected with the issues we have penetrated. In at least three respects, the conclusions we have arrived at can serve as moral underpinnings of Vision Zero.

First, we found that some of the freedoms that were deeply cherished in former times, such as the freedoms to have "a little dirt" in your water pipes, to hire workers to work in mines with incessant rockfalls, or to drive drunk, are now considered by almost everyone as weird wishes, rather than worthy objects of liberty. This historical perspective shows that conceptions of what is normal and desirable can change. Vision Zero aims at one fundamental such change: Conditions and behaviors that lead to deaths and serious injuries in road traffic should no longer be seen as normal, or even acceptable.

Secondly, we noted that many habits and actions that are commonly conceived as "self-harming" are in fact the result of a combination of self-harming and other-harming actions. The smoker's own decision is only part of the causal history behind her unhealthy habit. Another, in fact quite crucial, part is the tobacco industry's ruthless promotion of a death-bringing product. Similarly, the motorist who speeds on the expressway is certainly to blame, but the reason why it is at all possible for him to do so is that the car manufacturer sells vehicles that can be driven at illegal speeds, and that the legislature allows this. This analysis shows that we need to consider the systemic causes behind events that have traditionally been ascribed exclusively to individual road users. This is one of the methodological cornerstones of Vision Zero.

Thirdly, we saw that traffic behavior is subject to strong effects of social contagion. For instance, people tend to wear seat belts and helmets if others do so, and to drive slower if others refrain from speeding. Therefore, safe traffic behavior is important not only for the direct effects of one's own actions, but also as a contribution to the creation of a safety culture that protects us all. This is the major reason why driving a motorcycle without a helmet is not a "purely self-harming" action; it unavoidably sets a negative example that contributes to enticing other bikers to do the same. This is a communal and socially inclusive perspective on traffic safety that has not had a large role in Vision Zero, but it can arguably contribute constructively to its implementation.

Cross-References

► Arguments Against Vision Zero: A Literature Review

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Part II

Vision Zero: An International Movement for Traffic Safety

7 Vision Zero: How It All Started

Claes Tingvall

Contents

Abstract

This is a presentation of how I remember the first steps of Vision Zero, the Swedish reorientation of traffic safety policy that took place from the mid-1990s and onwards. It is not an objective text that would be impossible to write as one of

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the initiators of the policy change. But it brings up some of the steps of the process and presents some hypotheses on how policy change might happen.

It is claimed that there was no planned process, not even an ideology or well-developed idea, behind VZ from the very beginning. But there were opportunities and events where one thing led to another. The most fundamental being the immediate acceptance from the Swedish Minister of Infrastructure back in January 1995.

The most prominent ideas behind VZ are that firstly safety is a matter of how the providers of the road transport system design and build and manage the system. The second idea is that a professional provider cannot trade off the citizens' life and health for benefits to the society and its citizens. The underlying hypothesis is that tradition and road traffic rules for the road users have been used as an excuse for not undertaking necessary system changes and modifications. The users have always been blamed for crashes and its consequences by the legal system as well as general approach from the society.

The last part of the paper reflects on what is necessary to do in the future to eradicate amateurism, populism, and trade-offs from the road traffic safety field. Maybe a "duty of care" legislation needs to be introduced, protecting the citizen from poor design and operations.

Keywords

Vision Zero · History · Ethics

Introduction

"Zero" was my answer to Lars Harms-Ringdahl when he asked me how many deaths would be the target for the design and development of our child restraints. Lars Harms-Ringdahl was a consultant that Folksam Insurance Group had hired to help with the quality management for the child restraint program Folksam had developed to protect children traveling in cars. Lars was a very competent consultant in safety management, and he knew what questions needed to be asked to the management. At this time I was responsible for the design and quality of the development of the child restraints, and the question asked by Lars was the first time for me. This was back in 1989, and I have been thinking of it since and asked myself the question if there was really any alternative to the answer I gave. I have come to the conclusion that I had no such alternative but that the analysis behind has deepened a lot. In 1989, I answered more from what my feeling said.

On January 26, 1995, I got the same question, but from the Minister of Infrastructure, Ines Uusmann. I had just taken up the position as Director of Traffic Safety, being recruited by the Director General at the Swedish Road Administration (STA). The whole management of STA was assembled to meet the Minister for her yearly visit to STA. The Minister had her staff with her, and she asked questions of different kind. She was also new to her job since September 1994. Her background was at least partly from occupational health and safety, something that should prove important for the story.

Her question was simply: “How many deaths should we have as our long-term target in Sweden?” My answer was the same as in 1989: “Zero!” I can still recall the feeling in the room. It was quiet – it was everyone waiting for the reaction from the Minister. I had said something that was completely against the culture of a road administration and against the transport politics in Sweden and against any policy expressed by any road administration and parliament across the world. Zero would mean that safety would stand above all other factors building up transport politics and priorities. This was completely against the trade-off paradigm.

The Minister reacted, against all odds, very positively and expressed that this would be something she would like to hear more about. Anyone used to the life inside the bureaucracy within a state government understand what this means. It means that as long as the Minister will stay in office, what she expressed is protected. Any other answer from here would have killed the idea and probably led to immediate resignation from my position.

I was naive, but I also knew the background of the Minister. So I made the comparison to the workplace, where there is a clear line of responsibility and a clear expression of that trade-off between the effectiveness and profitability of the operations versus the life and health of the employees, is not allowed. The road transport system with its long history of just blaming the victims should be questioned. And mobility would develop as a function of safety, as safety would form the boundary condition for mobility.

That evening, the Director General came to my room and said, not aggressively or in a threatening way, that: “I don’t expect a Director of Traffic Safety to stay any long time here if he talks about zero.” It was simply saying that this would be expected to happen with such a radical and “impossible” statement in a culture that clearly express that lacking safety and other negative aspects of the road transport system should be weighted against positive factors like mobility and improved economic activity. Safety investment should be cost-effective and carry its own merits to be given green light.

My insights in seeing the road transport system as a real system with interacting components came late. It was in the beginning of 1995, before the meeting with the Minister, that I happened to pass a meeting room, where a researcher that I had known for long presented a study of the effectiveness of roundabouts in comparison with traditional signalized or non-signalized intersections. The results were simply astonishing. The roundabout decreased the risk of a fatality for a car occupant with more than 90% in comparison with a conventional intersection. But the effectiveness on crashes with only minor injuries was small, if any. First of all, this meant that the action taken by the road infrastructure provider has a fundamental influence of safety in terms of fatalities and serious injuries. Secondly, it all came together in that it was the combination between the ability of crash protection from the car in combination with the typical speeds and angles at impact that generated the results, not the fact that there were fewer crashes. This is maybe the biggest eye-opener for me ever in my career in traffic safety. We have a system where humans, vehicles, infrastructure, and energy all come together and relate to the human tolerance to kinetic energy –

the perfect match. Without this approach I am sure I would not have any chance to survive the next months after the visit of the Minister. She accepted the political framework, but everyone would follow up with the question on how it would be possible in reality to improve traffic safety at a completely new scale.

The insights I got from the short visit in the meeting room dealing with roundabouts were my own. I am sure many others already had that insight, and I must say that I felt a bit shamed by myself, looking at my research career before this insight. It really marks a completely new era for me. The insights about responsibility and scientifically based solutions suddenly fitted.

So Where Is the Starting Point?

The insights led me and my team to a very fast development of thinking. Roger Johansson, Lars Stenborg (today Eriksson), and I started to express this development in writing. And I checked and got inspiration from my network, Maria Krafft, Anders Lie, and Anders Kullgren, all through the process. We did the following analysis.

We need to move from the “blame the victim” approach to road crashes and casualties. In short, this is a matter to move from the approach of backward-looking responsibility to forward-looking responsibility or from a juridical view on the human and his or her action before a crash to the system design and its role to protect the road user from being killed or seriously injured. In even more simple terms, it is a matter of protecting the road user from his or her own mistakes, misunderstanding, and even violation of traffic rules. The failing human must be the norm for all providers of the road transport system. “Errare humanum est” must be our first sentence. It is human to make mistakes, and we must design for the human as we are, not the perfect human that in reality does not exist.

Very early, this first step led us to the number zero, by deduction rather than only a target that sounds ambitious or even revolutionary. Our simple translation of moral philosophy told us that, while every individual human is free to take risks, or choose to use the road transport system or not, the responsibility that would fall on the provider of the system. There would essentially be no excuses for anyone’s loss of life and health. To have someone else’s life in your hands is something completely different than just your own life. This is why there is no alternative to zero, although someone could question if zero is possible. We stole the ethical imperative to always put life and health above anything else from Hippocrates and the ethical rules of the medical community.

Vision Zero was a way to compare the workplace, aviation or railway, nuclear power production, or other activities and systems in the community that handle potentially hazardous operations but where the individual human would expect an operation without weighing his or her life to the effectiveness or profitability of the system. An employer is not allowed to improve the effectiveness of the workplace by risking the life of the employee. While this happen in reality, rules and moral philosophy would not allow it.

Many have seen Vision Zero as a true vision, a target, or even a strategy. In fact, the expression is the notion of responsibility for the providers of the road transport system. This is why the expression “Vision” came a bit later than “Zero.”

The other step was to build a simple model of how to go about saving lives at a level never seen before by a national governmental body. Haddon had already shown the way! It was really kinetic energy that led to loss of lives and health. And to control, harness, reduce, cushion, or redirect harmful kinetic energy was the trick (Haddon 1970). It was just a matter of bringing all the components of "Haddon's matrix" together to form a system of protection and prevention. This had not been done before with the objective to eradicate the risk of death and loss of health. The starting point was the human tolerance to kinetic energy, and the end result was to have zero deaths and serious injuries – simple in theory, very complicated in practice.

One of the first misunderstandings was that we looked for "passive" solutions, in those days meaning crash protection and not crash avoidance. So the challenge was to describe prevention as a chain with numerous possibilities to stop the crash, change the crash, or mitigate the consequences of the crash.

The third step was to "develop" a number of proposed initiatives that would increase safety significantly. The main idea of these proposals was that they would be directed towards the providers, not the road users. The idea to first say that we as providers have an unlimited responsibility for human life and the turn to the public and tell them to behave better was considered impossible and even counterproductive. At the same time, it was essential to show what Vision Zero would mean in reality, and not just as nice words, to both politics and the public.

The Ethical Rules of a Road Transport System Provider

A new framework for responsibility, moving the main responsibility for future safety from the road users to the providers, is no doubt very challenging. And the challenge is not only structural, in what it would mean for road user rules, legislation, and democracy, but also from a moral point of view. Very early in the process, we noticed that many reacted to the expression "moving the responsibility from the road users to the system providers." In essence the reaction was moral: "maybe the citizens will start behaving without any sense of responsibility. . .?"

Our thoughts went more in the direction of "ethical rules" rather than new legislation. While legislation towards the providers might be an issue in the long run, our ideas were directed more towards the mindset of the ethical rules in medicine and health care or the guidelines for engineers. We came up with five ethical standpoints (Tingvall et al. 1996):

1. One must always do everything in one's power to prevent death or serious injuries.
2. The right action must always be taken from the very beginning, i.e., all action taken must rest on scientific, tried-tested experience.
3. The best-known solution must always be applied.
4. The factor that ultimately governs the decision to change a situation must be both the risk and potentially harmful effects of an existing situation.

5. Work must always be based on the fact that the responsibility for every death or loss of health in the road transport system rests with the person responsible for the design of the system.

While the original expressions above might not be optimal today, they would still be relevant. The first ethical “rule” reflects that safety cannot be traded off to mobility or any other benefit. The second is really that all actions must be evidence-based. The third is really that given the circumstances and available resources, the most effective solution must be chosen. The best example would be to apply a speed limit setting regime that would be based on safety.

The fourth “rule” would simply mean that both risk of a crash and its consequences should be in focus – this as a reminder that VZ is not a crash protection policy, but an injury prevention policy.

The fifth “rule” is really pointing at mandatory crash investigations concentrating on system design and defects, rather than a road user approach trying to find the guilty person.

The Simple Model to Save Lives, Including Illustrations

Our simple model for eliminating death and serious injury was a dose-response relationship between energy and risk of death and serious injury (Tingvall and Lie 1996). The energy would be the most relevant parameter for each road user category and crash type. But in the end, it was really what speed limit over ground that we in the long run would be able to handle without risk. For pedestrians it would be 30 km/h and for car occupants 50 km/h in conventional intersections, 70 km/h for roads without median barrier, and 100 km/h or more if the road had a median barrier. The boundary conditions for the vehicle were “four stars” (maximum crash protection), the occupant in the car must wear seat belts, and the driver must be sober and drive within the speed limit. It was a sort of a cross-condition model, and it was presented already in 1995. Of course it had its problems with validating if it would hold in reality, but it was a clear message that mobility was a matter of safety design; higher speeds could be the result of a safety improvement, meaning that investments should be going to safety, as this would mean a better mobility in terms of the conventional time saving optimization. I never felt this was a complicated relationship, but for unknown reasons it took years for transport planning to grasp this, and still seems to be.

In any case, it meant that if a higher speed than 70 km/h should be allowed, the road must be divided. This was a chock for some, but we “invented” a solution to that.

The “Solutions” to Improve Safety

It goes without saying that presenting a radical idea without showing at least something that would make it possible would be detrimental to the idea. So we had to show something, and it had to be quite radical but possible. While we were clear about that a complete "plan" for VZ would not only be impossible to do at this stage, we even tried to claim that we should leave the whole idea of innovation to the community to develop. But in any case, we had to show something. So we made a short list of things that we were quite clear about. Strangely enough, the most radical was also the simplest. It was the 2 + 1 road with a physical median barrier. It was not really an innovation; a 5-year-old child would come up with this immediately if you would ask for a solution of eradicating high-speed frontal crashes. The overall idea about dividing traffic was old, and in a report from VTI, the Swedish National Road and Transport Research Institute from 1991 showed how 13-m-wide roads could be divided by a concrete barrier. What we did was to demonstrate our knowledge about car safety and combined a narrow flexible barrier with a 2 + 1 design: a low-cost and really "safe" solution. But the road designers really hated the idea from the beginning, and how would we know that it worked?

We also suggested intelligent seat belt reminders in all new cars (seat belt use among killed car occupants at that time was below 30%), alcohol interlocks, safer cars, and all intersections built as roundabouts and a maximum 30 km/h in areas where cars and unprotected road users would be mixed. That was it. Today it would be mainstream, but in 1995 it was very radical!

How the Initiatives Were Shown: The Tylösand Story

The real test for the ideas took place at the Swedish Annual Traffic Safety Conference in Tylösand. It was not really a plan, but I had prepared a number of slides (at that time overhead slides) with most of the thoughts we had at the time. My presentation was really going to be about management of traffic safety and the new National Road Safety Plan. But in the morning before the presentation, I decided to show our thoughts and ideas instead. Being the Director of Traffic Safety at the Road Administration, what I said was the official policy of the STA. And the Director General and all the regional directors of STA were there, sitting in front of me.

This was the most risky situation in the whole sequence. To present something that sounded like a whole new policy from the national body, without any internal process in advance, should not be possible. But this was the chance. I understood that there could be no open criticism from the management of STA, and if things went well with the presentation, that would protect the ideas for a long time, although I might lose my position. I was willing to do so. But I also felt that I had legitimacy from the Minister of Infrastructure.

My presentation went very well, media reported, and the ideas landed the way they should. We had presented not only a new framework for responsibility but also how it could be done and new processes and solution. One idea that became popular at once was that we planned to make an in-depth system study of all fatal crashes in Sweden, looking for what we as system provider could do in the future to prevent all fatalities. And the first ideas about 2 + 1 roads were presented.

But the regional directors at the Administration were not happy. In fact, they were not happy at all. They were not necessarily against the ideas, or rather not all of them, but they were upset since I had not asked their "permission" to present a new policy. Today, I fully understand them, but I can also see that VZ would not have happened unless I had broken the rules of the system – at least not in Sweden.

It was the new Director General for STA, Jan Brandborn, who protected me and supported us in developing the concept. While he was not in favor of all individual ideas, he liked the way we moved forward and was proud to have a team that was trying to be in the forefront. He even asked me to build a new traffic safety department at STA a few months later. And we did!

During the autumn of 1995, we had the opportunity to deepen the ideas and, as so many were interested, to present the ideas to many stakeholders. The support started to grow and so also the forces against.

I was allowed to recruit Anders Lie as responsible for building up an in-depth crash investigation organization. The idea was to look for the opportunities to partly find what we as an organization could have done to save every life lost and partly to educate our organization what professional prevention was all about; to emotionalize our management not by feeling guilt, but to understand the tragic behind every fatality; and to understand that it could happen to anyone. Crash victims are just normal human beings, sometimes doing quite stupid things, sometimes doing very small mistakes. The in-depth studies of all fatalities in Sweden were to be presented to the regional directors and their management teams. This was a very large step forward.

The Government Investigation and the Parliamentary Decision

In record time a governmental investigation of traffic safety was assigned. The main writer, Johan Lindberg, undertook to describe the background, the content, and the consequences of VZ as well as proposing decisions to be made by the Parliament, the Government, and Local Governments. Most of the ideas for the future were there when the investigation was launched in early 1997. The most far-reaching point was the proposal for a new line of responsibility. It was said that the provider was ultimately responsible for the safety and the road user for following rules and regulations. The most striking and unusual sentence was, though, that if the road user failed to follow rules and regulations, the responsibility would fall on the provider to come up with new solutions. This last sentence was really controversial, and before the investigation was published, this sentence was included some days and not there some days.

Another very important sentence was that the speed limits were to be set based on the safety standard of roads and vehicles. A higher standard would mean that a higher speed could be allowed. Formulated in this way, none would be against the idea, and this sentence survived and could be picked up later. This was really the fine art of authorship in the state policy area: to formulate clever sentences that would be able to survive and be used in the steps to come. Johan Lindberg was a master in this art, with some good help from Lars Stenborg.

The investigation went for circulation among different stakeholders and generally got positive comments. The most striking negative comments came from VTI, the state transport research body in Sweden, claiming that VZ would be in breach of the balanced development where different qualities were weighted in relation to each other. VZ would be a suboptimal use of the societal resources according to VTI.

The Swedish Parliament voted for VZ in October 1997, and all parties were in favor. One party had a minor alteration of the proposal, but in essence all were positive. No political party or any Minister of Transport has ever openly questioned that decision since.

The whole sequence from the presentation of the first ideas in 1995 to the decision by the Parliament in 1997 must be a "world record" in policy change. I am not sure all members of the Parliament understood what they decided, but I am sure enough many knew to say that the decision was legitimate. The texts from Johan Lindberg stood the test, and most of it survived the whole way, including all relevant parts.

The Crash Tests

The attempt to improve vehicles and road infrastructure as main objective in the first phase led us in many directions. One of them was to find ways to make car industry to compete on road safety, in modern terms to bring car safety to the market. For many years, car safety was led by regulation. But the regulation had been bypassed many years ago by research and knowledge to go far beyond current standard of mainstream cars. A new EU regulation was on its way, and this was a chance to use the new tests of crash protection to compare new cars on the marketplace. Something similar had happened in the USA in the late 1970s with good results. And Australia had started on the same journey in the early 1990s. So now it was time for Europe. The UK had already made some tests at TRL, their national test laboratory, and we knew they were keen to publish the results. But they were reluctant as it would be a tough journey for them to tackle the anticipated criticism from the car industry – and to do that alone. So we contacted the British Ministry of Transport and asked if we could support publishing. Their answer was simply yes, if our Minister would openly back the initiative and if we could fund a second row of tests. Our Minister supported the idea, keenly, and we said yes to fund the second row of cars, this time mid-sized cars.

The first set of cars were superminis, and the resolution was not great. In fact the results were more like very poor cars compared with even poorer cars. The worst of them all, the Mini (still in production in 1995 under the Rover badge) was never published, for quite obvious reasons. I saw the crashed car several years later, with the crash dummy still inside as they could not get it out without completely destroying the car.

The second row of cars was published later, and the results showed a much larger resolution. And the good news was that there was a four-star car, something industry said was impossible. And the manufacturer, who happened to be Volvo, could not resist to tell the market they were the best. And from that moment, the competition started. Euro NCAP, the consumer safety rating system, was born, and more members came on board. And it has given us more than what we ever could have hoped for. Studies and analyses have shown such large differences between “old” and “new” cars that give us a real hope for progress also in the years to come. And industry policy statements that Euro NCAP was the wrong way to go and that there was not much potential in further safety development (yes, this was officially declared by the Association for European car manufacturers spokesperson in front of the EU Parliament) have been proven wrong on and on again.

A year later, STA decided only to buy and rent cars with top ranking in Euro NCAP – good news for those car manufacturers with high ambitions. But as we combined the safety ratings with fuel consumption, both Volvo and Saab got furious. Maybe not the most useful reaction as they told the public at the same time that their cars were thirsty for petrol. And the Minister for Environment and the Minister of Enterprise also got in open conflict over if a state administration was able to choose cars on the basis of safety and environmental performance. Our Prime Minister had to decide, and he declared that STA could of course choose cars. And of course many other stakeholders copied our requirements.

Since then, actively informing and acting on the marketplace for vehicles have been a real cornerstone of safety management. And to support the market penetration of new and very effective safety innovations like ESC or AEB is a given success. And to also bring solutions to the marketplace that really would not happen by itself, like intelligent seat belt reminders, has been instrumental through the Euro NCAP mechanism.

In 2008, Volvo Cars declared that they by 2020-year model would have zero deaths and serious injuries in and by a Volvo. This was a major step, although also Mercedes-Benz and Toyota had declared the same thing, but with no year given. Volvo seems to fulfill their target, at least for deaths in their “own” car. Many thanks to Anders Eugensson at Volvo Cars for getting this vision through the management at Volvo Cars!

The 2 + 1 Roads

The divided road with a barrier or simply just space has been known to be much safer than an undivided road for almost 100 years. The German Autobahn was the first attempt to apply the principles of the divided road with no intersections, no pedestrians or bicycles, and no slow-going traffic. So it was no real invention to use the same principles but packaged in something smaller and more narrow, like the Swedish undivided 13-m-wide roads built in the 1970s and the 1980s, over 4000 km, with high speeds and horrific results in terms of fatalities and serious injuries.

We developed the idea to modify the 13-m-wide roads to a 2 + 1 design with a very narrow barrier. At that time, the best alternative was the flexible wire rope barrier. And with the section 2 + 1 where we changed from one to two lanes every 1–3 km of road length, the possibility to overtake other vehicles was in fact better than for the undivided road. But the resistance to trial the 2 + 1 road was solid and widespread. We could not find any project leader within STA, so we had to bring in a retired road engineer, and much of the job was made by Hans Wahlström as one of the members of my own team. And when we asked citizens in the neighborhood of the road we had chosen for our trial, only 0.3% was positive. And most newspapers, NGOs, and road infrastructure entrepreneurs were also against. But we were successful in getting the support from the Director General of STA, although he was lukewarm and made it clear to me that he was not willing to take responsibility if something went wrong. That was something I had to do, and in fact I accepted that thankfully.

Our preparations were comprehensive and serious. We knew that a crash into the barrier with a passenger car would not harm the occupants as the acceleration levels would not be high enough. The threat would be a motorcyclist hitting the barrier.

We managed to build the first 2 + 1 road outside the city of Gävle, and it was opened in June 1998, just 3 years after the first ideas. I had to open the road, as no regional director or alike was willing to go there and show their support. Media came and asked only questions about our plan when the first serious crash happen.

A couple of weeks after the opening, several crashes into the barrier had already occurred, all with no injuries. We even got a cake from a person that had crashed into the barrier. She was clear about that she would not be alive if the barrier would not have been there. She thanked us for her life, and that was the turning point for the 2 + 1 road. Since then, the support started to grow, and just a year later, more than 80% of the Swedish population wished more of the 2 + 1 roads. And STA started to plan to roll out many more such roads. And later, it was shown that the 2 + 1 roads lowered the risk of fatality more than 80%. For a very small amount of money and with the possibility to maintain a high speed limit of 100 or 110 km/h. In total we must have saved more than 1000 lives since the first opening in 1998.

The Australian Story

In 1998, I decided to leave STA and take up the position as Director and Professor at Monash University Accident Research Centre in Melbourne, Australia. I was quite worn out from my work at STA, and it was time to do something different. And MUARC was one of the most famous and successful research centers in the world.

Australia, in particular Victoria, had a quite good track record in traffic safety, driven by research and serious follow-up of initiatives. But it also had a road user-centric approach and a high level of police enforcement. I found this interesting and in sharp contrast with Sweden and VZ.

As MUARC was contracted by VicRoads, the road administration in Victoria, as well as other major organizations in Victoria, I very quickly joined the network and the strategy and tactics development. And of course many were interested in the Swedish policy development with VZ. After a while I got invited by Eric Howard, the talented and enthusiastic Director of Traffic Safety at VicRoads. He wanted me to meet and present for the CEO of VicRoads. The CEO listened and immediately hated the whole idea of Vision Zero. Eric, analyzing the situation and needs for progress in Victoria, came up with a new name for VZ (or someone in his staff) that is less provocative and with less risk of being confrontative with his CEO and alike. The new name was Safe System – identical to VZ but framed in something more likable for many. Since this time, VZ and Safe System are synonyms, but of course each country and each organization have its own way to progress the principles and solutions. Tony Bliss, at that time working for the administration in New Zealand, picked up the ideas very early as well and helped to develop the ideas worldwide.

The Rhetoric and Illustrations of VZ

From day 1 we tried to find ways to express ourselves in a way that would stimulate thinking, debate, and reconsideration on earlier approaches. I am well aware that many got quite upset, and some felt even attacked. Sometimes I would be too harsh on earlier work or design of road infrastructure. One particular moment was a crash outside Stockholm with five deaths, all young. The car had probably aquaplaned and hit a concrete foundation to a lamp post. A concrete "barrier" just beside the most busy road in Sweden is no good idea, and while none could blame STA for the deaths of the five car occupants, it would be in line with VZ to stop using such design solutions and of course not replace the damaged lamp post with its concrete foundation at the crash location. The then Regional Director of STA claimed that not replacing the damaged post and foundation would indirectly mean that we blamed ourselves and that this would be a trauma to the regional staff. I might have reacted a bit too strong to this argument, and the idea to replace the concrete foundation with an identical one was simply abandoned. Later, I have understood that the feeling of responsibility for deaths might occur in an organization even if this is not the intention at all.

The most useful sentence or rhetoric question we would ask in the beginning was simply "how many deaths on the roads would be a reasonable number?" or even a bit sharper with "how many child deaths would be acceptable per year?". Any sensible person would answer "zero." Among the political parties in Sweden, none dared to discuss anything else than a zero long-term target or goal with the apparent risk of being accused of being cold hearted.

The favorite illustrations would be "the Jilg" drawings. Karl Jilg is a Swedish artist who was commissioned by STA to make four illustrations of turning kinetic energy (i.e., speed) to height. They are really brilliant and used extensively to explain the consequences of simple human mistakes and how wrong the design of the road infrastructure was. The rhetoric around the drawing was: "Has anyone ever met a perfect human?" They are still in use to demonstrate the odd distribution of space and security in urban settings and the consequences of simple human errors (Lindberg and Håkansson 2017).

The favorite rhetoric sequence about responsibility and who has the main role was the comparison between the signalized intersection and the roundabout, the latter having more than 90% reduction of fatalities, and the most risky situation being the road user by mistake running a red light. So the following question would be: "Who has the main opportunity to reduce fatality risk at an intersection, the road users or the provider of the intersection?"

The Integrated Safety Chain

Our first models for a safe system were static that had no dynamic sequence for a crash and the exchange of energy. They also lack an integration between pre-crash and crash criteria. For me, the insight of bringing together pre- and crash factors and start looking for new opportunities came with a meeting with "Mr. Safety" at Mercedes, Rodolfo Schöneburg. It was around the millennium shift, and it gave the first glimpse of what was going to come in terms of pre-impact braking, etc. To me, it was really the next eye-opener after my understanding of the relativity between the vehicle and the road infrastructure, and it was the answer to the future and how to get to zero. Braking before impact is the big answer to the relation between travel speed and impact speed, and 1 s of braking, in theory braking 36 km/h (1 g during 1 s), would be worth as much as the whole area of crash protection. Seat belts and better vehicle structure have given us something like 35 km/h better safety, and now we were approaching a new major step in the history of traffic safety. And to also brake for a pedestrian or a bicycle was the answer to so many issues in urban traffic. We have not used the potential yet, but we are no doubt on the way.

The integrated safety chain makes no difference between pre-impact and impact countermeasures, and it is the way to see how different technologies come together and become the precondition for the next link in the chain. A pre-impact braking makes the crashworthiness more effective. But it also puts the driver and his or her condition in the right spot. And it creates the natural question to the automotive industry how they can make sure that the driver is fit, not speeding or driving aggressively. This was the starting point for what technology should do in supporting the driver as well as limiting the drivers' intentions if necessary.

What Was Achieved and What Did Not Happen

It is always more or less impossible to predict what would have happen if a certain process or decision would not have taken place. In the case of VZ, one might suggest that many of the initiatives taken could in fact have taken place without VZ. But most of what was predicted and necessary has happened and much more than this. The 2 + 1 roads, the 30 km/h speed limits in cities, the state policy to only buy and rent safe cars, the intelligent seat belt reminders, etc.

It is easier to find those proposals that did not happen. And there are in my view mainly three things that still seem to be hard to implement. The first one is the ownership over speed limits. It has been one of the cornerstones of VZ from the very beginning to control kinetic energy, by speed. Setting speed limits is therefore the most important decision to own, as any combination of infrastructure design and vehicles could be catered for. But still today, speed limits are set on the basis of several factors, like mobility and time savings, although this is exactly what is banned under VZ. And decisions are still taken in a political context, while in fact they are technical decisions. No one would dream of letting the Parliament set the speed limits for trains, or maximum load weights for bridges, since they are technical limits. Regardless of how hard it may sound, democracy does not stand above physical laws.

There are guidelines for speed limits in the early VZ texts, and in Sweden there is a long-term plan to follow the guidelines set up in 2008 about speed limits in relation to cars of the future, but still decisions are taken outside the safety culture, in Parliament, and by the Government. This is of course not acceptable.

The first attempt for a global speed limit is the recommendation given by the Academic Expert Group for the Third Ministerial Conference 2020. In one of the nine recommendations, 30 km/h is the highest speed that could be acceptable where active road users are present. It would be quite odd if someone would argue against and on what basis that would happen.

The second is the technology that would stop driving under the influence of alcohol. It is without doubt a very complex issue to equip all motor vehicles with a technology that is only relevant for a few and to force each citizen to undertake a test with a breathalyzer each time the vehicle is started. In reality, it is not possible unless it is a vehicle used for certain types of transport, like buses. So there is a real challenge to develop a technology that is safe, nonintrusive to the sober driver, and still not possible to manipulate. The real trick is to drop the legal limit for intoxication by the technology and concentrate on stopping a trip that seems to be performed by a driver that drives as if he or she is intoxicated. This would open up for many solutions.

The third is also a fundamental issue. Since the late 1960s, the Vienna Convention has been used by many countries across the world. This convention is the basis for national traffic rules. In doing so, it has a central role in norms, insurance claim practices, and the division of responsibilities in the community between the road user and the provider of the road transport system. It has produced and distributed a set of rules that no doubt are simply impossible to follow. Article 13 in the Vienna Convention on Road Traffic, Rules of the Road, stipulates a rule that in every country the driver be able to stop his vehicle within his range of forward vision and short of any foreseeable obstruction. This rule is simply impossible to follow, in particular in combination with other rules of not hindering or disturbing the traffic flow. To have central rules that are not possible to follow would in any organized system be banned and removed.

It is even more sad to see the complete lack of “road rules” for the providers of the road transport system. Not even vulnerable road users, like pedestrians or bicyclists, are protected by any obligation for the providers.

Another issue where we failed miserably for many years was the ambition to stimulate the transport services to improve their safety and to manage this by self-regulation. Already in early 1996, we started to develop the ideas on how organizations could act as responsible citizens, both in procurement of vehicles and transport services and how the market would react positively. It worked well for vehicles, but it did not work for transport services. Taxi transport, public transport by buses, and goods transports were all exposed to a marketplace that at least in saying expected that safety would be a prime parameter. But it seems more or less nothing happened. Taxis are still driven above speed limits, and it seems to be the same for goods transport. We learned by all mistakes we made, and maybe today, we can expect market forces channeled via improved sustainability records might work. But it is still hard to understand why the normal chain of delivering service or products, where every link in the chain would have to deliver without “defects” to the next link, has not taken place for road transport. This is a more or less mandatory “rule of the game” in the professional world that no one needs to check “incoming goods” to find defects, but even in logistics chains for industrial production, driving above speed limits and alike seems to be normal.

The Criticism

No doubt, there was criticism from the very start of VZ. Some would be related to the process, some would be misunderstandings or misinterpretations. However, some would be more fundamental and worth considering seriously. I have tried to pick these and comment on some.

The Society of Economics

No doubt, the most serious criticism came from the socioeconomic society (Elvik 1999), and they were both vocal and had many years of major influence. The planning of investments and activities within the road administration as well as in the Government was based on cost-benefit and cost-effectiveness approaches (SafetyNet 2019). An approach based on setting boundary conditions for one of the core factors in road transport would be against this paradigm and even against the transport policy as expressed by the Parliament. Added to this, it was claimed that it was against the core philosophy of decreasing marginal benefits, meaning that the socioeconomic cost of saving lives would be gradually higher as we would approach zero fatalities. Therefore, it would be detrimental to both the transport system optimization and mortality as a whole in the society if one factor would dominate and be funded at all cost.

The economic arguments are no doubt valid, if the background facts were adequate and true. We argued against saying that (1) human life is another dimension than transport effectiveness. It would be comparable to let the economic margins of a corporation be weighted against occupational health and safety. And (2) if we manage to save life at a gradually lower cost, the argument of decreasing marginal benefits would fall. And this would happen if we invented new methods rather than applying just one method.

It became clear after some time that the real difference between the standpoints of the economic society and the VZ proponents could be found in the basic analyses of the traffic safety problem. The conventional analysis concentrated on the individual as the agent of the economic burden to the society. The collective economic burden would be lowered with cost-effective prevention, but in the end it is the road user that takes his own risks. The collective demand for improvements would be channeled via the willingness to pay by the citizens and the revealed acceptable risk being measured by the fact that citizens used the road transport system. Improvements would only be defendable if the benefit was higher than the costs or at least the most cost-effective method used. There was no internal criticism to the basic analysis as we understood at that time. Not even the way injuries of different severities were weighted in relation to each other. In the socioeconomic principles, many minor injuries could be more costly than a few serious injuries or even deaths. VZ would not do so but instead have one threshold for injury. The threshold was deaths or an injury leading to a long-term health loss. In reality, we should not overestimate the importance of this change in how different injuries were prioritized. But in theory the difference is substantial and led to a new way of collecting health data from hospitals, while crashes with only vehicle damages were not counted at all.

We, on the other hand, claimed that the citizen intrinsically has the right to life and would not trade his own life and health to someone else's benefit. We claimed that the individual road user was in the hands of the providers and that there is a special responsibility that comes with this role – and that this was the dominating view and roles in other parts of the society and that the road user is more or less forced to use the road transport system in contrast to the economic theory saying that the use of the road transport system is voluntary and that the risks associated with using the system are widely accepted. As a consequence we should apply the principle of setting a predefined acceptable risk. And this risk must be close to zero, as it is in other parts of the society.

The discussion would sometimes be quite vocal, and too often it became a matter of ethics and moral philosophy rather than going back to the basic analysis and the role of the provider depending on how we judge responsibility.

Personally, I am puzzled that the old economic models are still in use, where time savings and loss of health are weighted against each other. Traffic safety, clean air, noise, climate, etc., are all boundary conditions for mobility but still seem to be prized and used in the weighing process.

The price of saving lives has dropped substantially over the years, and the economic theory has in this case been falsified. A great example is that the result of the economic investments in 1995 was one life saved per year by three billion Swedish Crowns. Five years later, it was 10 times better, 1 life/year saved/300 million investment. And it became even better by time. And for cars, the safety improvements that have been extraordinary have not meant that cars are more expensive. The industrial logic meaning that the costs for achieving a certain quality are reduced seems to be true also for safety. This is something we all need to understand better in managing progress in traffic safety.

The “Nanny State” and the Paternalism

From time to time, there has been a discussion of VZ as really an another policy of state paternalism, where political and administrative decisions could be taken and force individual citizens to act against their will. The discussion in itself is not new; it has been there for a very long time. We heard it when seat belt legislation was discussed, and it is still there when different ways to increase bicycle helmet use are compared. And it is a healthy discussion in a democracy. Where are the limits for the collective to force the individual to act in a certain way? And of course the answers from the citizens vary in time, and often it takes years and decades for attitudes to change. At the same time, we have examples of individual actions that are pre-requisites for effective solutions. Many safety technologies in a car are far less effective if the seat belts are not worn. And investing in road design means that the effectiveness is higher if we can control speed. So it is not trivial to mix individual behavior with societal investments and action, something that kept Bill Haddon at NHTSA busy. He developed the ideas of active and passive safety, when these words had another meaning than today. Active meant safety that had to be “activated” by the individual. Conventional seat belts are active. Passive safety would be solutions that would be there irrespective of the individual, like airbags. Haddon’s theory was that passive was more effective, more equal across the citizens, and easier to implement. Once again, this is an ongoing process in the community where technology and passive solutions are easier to accept than intervening in the “freedom” of the individual.

But there is, at least in Sweden, in my view a strange discussion about how far we should go in protecting the individual, as if there was a mechanism that made us mentally different and even mentally disordered by improved safety. It has even been presented as a scientific idea by a psychiatrist (Eberhard 2006) that we suffer from a collective security addiction. While it is not possible to find any scientific background to this “diagnose,” it has been picked up in the debate. Personally, I think this is the best example of “Münchhausen by proxy” but on a level seldom seen before where a psychiatrist in his examples give the advice to limit the use of bicycle helmets to avoid the development of the safety addiction. Münchhausen by proxy is a diagnosis where a caretaker invents a disease or mental disorder in order to treat the patient or expose the patient to unnecessary treatment or potentially risky and painful treatment. To my surprise, even serious media and the large newspapers have picked up the idea about safety addiction. There is a risk that such approaches mixed with the “risk compensation theory” that never was validated either become a serious problem for a safety progress or open up for ideas that are just populistic.

Discussion

The Vision Zero was never a planned process. This is probably the most important characteristic of a major shift in this policy, and it must be stressed in a discussion on how it started and developed. I would rather characterize VZ as simple step-by-step sequence using opportunities added with random events. There were no doubt a number of characteristics of the VZ included from day 1. But they were all separately already known and expressed before, either as arguments in road safety research and policies or from other sectors. But in combination they were new or at least novel as a policy (Belin 2012). The ethical standpoint leading to the "zero," based on a shift of responsibility from the user to the provider, is "stolen" from the occupational health and safety sector. And the ethical rules were essentially borrowed from Hippocrates and the ethics in medicine and engineering. But the rationale for applying them in road transport was new. And the driving mechanisms for change, that is, the citizens' right be safe instead of the road user to be blamed once a victim, was a new application of the classical three-party ingredients of prevention (the host, the agent, and the environment that brought them together). And being led to that safety is something we demand and should not be seen as a burden or restriction.

Finally, the use of kinetic energy as the main ingredient to control injury risk was really borrowed from Bill Haddon, but we developed his different prevention strategies to one model for boundary conditions based on the human tolerance for mechanical force. One could say that this was invented already by Hippocrates, but we brought figures and a systematic modeling to it.

The most important ingredient was, however, that it became known to the political system as an alternative to conventional transport planning based on socioeconomic models. Here was the real contrast and where things were brought to new discussion level. And once again, this was all a matter of circumstances. Maybe it would have happened anyway, and most certainly it would happen today, with sustainability as the new planning paradigm just around the corner.

What took years to understand in an institutional context was the shift from safety being a burden or restriction to mobility to that mobility is a function of safety (Tingvall and Lie 2017). An improved safety is the key to improved mobility. Normally, we can understand this for railway, or a workplace, but it has taken a very long time in road transport. It was maybe the most important sentence in the bill that went to the Swedish Parliament in 1997 when the final decision to adopt VZ was taken. In any case, this opens up for investments in safety seen as investment in mobility. And to see that, a separate "safety budget" is not necessary. An example was the 2 + 1 road, where the investment of modifying the road from undivided to divided meant that the speed limit could be 100 km/h or higher instead of 70 km/h. But what some had a problem to understand was that the speed limit would actually be 70 km/h if nothing was done to the design of the road. They might still have believed that we could keep 100 and accept the deaths. This opportunity was no longer possible with VZ. But still today, speed limits are set in a political and economic context, and this is no doubt wrong. They should be set entirely on a technical ground.

The economic models not only get the roles of mobility and safety wrong by putting them on a platform where they are exchangeable. They also seemed to fail in predicting the price to save lives. New methods, innovation, and cost reduction normal for the industrial sector have all contributed to gradually lowering the price of life. In particular, benefit-cost ratio models to choose alternatives do not seem to drive innovation. These models do not seem to account for things like competition and consumer demand and not even innovation. They do not even seem to be able to handle what we would call system effects, one example being improved pedestrian protection by vehicle design. What is evident from both experimental models and empirical results is that the effectiveness of improved design is far larger if the speeds are low. So if urban areas reduce speed and speed limits, the investment in car design is higher. These kinds of effects are probably more common and larger than we have earlier claimed, as we have treated safety as a matter of individual countermeasures rather than system design.

What we might discuss as a way to be more "technical" would be the introduction of "predefined acceptable risk" meaning that we decide what safety level we accept at any location and any design solution. In aviation, railway, and many other parts of the society, this is a natural way to handle safety and impact on health. Railway regulation in the EU is strict about the acceptable risk and in essence has decided on a level for each country of one per one million lifetime risk for a fatality. Applied to road traffic, we would have around 5 deaths/year in the EU instead of 25,000. The beauty with this approach is that each provider would have to calculate in advance what a certain design solution would perform. In any case, some kind of movement towards a more regulated role for the providers would probably be helpful. The current situation, more or less unregulated, seems to allow the use of inferior solutions without any restriction.

The issue about acceptable risk will become evident when we get closer to automated vehicles. No doubt, a "machine" or robot designed by humans must be safe, at a level where railway and aviation is. And it is a fair assumption that any risks taken by an automated vehicle are not acceptable, i.e., we are getting close to the one per one million lifetime risk level. I am not sure that everyone understands that even if an automated vehicle is far safer than the vehicle driven by a human, it is never going to be enough. On average, an automated vehicle needs to be on a level that is 1000 times better than the conventional car. Anything else would be seen as unethical.

The introduction of the 2030 Agenda, or the Sustainable Development Goals, is a major step forward for safety. But it is not restricted to the first global goals for traffic safety, it is even more important to be able to use all the instruments and arenas associated with the 2030 Agenda. The institutions and large corporations, the economic logics of investment funds and actors, and the combination between safety, health, and climate will change the world quicker also for safety. When the large corporations in their value and supply chains will be asked how many children they kill by using the road transport system, this will no doubt start processes we have never seen before. Or when taxi and transport services must declare how they secure their vehicles and the way they are driven, something extraordinary will take place. Investors wish to keep their assets safe and will be talking to the large players how they will go about to reduce their societal harm.

When cities discover that they by procurement can control the urban mobility and its qualities; reduce particles, CO_2, etc.; and increase the attractiveness by geofencing of speed, this is a really big change. The nine recommendations from the expert group for the third ministerial conference on road safety pick a lot of opportunities when combining the instruments of the 2030 Agenda. And it picks up a sort of Vision Zero for many qualities of the world, by saying that we cannot just concentrate on one target at the time.

The question about how we formalize VZ is and has been common. Is it necessary that nations, local governments, road administrators, and others are bound to VZ by regulations and even laws? This question has been exposed in two governmental investigations, both times with Matts-Åke Belin as an insightful secretary. And both times, it was proposed that such regulations should be brought in place. It would give the Parliament a more secure situation as to what public bodies would be expected to do. But very little of the proposals in the investigations were brought to the Parliament for decision.

Reflections

Should we be angry and upset over the 100 million deaths over the past 100 years? Is there anyone out there who is guilty of all deaths or at least many of them? Or did anyone make a fortune through all deaths or stop progress? There are more questions that we should try to answer when we look back at an almost unbeatable man-made catastrophe. The answer to the above questions is probably no, and there has certainly not been a conspiracy. We could have done things better, earlier, or more widespread. And we could certainly have done things in parts of the world where too little has been done. But many professionals, researchers, engineers, and organizations have done great things that gradually have made road transport safer and given us very much knowledge.

At the same time, our field has been full of good hope, amateurism, and poor science. Even today, the populism around speed is widespread, and proponents of a better speed management are often treated negatively, as if their facts are just an opinion and should be compared to the opposing opinion that speed does not really matter. In a way speed becomes a political issue.

And there are things that still might be hurdles to progress. I find very little excuse in the lack of funding. Safety is cheap, simple, and possible anywhere. And there is no excuse at all for building another undivided road, an intersection that is not a roundabout or a street without pedestrian crossing that create safe speed; or to build another car without seat belt reminder or pedestrian-friendly design; or to develop a supply chain with trucks and lorries without controlling their speeds; or run a bus line without geofencing. None of these examples cost any substantial amount of money, but improve safety greatly. I am not sure what stops us to do things better, if there are no costs, no drawbacks, and no side effects. Probably there are still norms, beliefs, and amateurism or even populism stopping. In any case, there is scope for large reductions, anywhere in the world.

The real hope is the 2030 Agenda and that safety becomes quality of life (Beyond 2020). That safety is something we like because it creates freedom – not only freedom of injury but also freedom to move and freedom for our children to walk to school, activities, and friends. When freedom to move mean education, social interaction and better health trough exercise.

What has been bothering me since the very beginning of VZ is if we need legislation to force providers of road infrastructure, vehicles, and transport services to start acting as responsible cultures. Do we need laws to put the human life and health in the middle? We started with an insight that the providers have the major role for safety and thought a few ethical guidelines would be enough. It was probably a good first step, but it seems not to be enough. And policies and targets set by the Parliaments have also been helpful, but not enough.

Maybe we should express traffic safety as a "human right" like we did with the Tylösand Declaration. In this declaration, individual citizens should expect providers to do their outmost to protect their lives and to adopt the principles of continual improvement. The Tylösand Declaration was the forerunner to ISO 39001, the safety management standard for traffic safety. But it is still not a legal rule to adopt and use ISO 39001. All sorts of providers can still at large use their own standards and internal rules. So maybe we are about to ask ourselves the question if we need to bring traffic safety into the human rights corner and make it legally binding to act with the human life and health at the center – a "duty of care" rule for all providers. Maybe we need to legally protect every human against being the victim of amateurism, trade-offs, and blame!

Cross-References

► Saving Lives Beyond 2020: The Next Steps

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8 Vision Zero in Sweden: Streaming Through Problems, Politics, and Policies

Matts-Åke Belin

Contents

Abstract

In 1997, the Riksdag, the Swedish Parliament, adopted Vision Zero as a new goal and strategy for road safety in Sweden (Swedish Government 1997). In the more than 20 years since the Vision Zero policy was adopted, it has spread internationally as a model of a public road safety policy (OECD/ITF 2008, 2016; World Health Organization 2017). It is not only in the transport sector that Vision Zero has attracted interest; it has also spread and continues to spread to other sectors of

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Swedish society such as fire safety, patient safety, occupational accidents, and suicide (Kristianssen et al. 2018). Although, road safety policies and strategies can be developed and adopted by a variety of actors at different levels in the society in a democracy, parliaments have a special position, and it establishes an exclusive legitimacy in the society. According to the Swedish Constitution (Swedish Parliament 2016), all public power proceeds from the people, and the Riksdag (the Swedish Parliament) is the foremost representative of the people. Therefore, this chapter focuses on the Swedish Parliament and the Swedish Government and how road safety, as a public policy, finds its way into public agenda in a competing political environment. The decision to adopt Vision Zero in Sweden was a rather radical change (Belin et al. 2011) of that time safety policy. This chapter examines the political decision-making process that preceded the decision by the Swedish Parliament to adopt the Vision Zero policy in 1997 (Swedish Parliament 1997) and the decision to re-evaluate Vision Zero in 2004 (Swedish Parliament 2004).

Keywords

Road safety · Public policy · Implementation · Public policy process · Sweden · Garbage can

Introduction

In 1997, the Riksdag, the Swedish Parliament, adopted Vision Zero as a new goal and strategy for road safety in Sweden (Swedish Government 1997). In the more than 20 years since the Vision Zero policy was adopted, it has spread internationally as a model of a public road safety policy (OECD/ITF 2008, 2016; World Health Organization 2017). It is not only in the transport sector that Vision Zero has attracted interest; it has also spread and continues to spread to other sectors of Swedish society such as fire safety, patient safety, occupational accidents, and suicide (Kristianssen et al. 2018). Although, road safety policies and strategies can be developed and adopted by a variety of actors at different levels in the society in a democracy, parliaments have a special position, and it establishes an exclusive legitimacy in the society. According to the Swedish Constitution (Swedish Parliament 2016), all public power proceeds from the people, and the Riksdag (the Swedish Parliament) is the foremost representative of the people. Therefore, this chapter focuses on the Swedish Parliament and the Swedish Government and how road safety, as a public policy, finds its way into public agenda in a competing political environment. The decision to adopt Vision Zero in Sweden was a rather radical change (Belin et al. 2011) of that time safety policy. This chapter examines the political decision-making process that preceded the decision by the Swedish Parliament to adopt the Vision Zero policy in 1997 (Swedish Parliament 1997) and the decision to re-evaluate Vision Zero in 2004 (Swedish Parliament 2004).

Theoretical Considerations on Agenda Setting

Public health experts in general and road safety experts specifically by nature look favorably on a rational comprehensive approach to public policies and public policy processes (Sleet et al. 2003; Elvik et al. 2009; Bugeja et al. 2011), at least from a normative perspective. Therefore, based on this rational view, experts have a tendency to mistrust public policy process and see them more or less as irrational. On the other hand, practitioners often highlight policy processes as incremental to its nature. In contrast to the comprehensive approach, scholars such as Lindblom (1959, 1979) praise incrementalism both a good description of reality and something to strive for. In 1984, the first edition of Professor John W. Kingdon's famous book *Agendas, Alternatives, and Public Policies* (Kingdon 1995) was published. Its theoretical starting point challenged both the rational and the incremental approach to public policies. In this book, a policy stream model is described, which could be applied to analyze and explain public agenda setting in our society. According to Kingdon (1995, 2003), a public policy process in the society is rather chaotic in its nature, and the work of the governments could appear as organized anarchy, and by this statement he joined what was referred to as the "garbage can" perspective on public policies (Cohen et al. 1972). Kingdon (1995, 2003) emphasized *organized* because public policy processes are not only total chaos; on the contrary, it still has structure and patterns. Separate streams run, and each has a life of its own. Three major streams –problems, policies, and politics – are coupled at critical junctures and produce changes in agenda. First, according to the model, various problems capture the attention of people in and around the Government, and there are various different reasons how and why one set of problems rather than another comes to the attention of public officials. Secondly, there is a policy community with a wide range of people who each have their own ideas that they want to promote. Thirdly, the political stream is composed of factors like swings of national moods, public opinion, elections results, and changes of administration, which might result in shifts in partisan or ideological distribution. People, such as politicians, bureaucrats, experts, and those involved in interest groups or media businesses, among others, are all involved in the different processes and could both push for changes or work against changes. However, the policy entrepreneurs, advocates who are willing to invest time and efforts, play a crucial role both within different streams and also in moments of coupling. According to the model, the three different streams develop and operate largely independent of one another; however, sometimes these streams come tighter at critical times, and a window of opportunity opens. A problem is recognized, a solution is on the table, and the political climate makes the time right for change, and the constraints do not prevent things to happen. Based on the stream model, in this chapter, the problem-, politics-, and policy-stream and how they are joint together in two different Vision Zero cases (Fig. 1).

Fig. 1 Summary of actors and processes in a public policy process

Multiple Streams Leading to the Adoption of Vision Zero, Adopted by the Swedish Parliament in 1997

Sweden has a long-standing tradition of managing the public road safety with the support of overall goals rather than detailed instructions to public authorities and via governmental regulations (Belin et al. 2010, 2014). Already in 1982 the Swedish Parliament decided to adopt goals for road safety (Swedish Parliament 1982). These goals were in effect for 15 years, until they were replaced by Vision Zero (Swedish Parliament 1997); see Table 1.

The goals adopted in 1982 were largely based on a socioeconomic framework. The total number of people killed and injured indicates that an increased number of fatalities could, in theory, be compensated by a reduction of injured. In other words, these goals could lead to an emphasis on interventions that aim to reduce less complicated injuries rather than to interventions which could save a fewer lives. The last two goals were focused on vulnerable road users and were aiming at fair and equal safety among all different road users.

The Logic and Approach of Vision Zero

In order to identify, analyze, and explore different public road safety policies between countries, cities, sectors, and changes over time, one might need a method which uses a model for a schematic view over reality and where the real world complexity is reduced and made more comprehensible. In social science these models, the ideal type (or pure type) is closely associated with sociologist Max Weber (https://en.wikipedia.org/wiki/Ideal_type) and has been used in many different settings (e.g., Vedung 2021) but also to analyze Vision Zero (Belin 2011; Kristianssen 2018). Vision Zero differs from a traditional road safety policy in a number of ways. A more traditional approach to people killed and seriously injured as a consequence of road traffic accidents has been the utilitarian philosophical approach (Bowen 2012; Belin 2012). Utilitarianism, as it has come to be applied

Table 1 Road safety goals. (Adopted by the Swedish Parliament 1982, 1997)

	1982	1997
Overall goals	The total number of people killed and injured in traffic should steadily decline	No-one shall be killed or seriously injured as a consequence of accidents in road traffic. The design and function of the road transport system shall be adapted to meet the requirements that follow from Vision Zero
	The risk of being killed or injured in traffic should be steadily reduced for all categories of road users	
	The risk of being killed or injured in traffic should be reduced to a greater extent for vulnerable road users than for protected road users	
	Particular attention should be paid to the problems faced by children	

within the road traffic sector, means that safety has to be weighed against other types of benefits. In theory, and to a large extent in practice, this approach means that those killed and seriously injured are a price that society simply has to pay for the mobility of the road transport system and that there are an acceptable number of deaths and serious injuries. Safety is to be gradually improved, but only to the extent that is socioeconomically advantageous. In addition, to a large extent the traditional road safety work is based on the fact that people are willing to take risks and that it is simply part of human nature. The long-term objective of Vision Zero is to establish a road transport system in which nobody is killed or seriously injured as the result of a traffic accident. Thus, Vision Zero aims in the long term to create a safe road transport system.

The justification for this absolute and uncompromising attitude is what moral philosophy would attribute to deontological ethics (Bowen 2012; Belin 2012), i.e., it should not be inevitable that anyone would be killed or seriously injured when moving via the transport system from Point A to Point B. Road transportation can be regarded as a type of transport production. The same as a society cannot accept people killing or seriously injuring themselves as a consequence of producing goods and services within industry, Vision Zero finds it unacceptable when transportation is produced. According to Vision Zero, mobility is therefore subordinate to safety, at least over the long term. If it is impossible to create a safe system, it should inexorably have consequences for mobility. Furthermore, Vision Zero is based on the fact that people do not want to die or be seriously injured as the result of a road traffic accident, and therefore each person has his or her own Vision Zero. Vision Zero and the traditional safety policy thus differ from each other when it comes to what is the long-term objective of the safety work and its normative ethical fundamentals.

Knowledge based on investigations of actual traffic accidents that answer questions about why accidents happen points sharply in the direction of the fact that it is the individual transport user who is the missing link in the road transport system. To a significant extent, the traditional road safety activities are based on behavioral science research which draws the conclusion that 90% of all road traffic accidents can be explained by a human factor (Evans 2004). In the traditional safety work, the principal challenge is to prevent conscious and subconscious faulty human action. As a basic starting point, Vision Zero instead accepts that human beings make conscious and subconscious mistakes, which is why accidents occur, and that the safety work primarily must be directed at those factors which can prevent accidents leading to death or serious injury. Accidents in and of themselves can be accepted, but not their serious consequences.

According to Vision Zero, the principal cause as to why people die or are seriously injured is that the kinetic energy to which people are exposed in a traffic accident is excessive in relation to the energy that the human body can withstand. Vision Zero is based on among other things the research that the well-known American road safety expert William Haddon conducted in the 1960s (Haddon 1968, 1980). Knowledge about energy forces and tolerance has largely served as a basis for the development of the passive safety characteristics of vehicles and for the development of different protection systems such as child safety seats, helmets, seat belts, etc. One important consequence of the adoption of Vision Zero as a public policy is that scientific knowledge about kinetic energy, which has served as a very important basis for the development of a sub-component in the road transport system, namely, the vehicle, also has become a general principle for the entire road transport system and its components.

In the traditional safety work, ultimate responsibility for safety rests with the individual. According to the traditional view, it is the individual road user who ultimately controls and manages the risks that may occur when travelling on the road transport system. The regulations surrounding the road transport system are clear and unambiguous on this point. If a road traffic accident occurs, it is possible in most cases to hold a certain identifiable road user liable for the deficient observance of regulations. Even if, for example, a road authority has made a mistake in the design of a road, it is the responsibility of the road user, via the general requirements for caution that are built into the traffic legislation, to provide compensation via his/her behavior for such road deficits. According to Vision Zero, it is not the individual road user who has the ultimate responsibility, but rather that falls upon the system designers. The responsibility for safety is thus split between the road users and the system designers (i.e., infrastructure builders and administrators, the vehicle industry, the haulage sector, taxi companies, and all the organizations that use the road transport system professionally), on the basis of the principles that:

- The system designers have ultimate responsibility for the design, upkeep, and use of the road transport system and thus are responsible for the level of safety for the entire system
- As before, the road users are still responsible for showing consideration, judgment, and responsibility in traffic and for complying with the traffic regulations

- If the road users do not adequately assume their share of the responsibility, for example, due to a lack of knowledge or skill, or if personal injuries occur or risk occurring for other reasons, the system designers must take additional further measures to prevent people being killed or seriously injured

In Vision Zero, the responsibility for safety is a chain of responsibility that both begins and ends with the system designers.

To a large extent, traditional safety work is based on the notion that individuals and the society largely speaking do not ask for safety. There are other values that that are given a higher priority, such as accessibility. Traditional traffic safety strategies are thus based to a large extent on the "unwilling road user" who must be forced into giving consideration to safety. Vision Zero is instead based on individuals and society demanding and requiring safety. The basic starting point of this policy is that everyone has their own "personal vision zero." The fact that people sometimes act as though they do not need or require safety has, according to Vision Zero, rather more to do with inability, ignorance, and a lack of social support than a lack of will or need.

Problem Stream

In order to understand the context in which Vision Zero was originally developed from, we need to look back historically on the road traffic injury trends in Sweden. After World War II, Sweden experienced tremendous economic growth, along with fast motorization and urbanization. The popularity of the automobile took off, and the road transport system was developing rapidly. Unfortunately, there was also a negative side to this development: the greater the volume of motor traffic, the more people were killed and seriously injured in traffic accidents. In 1964, Sweden had 17 fatalities per 100,000 inhabitants annually on the roads. This is similar to the average number for what the whole world is facing nowadays: 18.3 fatalities per 100,000 inhabitants (according to the World Health Organization's estimations (WHO 2018)).

The situation during the 1950s and 1960s was unacceptable, and it correlated poorly with the modern welfare state that was beginning to take form and especially among the medical professionals; there was a growing frustration and a growing demand for measures to be taken. Parallel with this growing awareness of the need to do more to reduce road traffic injuries, the Swedish Government prepared a rather unique reform, namely, the transfer of the road traffic from left-hand traffic (LHT) to right-hand traffic (RHT) (1954 Års Kommitté för Utredning om Högertrafik 1954).

The rationale for this reform was that Sweden's Scandinavian neighbors were driving on the right side of the road as was most of Europe. Furthermore, most Swedish cars also had left-hand steering. However, there was a strong public opinion against this reform, and the public argued that a change from left-hand traffic to right-hand traffic could increase the number of road traffic injuries even more (1954

Års Kommitté för Utredning om Högertrafik 1954). However, the Swedish Government decided to adopt the reform (Swedish Parliament 1963), but in order to react on these public fears and to make sure that the reform could be carried out without increasing the number of road traffic injuries, the Government set up a special organization, "Högertrafik Kommissionen" (Commission to Study Right Hand Traffic) (Swedish Government 1963). This commission consisted of several experts within different areas of expertise such as road, human factor, and vehicle design. The commission planned and implemented massive informational campaigns before and during the change in 1967, and the reform was a great success. Figure 2 shows that the change was successful from a road safety perspective. Instead of increasing the road traffic deaths, which had been the worst fear among critics of the reform, the number of deaths in road traffic decreased the next year; however, in the years that followed, the number went up again.

However, during the middle of the 1960s, a seed had been sown for a comprehensive and systematic road safety work through Ralph Nader's book *Unsafe at Any Speed* (Nader 1965). In the United States, this book contributed to spur the passage of the National Traffic and Motor Vehicle Safety Act in 1966 and the creation of several predecessor agencies which would eventually become the NHTSA, the US National Highway Traffic Safety Administration (Graham 1989). This book played a similar role for the road safety movement as what Rachel Carson's book *Silent Spring* played for the environmental movement (Carson 1962).

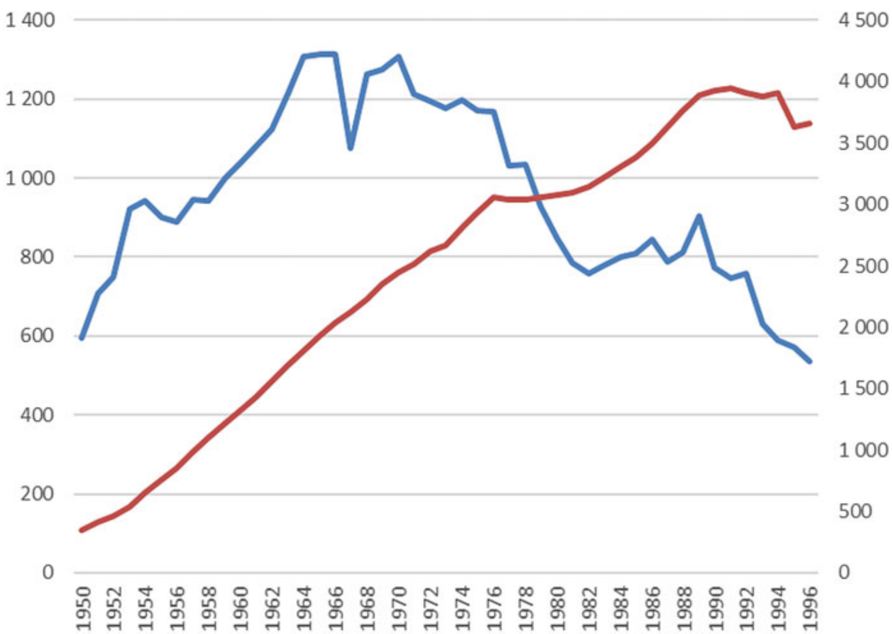

Fig. 2 The number of killed persons in road traffic accidents and the number of passenger cars per thousand inhabitants 1950–1996 in Sweden

Around the same time, a former Swedish Prime Minister, Olof Palme (https://en.wikipedia.org/wiki/Olof_Palme), who at the time was Minister of Communication, was deeply influenced by Ralph Nader and his book. He even arranged for the book to be translated into Swedish, and he also took the initiative, based on an American model, to set up a special authority for road safety issues, Statens Trafiksäkerhetsverk – the Swedish Road Safety Agency.

The establishment of the Road Safety Agency can be said to be the starting point for systematic road safety activities in Sweden. This work was successful during the 1970s, and the number of traffic fatalities people killed on the roads dropped from 17 fatalities killed per 100,000 inhabitants in 1964 to 9.1 killed per 100,000 inhabitants in 1982 – a decrease of over 40% (Transport Analysis 2020).

During the 1980s, the positive trend was broken, and traffic growth and road injury figures began to follow each other: the more car traffic, the more people were killed on the roads. In 1989, Sweden had 10.6 fatalities per 100,000 inhabitants, and Sweden was, once again, approaching four-figure numbers of road deaths. A sense of a loss of control was spreading in the society and together with political pressure to do something more radical – and this eventually (in 1993) led to the dismantling of the Swedish Road Safety Agency and to an enhanced role for Vägverket, the Swedish Road Administration (Swedish Parliament 1992).

Parallel with this process to change the institutional prerequisites for the national road safety work, Sweden was facing a severe economic recession in the first half of the 1990s. During the period 1990–1993, Swedish GDP fell by almost 5%, and the level of unemployment increased dramatically (Hassler 2010). From a road safety perspective, at least in the short run, we know that economic recessions might have a positive impact on safety, and this was also the case in the beginning of the 1990s (OECD/ITF 2015). The number of fatalities fell between 1989 and 1996 by more than 40%.

The trend in the beginning of the 1990s was therefore different from what Sweden had experienced in the late 1960s. The situation went from the negative alarming situation, which demanded a remedial response, to a more optimistic promising situation which signaled possibilities and future confidence.

Political Stream

Historically, the Swedish Social Democrat Party has a unique position in the five-party configuration party system of Sweden which emerged at the end of World War I. They were in power, by themselves or in coalition with other parties, from 1932 to 1976 (Vedung 1988; Östberg 2012). A systematic road safety work after World War II is therefore highly associated with the Social Democrats' political ambition to create a modern welfare state. Political road safety initiatives taken in the late 1960s and during 1970s were important from a road safety perspective and contributed to decoupling the trends with more traffic and road deaths. In 1976, the Social Democrats lost the Government office, and they were in opposition until 1982 when they came back into power. Several of the most obvious road safety interventions in that time were already in place, such as legislation concerning drink and driving, the wearing of helmets and seat belts, speed limits, the driving license system, periodical inspection of motor vehicles, upgraded road infrastructure in both rural and urban areas, etc. Therefore most of the political discussions during the 1980s were about organization and working methods and efficient delivery methods, rather than new interventions (Swedish Standing Committee on Transport and Communications 1984; Trafiksäkerhetsutredningen 1991).

From a road safety perspective, the 1980s became the lost decade, and the Social Democrats started to distrust their lead agency on road safety. Further, although we cannot know for sure, Olof Palme, the main architect who was assassinated on a street in Stockholm 1986, was not around to defend his creation. In 1990, the Social Democratic Government appointed a commission of inquiry with the main task to change the government organization, and its directive pointed out rather clear that there was no need for a special road safety agency (Trafiksäkerhetsutredningen 1991). In 1991 the Social Democrats lost their power again to a moderate, center-right Government, and it was a transport minister from the Christian Democratic Party who carried the commission proposal further, and the Government decided to, from the end of 1992, close down the former Swedish Road Safety Agency and move all its tasks and responsibilities to the former Swedish Road Administration (Swedish Parliament 1992).

The underlying political argument to close down the former Swedish Road Safety Agency was to increase the effectiveness in the road safety work via a reduction of the number of stakeholders within the sector and extend the road authorities responsible, not only to build and maintain roads but also to an overall responsibility for safety in the whole system including vehicles and the use of the system (Swedish Government 1992). Perhaps a backward way of doing things, but first the Government decided on the organizational changes and then came the political direction of the road safety policy looking forward to the twenty-first century (Swedish Government 1993). According to the direction, the focus should be placed on the road users, and good road safety was ultimately a matter of individual road users' moral and attitudes. A fundamental concept that underpins this political direction was the thinking that both individual road users and the various decision-makers do not value safety sufficiently enough. In other words, a poor safety culture within the society is a major contributing cause to lack of improvements.

In October 1994, the Social Democrats came back into power. Mr. Ingvar Carlsson (https://en.wikipedia.org/wiki/Ingvar_Carlsson), now became Prime Minister, formed a Government of which for the first time half of the members were women (Swedish Parliament 1994). Ms. Ines Uusmann became Minister of Communication (https://en.wikipedia.org/wiki/Ines_Uusmann), and during a public speech in January 1995, she revealed three issues that she would prioritize during her term as Minister of Communication, namely, better environment, more use of information technology, and road safety (Lindberg 2002).

In 1996, the Government was reorganized, and Mr. Göran Persson (https://en.wikipedia.org/wiki/G%C3%B6ran_Persson) became the Prime Minister; however, he kept Ms. Ines Uusmann in the Cabinet as Minister of Communication and Transport.

Policy Stream

When the Swedish Road Safety Agency was dismantled, the Swedish Road Administration became the lead agency for road safety. The Swedish Road Administration was a complex multi-goal agency, and to ensure that road safety gained a strong position within the organization, the Government instructed the Swedish Road Administration to have a person employed as a Road Safety Director. With other word, a policy decision aimed at ensuring that road safety interests were represented at the highest management level. Professor Kåre Rumar was appointed as the first Director of Road Safety. Mr. Rumar (http://web.hku.hk/~hhecwsc/KaraRumar.htm) was a professor of psychology and had extensive experience in the field of road safety plus was a world-leading academic in the field of human behavior and road safety. One of his first tasks was to develop, together with his colleagues at the Swedish Road Administration, a new road safety strategy. Although this strategy acknowledges the need for safe roads and safe vehicles, its primary policy priority was human attitudes and behavior (Swedish Road Administration et al. 1994). According to this strategy and the followed road safety program, the greatest potential for road safety improvements was to change peoples' attitudes to risk and lower their level of acceptance to risks. This strong focus on human factors was to a large extent based on research about behavior adaptation (Rumar 1988; Wilde 1994; Evans 2004). In the late 1980s and in the beginning of the 1990s, probably due to the negative road safety trend experienced in many western countries, the road safety community started to question some of the general road safety strategies (OECD 1990). These strategies, which were primarily focused on increasing people's capability (e.g., road users' skills) to handle risk and via different technical solutions (e.g., vehicle and road improvements which were aimed at lowering the demands made on the individual), make it easier for people to handle a complex road environment. According to this research, the road safety effects of these interventions could be everything from less effective to even increase the risks because of people's value of risk. Some researchers (Wilde 1994; Adams 1995) even launched the idea that all road safety interventions are useless and ineffective due to risk homeostasis. In the early 1990s, the road safety strategies were very much based on this behavior adaption concept, and if we could change people's appreciation and social norms for a focus on increased safety, even those interventions already implemented would deliver more safety. A strong focus was made therefore on individuals' attitudes and social norms which also was, as already mentioned, supported politically.

In the autumn of 1994, Adjunct Professor Claes Tingvall (https://sv.wikipedia.org/wiki/Claes_Tingvall) was employed as a new director of road safety at the Swedish Road Administration. Before Mr. Tingvall took up his new position, he worked as a research leader at Folksam, a Swedish insurance company. Mr. Tingvall represents a long tradition of researchers with the focus on injuries, biomechanical and protection devices such as seat belts, child restraint system (Tingvall 1987), and overall vehicle safety performance which started with Professor Bertil Aldman (https://sv.wikipedia.org/wiki/Bertil_Aldman) (Kolbenstvedt et al. 2007), a famous

Swedish researcher who made groundbreaking research in the field. Fairly soon after he started his new job, Mr. Tingvall and his colleagues at the Swedish Road Administration developed a new strategy which was named “The Vision Zero: A Road Transport System Free from Serious Health Losses” (Swedish Road Administration 1996). Very much based on his experiences within biomechanics, there was an opportunity to adopt this for an entire system. This strategy was to a large extent a 180 degree reversal from the previous strategy led by Mr. Rumar. Instead of focusing on individual attitudes, the strategy changed instead to create a safe system (vehicles and roads, in both urban and rural areas) for all road users. Control of harmful energy becomes a core aspect in this strategy. People’s attitudes vis-à-vis safety were not seen as a major problem. Rather, it was the opposite; everyone has their own Vision Zero for themselves and their loved ones, and Vision Zero was only a way to make that more explicit. Attitudes needed to change in the society and especially so among system designers rather than among individuals. It is not an overstatement to argue that Mr. Tingvall and his team suggested a paradigm shift in the way road safety as a problem in our society was framed and what appropriate strategies needed to be implemented along with what we should aim for – namely, to create a safe system without any fatalities or serious injuries. The former General Director, Per Anders Örtendahl https://sv.wikipedia.org/wiki/Per_Anders_%C3%96rtendahl), of the Swedish Road Administration was however skeptical. He was not in favor of this new idea, and the prospect that it would survive as a public policy under his leadership was rather non-existent. However due to a conflict with the new minister, Ms. Uusmann, Mr. Örtendahl resigned in early 1995. Mr. Örtendahl was a very colorful and strong leader, and when he resigned, the Swedish Road Administration was left in a state of vacuum, and the space to suggest new ideas increased substantially. Mr. Jan Brandborn replaced Örtendahl, and he initiated a major change of the organization, which commenced on 1 January 1996. General Director Jan Brandborn (https://sv.wikipedia.org/wiki/Jan_Brandborn) commissioned Mr. Tingvall to become responsible for a strategic road safety unit with approximately ten employees.

Policy Window Opens Up

During the spring of 1995, a delegate from the Ministry of Communication led by the new minister visited the Swedish Road Administration, and they were briefed about the administration and its various important areas of work. Professor Tingvall got the chance to promote his view on road safety, and he shared the idea about Vision Zero for the first time with a political level. Ms. Uusmann found this idea politically attractive, and soon thereafter the political part of the policy process was initiated. In August 1995, Ms. Uusmann launched Vision Zero for the first time to the public via a debate article (Uusmann 1995). During the autumn, an intergovernmental task force was established with civil servants from the Ministry of Communication, Ministry of Justice, and other ministries together with three experts from the Swedish Road Administration: Tingvall, Lars Eriksson (former Stenborg), and the author of this chapter (Swedish Ministry of Communications 1996a). The task force's mission was to describe and explore Vision Zero and to formulate concrete recommendations based on Vision Zero approach. A list of 28 topics was identified within the task force relating to different policies. Some of these had been discussed previously, and some were new and due to Vision Zero. Most of the recommendations were investigated and prepared by the Swedish Road Administration and discussed in the Group for National Coordination (GNS group) . In 1993, the Swedish Road Administration had established a group for national coordination of road safety with participation from different stakeholders in the Swedish society which worked on and had a stake in road safety. This group played an important role to both identifying important interventions and anchoring various different recommendations before a political process. They also supported the organization of two open road safety seminars (Swedish Ministry of Communications 1996b) during the spring of 1996. These seminars played an important role for Ms. Uusmann to try Vision Zero publicly as a concept and some of the interventions which would follow of a policy such as Vision Zero. The feedback both from the general public and the news media coverage strengthened Ms. Uusmann and her desire to transform Vision Zero from an expert idea to public policy. Both Vision Zero and some of the policy recommendations were incorporated into a public document by civil servants at the Ministry of Communication. However, in order to obtain full support from the other ministries, the concrete recommendations were somewhat watered down. The public document was thereafter referred for comment to over 100 organizations in the Swedish society. The support for Vision Zero in general was overwhelming, except a few critical comments focusing primarily on costs, effectiveness, and realism. Based on this support, a draft proposal to the Parliament was developed. Due to the fact that most of the concrete recommendations were pushed into the future, the proposal was more of an overall long-term strategy, without concrete measures taken (Swedish Government 1997).

On 9 October 1997, the Swedish Parliament decided to adopt a new direction and a new long-term goal for safety in road traffic – Vision Zero.

> The Parliament supported the Government's decision to adopt a new direction for traffic safety based on the Vision Zero framework. The goal is that nobody will be killed or seriously injured as a consequence of accidents in road traffic. The design and function of the road transport system is to be adapted to meet the requirements that follow from Vision Zero. (Swedish Parliament 1997)

Five months earlier on 22 May 1997, the Social Democratic Government had submitted a Bill entitled "Vision Zero and a traffic-safe society" to the Swedish Parliament for processing. The Parliamentary Committee proceeding concerning the Government Bill did not lead to any changes, and all the parliamentary parties voted in support of it. On the other hand, the Green Party objected, in a reservation, to the decision to replace the traffic safety goal that was in effect at that time. The Green Party felt that Vision Zero should include specific sub-goals which, among other things, would focus on the problems faced by children in traffic. This reservation meant that the Parliament was forced to adopt a stance on two issues. Basically, all

Table 2 Vision zero as a long-term goal. Vote in the Swedish Parliament on the Committee's proposal against the Green Party reservation on 9 October 1997

Party	Yes	No	Refrain	Absent
The Social Democratic Party	137	0	0	24
The Moderate Party, Liberal Conservatism	66	0	0	14
The Centre Party, Centrism, Agrarianism, Social Liberalism	21	0	0	4
The Liberal People's Party, Social Liberalism	19	0	0	14
The Christian Democrats, Christian Democracy	9	0	0	6
The Left Party, Socialism, Feminism	19	0	0	3
The Green Party		15	0	3
Total	271	15		68

parties were in favor of Vision Zero; however, the Green Party wanted a general goal with sub-goals to be specified (Swedish Standing Committee on Transport and Communications 1997). Table 1 shows the outcome of the Parliamentary voting (Swedish Parliament 1997). The Parliament, with a substantial majority, adopted Vision Zero as a new long-term traffic safety goal, which entailed a new direction for the safety work involved (Table 2).

Vision Zero: Continued Action for Road Safety, 1998–2004

In November 2004, 7 years after the Swedish Parliament adopted Vision Zero, it was time for a comprehensive discussion of the direction of public road safety work in Sweden and to reconsider Vision Zero as a long-term goal and strategy. Additionally to Vision Zero, the Swedish Parliament had also in 1998 adopted (Swedish Parliament 1998) an intermediate target for 2007 to halve the number of fatalities. Thus, this was a moment for the Swedish Parliament to reflect and to reconsider Vision Zero and the intermediate target for 2007. The decision could be summarized in one sentence: Vision Zero lies steady, and although it will be a great challenge, the intermediate target is fixed. In contrast to the decision in 1997, this proposal was also discussing, to a greater extent, concrete road safety measures (Swedish Government 2004; Swedish Standing Committee on Transport and Communications 2004; Swedish Parliament 2004).

According to the Government proposal, the work with Vision Zero should not be seen as a one-off effort but rather as an ongoing process. To be successful, road safety work must be integrated into the processes that affect the design and function of the road transport system. The Swedish Government made an assessment and stated that the work with Vision Zero had just begun and should now be deepened and intensified. Many of the measures taken since Vision Zero was adopted were long-term solutions. For example, extensive measures have been taken to improve safety in road environments and in vehicles. The new direction in road safety work entails, among other things, that the system designers take greater responsibility for safe road traffic. In-depth studies of fatal accidents and the OLA process (a planning model in order to include different stakeholders) are important instruments for coordinating the work of different system designers to improve road safety.

Although the Government felt that the long-term work was doing well, they were more worried about the results in the short term. According to the Government, in light of the past 10 years of the road safety work and the available knowledge, it will require great efforts by all stakeholders to achieve the goal in 2007. According to the Government, system designers always have the ultimate responsibility for the design, maintenance, and use of the road transport system. They together have an informal responsibility for the entire level of security of the system. The work to integrate safety in the road environment, in the quality assurance of transport, in the occupational health work, and in vehicle development must therefore continue and intensify. According to the Government, this would make a great contribution also to the short-term target.

However, this was, according to the Government, not enough. The road users also have a responsibility to follow traffic rules, and according to the Government, road users' compliance was going in the wrong direction especially when it comes to speeding and drink and driving. Therefore the Government suggested several new interventions with a focus on individual road users, such as automated speed enforcement, increased penalties, and the requirements for a driving license, among other things.

Problem Stream

After the severe recession in the beginning of 1990, the Swedish economy started to recover in the second half of this decade. The unemployment rate decreased from about 11% in 1997 to 6% in 2001 (www.ekonomifakta.se/Fakta/Arbetsmarknad/Arbetsloshet/Arbetsloshet/). During the same period, after some years of stagnation, road traffic grew by about 10% (Transport Analysis 2019). Once again, the strong relationship between general economic developments, especially in the short run, and road safety was shown again. turned out again. Despite the bold policy of Vision Zero to eliminate fatalities and serious injuries, the short-term trend showed no sign of progress but rather the opposite.

According to Kingdon (2003), it is not only how the society traces common indicators that play a role for agenda setting and the policy system but also spectacular rare events that can trigger public decision-making. Based on this, one event in 1998 and two events in 1999 need to be mentioned. In November 1998, a large bus went off a slippery road and started to burn, but as a miracle, all passengers survived. In January 1999 in one traffic collision, six children and two adults lost their life. In February 1999 in one traffic collision, seven children and two adults lost their life. Together, 13 children were killed in these 2 road accidents.

Political Stream

Ms. Uusmann retained her position as Minister for Communications until the autumn of 1998. After a new election and despite a large drop in voter support, the Social Democrats stayed in the Government with support from left and environment parties. Prime Minister Persson decided to reorganize the Government, and the

Ministry of Communication, Ministry of Industry, and Ministry of Employment were merged into one large Ministry of Enterprise. The idea was to create a strong ministry for economic growth. As a consequence, the most important political proponent of Vision Zero lost her political power. Mr. Björn Rosengren (https://en.wikipedia.org/wiki/Bj%C3%B6rn_Rosengren) became the first minister with overall responsibility for this new ministry. Mr. Rosengren was not a great enthusiast of Vision Zero. Mr. Rosengren saw Vision Zero as a utopian unrealistic goal which at best could serve as a benchmark to encourage the society to do its best (Hakelius and Rosengren 2016). Despite his doubt, it seems that Mr. Rosengren had no intention to start a process in order to replace Vision Zero, and he emphasized that the main focus was to achieve an intermediate target, less than 400 fatalities and 3,700 serious injuries in 2000. Soon after Mr. Rosengren took office, he was forced to deal with the events mentioned above. In April 1999, the Government together with the Swedish Road Administration launched an 11-point program (Swedish Ministry of Enterprise 1999) for road safety which turned out to be, when we look back, a very important document to go from Vision Zero as a policy to real action. Despite this effort, the number of fatalities did not drop, and Mr. Rosengren in August 2002 took another initiative to create a national coalition for road safety with focus on behavioral risk factors (Swedish Road Administration 2002).

In 2002, after the election, Mr. Persson managed to stay as prime minister for another term, and the Government was once again reorganized, and Ms. Ulrica Messing (https://sv.wikipedia.org/wiki/Ulrica_Messing) was appointed as new minister with responsibility for infrastructure in the Ministry of Industry, Employment, and Communications. In contrast to Mr. Rosengren, Messing was a clear advocate for Vision Zero and in this respect more in line with the previous minister Ms. Uusmann. Ms. Messing became responsible for the second comprehensive proposal on Vision Zero to the Parliament in 2004 when she asked the Parliament for continued action for safe roads (Swedish Government 2004).

Even though Mr. Persson reorganized the Government in 1998, the Swedish Parliament and its different committees were the same. The Standing Committee on Transport and Communications is responsible to process Government bills and to process other proposals from members of the Parliament on road safety. In the autumn of 1998, a process was commenced to manage the various different proposals from the members in the Parliament which were focused on road safety. This is a reoccurring process that arises about once a year. One important factor was that the chairperson at that time was Ms. Monica Öhman (https://sv.wikipedia.org/wiki/Monica_%C3%96hman). Ms. Öhman represented the Social Democratic Party and had been in that position from 1994 and thereby had been responsible for the parliamentary process to manage the Government's Vision Zero proposal and to follow its implementation over the years. Ms. Öhman was a strong advocate for road safety, and after her time as chairperson, she became Executive Director of an important road safety non-governmental organization in Sweden, the NTF, National Society for Road Safety. Ms. Öhman and the rest of the members in the Committee on Transport and Communications expressed great concern about the situation and sent a clear message to the Government. In a committee report (Swedish Standing

Committee on Transport and Communications 1999a), adopted by the Parliament in April 1999 (Swedish Parliament 1999), the committee unanimously stated that Vision Zero provides a firm ground, and this required a continuous reduction in the number of killed and injured in traffic, and this must not be abandoned. According to the committee, it was important that the Swedish Government paid special attention to Vision Zero, and they also wanted the Government to present its positions as soon as possible to the Parliament regarding the continued focus of road safety work. The committee further requested that the Government should also investigate and set up an independent road safety inspectorate. Even though these kinds of parliamentary requests are constitutionally non-binding however politically important, the request to set up a road safety inspectorate was delivered by Mr. Rosengren in 2002 (Trafikansvarsutredning 2000; Trafikinspektionsutredningen 2006), and, as mentioned before, it was Ms. Messing who delivered the re-reporting to the Swedish Parliament in 2004 (Swedish Government 2004).

Policy Stream

The adoption of a new strategy such as Vision Zero is a significant and huge accomplishment, but to also change how road safety measures are implemented in practice is a different thing. To go from policy to implementation has been shown, by some academic researchers, to be a complicated task (Sabatier and Mazmanian 1979; Hill and Hupe 2002; Vedung 1997). In this case it was not only a question of starting new activities based on Vision Zero however also dismantling ineffective activities which were not supported by the new policy. In parallel, when some parts of the Swedish Road Administration were fully occupied with delivering in line with the road safety program adopted in 1995, Director Claes Tingvall with his new road safety team (the road safety unit, an organizational part of the Swedish Road Administration with approximately 15 employees. Tingvall reported directly to the General Director) was primarily occupied with the task to develop new activities, communicate the new direction, and support the Ministry of Communication to develop new policies. A rather unique relationship was established between the Road Safety Unit and the Ministry of Communication. The 1995 road safety program, due to failure to produce road safety result, started to be dismantled around 1998 (Assum and Usterud Hanssen 1999). The road safety unit succeeded to establish in-depth studies of fatal crashes, together with some other international stakeholders; establish European New Car Assessment Program, Euro NCAP, a program to influence the public and private organizations to quality assure their transports in terms of environment and safety; promote urban safety among different municipalities in Sweden; support the largest non-governmental organization for road safety, NTF; reorient their efforts to Vision Zero; start a new system to collect injury data from hospitals; and link the environment with road safety via strategic collaboration, among other efforts. In other words, in the years between 1995 and 1998, several new activities were established, the focus of which was primarily on new processes to influence the various stakeholders in the society. This included the move away from the traditional work to influence the individual road users' behavior to new efforts to influence the system designers. Despite the successful work of the Road Safety Unit in establishing new work processes and cooperation with new actors, the direct output in terms of safety improvements in the road transport system the results were meager. Vision Zero and its strongest representative, the Road Safety Unit, met strong opposition especially within its own organization, the Swedish Road Administration. Sweden had in that time a large state-owned network with 13-meter-wide roads which allowed 90–110 km/h as the maximum speed (Larsson et al. 2002). These had a high mobility; however, many of these were very dangerous and perceived among the public as death roads. Among road engineers, large motorways were regarded as being the best solution to strike appropriate balance between mobility and safety; however, at the same time they were very expensive. Among road safety experts, lowering the speed limits was considered a cost-effective solution but difficult to implement due to low public acceptance. In that context, a new road innovation, referred to as the "2+1 road" was discussed and promoted by the Road Safety Unit. The 2+1 road is probably the best example for how a new policy, a paradigm shift, materializes into a concrete action, but at the same time it challenged the old tradition of road planning and road design. However, Director Tingvall managed to convince the General Director Brandborn to build a pilot project (Larsson et al. 2002) despite strong resistance within the Swedish Road Administration. This was one of the last accomplishments by Director Tingvall before he moved, in the summer of 1998, to Australia and took up a position as the research director at Monash University. Professor Ulf Björnstig (https://www.researchgate.net/profile/Ulf_Bjoernstig), a medical doctor and researcher, replaced Claes as the third Director for Road Safety within the Swedish Road Administration. Within the Swedish Road Administration, efforts had commenced to develop a new national plan for the period 1998–2007 for the road transport system, which also included a special plan on road safety. In the work on the new plan, it became obvious that General Director Brandborn was about to give up the Government road safety target for 2000 and instead focus all efforts on the new target of a 50% reduction by the year 2007. It was not an easy position for the new Director Björnstig, he inherited and had to deal with both internal and external conflicts. In the recommended plan for infrastructure for the period 1998–2007, handed from the Swedish Road Administration to the Government before the end of the year, there was no special investment proposed for 2+1 roads. Director Björnstig developed to the best of his ability, along with staff at the road safety unit, the special road safety plan for the period 1998–2007. The referral edition of the plan was rather comprehensive with proposals such as support for pilot demo projects in urban areas; promoting road safety in procurement practices for transport and for new technology; consumer information such as Euro NCAP, information disseminated to road users especially in matters such as speed, alcohol, and the use of seat belts and bicycle helmets; partial speed limit reductions; winter speed limits; effective enforcement in general; automated speed control; more severe sanctions with speeding; heightened random breath controls; the introduction of ambulance helicopters; a new driving license system; mandatory winter tires; and the Government's intention to make bicycle helmet use mandatory. Together with an earlier presented infrastructure plan, the Swedish Road Administration made the assessment that it was not able to meet the target for 2000 but that the 2007 target was attainable if the Government allocated sufficiently enough resources.

However, as mentioned above, based on the Swedish Road Administration's reports and recommendation and other initiatives, the 11-point program for road safety was developed. Among other things, what most worth of mention is the first point in the program, namely, investment in the most 100 dangerous national roads in Sweden. A second important thing was the announcement that the Government intended to set up a committee of inquiry to clarify and suggest a more formal responsibility for the system designers in line with the overall direction of responsibility, which is stipulated by Vision Zero. However the Government acted only partially in line with the committee's proposal to implement a formal responsibility (Belin 2012). The Government did not adopt any new legislation, but it rather instructed the Swedish Road Administration to incorporate a road safety inspectorate within their organization. The head for the inspectorate Mr. Lars Bergfalk was appointed directly by the Government and reported directly to the board of the Swedish Road Administration, not to the General Director for the Swedish Transport Administration. In 2001, Mr. Brandborn retired, and Mr. Ingemar Skogö (https://en.wikipedia.org/wiki/Ingemar_Skog%C3%B6) became the new General Director. In 2002, Mr. Björnstig resigned, and Mr. Tingvall returned to his former position. The Swedish Road Administration made a major reorganization of its head office in 2002, and the road safety unit was shut down. Soon after the inspectorate started their activities, it delivered harsh criticism particularly against the Swedish Road Administration for lack of a safety culture (Belin 2012).

Policy Window Opens Up

Despite the strong political support for Vision Zero and its strategies, soon after its adoption dark clouds began to appear in the sky. To go from words to action, e.g., measures for the implementation of Vision Zero, turned out to be more difficult than its proponents had originally expected. Both Ms. Uusmann, within the Swedish Government, and Mr. Tingvall, within the Swedish Road Administration, encountered strong resistance, and when both of them moved to other challenges in 1998, there was a great risk, or if one prefers, a great opportunity, that Vision Zero and its mandated action program would disappear, having flown out of the window or at least would be substantially watered down. However despite Mr. Rosengren's initial hesitation to Vision Zero, the bus crashes in November 1998 and the two crashes in January and February 1999 along with the huge media coverage forced Mr. Rosengren to act. He needed to show political leadership. Furthermore, despite that Ms. Uusmann had left the political scene, the Swedish Standing Committee on Transport and Communications with Ms. Öhman in the forefront was intact and a strong supervisor for Vision Zero and the intermediate target. When we look back in the mirror, it seems like a paradox that a political leader who was perhaps not against

Vision Zero, however, at the least, not a proponent, has most likely become the most important minister when it comes to investments for safety. Instead of approximately SEK 300 million on average per year for the period 1996–1999, the investment increased to an average of SEK 1,888 million per year for 2000–2005. However, most of the interventions in the 11-point program were of long-term nature such as road improvements and initiative of institutional character such as change system designers' responsibility and set up a road safety inspectorate. The 11-point program did not solve the problem. The number of fatalities did not decrease at the rate which is stipulated of the 2007 intermediate target. The road safety inspectorate was not late to point out the lack of progress, and due to media attention and political initiative from the Swedish Standing Committee on Transport and Communications, the Government was forced to act. It was time for a more comprehensive assessment of Vision Zero and its implementation and a discussion about the future direction of the road safety work. Mostly, based on information from the Swedish Road Administration, the Government was confident with Vision Zero and its long-term direction and saw no reason to change its overall policy. However, the Government was more worried about the intermediate target for 2007 and recommended several interventions in order to strengthen the work in order to achieve the intermediate targets such as lower speed limits and increased road user compliance with traffic regulations, especially with automated speed enforcements. The majority in the Swedish Standing Committee on Transport and Communications supported the proposal from the Government; however, the opposition was critical. They were still in favor of Vision Zero as a long-term goal; however, they had strong views on the ways and means to achieve Vision Zero and its short-term targets. Therefore, the unanimous political support for Vision Zero was replaced with a political conflict between a coalition of the Social Democratic Party, Left Party, and Green Party against the Moderate Party, Centre Party, Liberal People's Party, and Christian Democrats. The right wing coalition made a joint reservation and what they were primarily critical about, as they perceived it, was the Government's lack of understanding of the seriousness of the problem and the urgent need for actions. They were especially critical of the Government's failure to develop different financing mechanism such as public and private partnerships. According to the opposition, the probability to reach the 2007 target was non-existent; they recommended therefore that an evaluation should be set up in order to assess the target and the existing road safety work and suggest a new target. The opposition highlighted the need for a mobilization and particular focus also on the individual road users. Although the opposition was unanimous in most of their reservations, some differences could also be discerned – for example, the Moderate Party (Swedish Standing Committee on Transport and Communications 2004) was not too happy about Vision Zero, and they were not in favor of automated speed enforcement in contrast to the Centre Party (Swedish Standing Committee on Transport and Communications 2004). In summary, it was still a great political support for Vision Zero as a long-term goal; however, there were significant political differences of opinion in the appropriate way to move forward (Swedish Government 2004; Swedish Standing Committee on Transport and Communications 2004; Swedish Parliament 2004) (Table 3).

Table 3 Continued action for safe roads. Vote in the Swedish Parliament on the Committee's proposal against the Moderate, Centre, Liberal, and Christian Parties' reservation on 25 November 2004

Party	Yes	No	Refrain	Absent
The Social Democratic Party	115	0	0	29
The Moderate Party, Liberal Conservatism	0	42	0	13
The Centre Party, Centrism, Agrarianism, Social Liberalism	0	18	0	4
The Liberal People's Party, Social Liberalism	0	34	0	14
The Christian Democrats, Christian Democracy	0	26	0	7
The Left Party, Socialism, Feminism	24	0	0	6
The Green Party	14	0	0	3
Total	153	120		76

Discussion

In this chapter, Kingdon's (2003) multiple stream model has been applied to two different decision processes about Vision Zero. The long-term development of the road safety problem in Sweden spoke in favor of adopting a Vision Zero policy. Politically one could argue if this trend continues in the future eventually, we will reach zero. Would it be possible to argue in the same way if the trend was more stable or even going in the opposite direction? Probably not, and that might be the reason why other countries were more reluctant to use the word Vision Zero. A safe system, Toward Zero, might be an easier concept to sell politically. However, it might not just be the number itself which is important politically. Vision Zero signals also another ethical attitude towards the problem. Instead of focusing on an aggregated number, Vision Zero is focused on every single human being affected by road trauma. Everyone has the right to safe mobility.

In Sweden, road safety in general and Vision Zero in particular are largely attached to the post-war project to create a modern welfare state and thereby to the Social Democratic Party. Vision Zero is an example of a policy that strives for everyone to have an equal right and access to safety along with governmental responsibility to ensure that all citizens have the same access to and possibility of safe mobility. Even though Vision Zero was proposed by the Social Democratic Party, it generally has substantial support also among the other political parties in the Swedish society, as there is a general agreement for our welfare state. However even though most parties are in favor of and support Vision Zero, it is more uncertain if any another political party would have pursued Vision Zero so strongly as new public policy.

Vision Zero as a concept is very much associated with Professor Tingvall and his expert fellows. However, without political support, his ideas would probably have ended up on a bookshelf. According to Kingdon, basically a window opens because of a change in the political stream or because a new problem captures the attention of governmental officials. It seems that both the political and the problem stream supported the opening of the policy window for Vision Zero. Minister Uusmann's announcement already in January 1995 opened a formal path to develop a new road safety policy, and the positive road safety trend made it possible to discuss Vision Zero rather than simply just seeking to improve the situation. Although both Professor Claes and Ms. Uusmann played key leading roles, it must be noted that they were supported or worked closely with a few policy entrepreneurs within both the Ministry and the public administration to ensure that their ideas were developed and written out. Despite a fast and smooth process and decreasing of controversial proposals, Vision Zero was almost stopped in the last minute in 1997 because of an internal discussion within the Government about Vision Zero and its realism. However, the Government decided to pursue the proposal due to the fact that Vision Zero had already been mentioned in an earlier proposal to the Parliament on road investment. In that proposal, the Government promised to come back and describe Vision Zero in more detail.

Eventually most of the principles that underpin Vision Zero found their way to the final decision in the Parliament, and a new phase in the Vision Zero policy process has begun to transfer overall principles to concrete actions. In line with was predicted by road safety experts, when Sweden started to recover from its economic recession and get back to a normal economic growth, the number of fatalities flattened out and started to increase. Although some activities, mainly of a process character, had been started, the implementation of Vision Zero was not an easy task either politically or among the most important implementation agency, the Swedish Road Administration. The policy window slowly began to close, however was suddenly widely opened due to some tragic events. If this window had opened earlier before the adoption of Vision Zero, the recommendations would have almost certainly only been focused on how to improve the road users' capability to handle minibuses and slippery roads. As a matter of fact, the only recommendation the road safety lead agency, the Swedish Road Administration, suggested was new licensing requirements for driving a minibus (TT 1999). However when the 11-point program on road safety was present in April 1999, the first action point was dedicated to road safety investment on the state road network. The policy initiative was moved from the lead agency to the highest political level, and the recommendation came from the outside. Even an insurance company, Folksam, pushed for more investment in the 2+1 roads (TT 1999). Most of the recommendations in the 11-point program were of long-term nature, and despite significant amounts of micro-successes where a middle barrier was put up, it was still a small part of the network in the beginning of 2000. Therefore, due to the problem stream and political pressure from the Swedish Standing Committee on Transport and Communications, road safety stayed as a topic on the agenda and forced the Government to ask the Swedish Parliament for new trust in Vision Zero and its stipulated way to eventually achieve a safe road transport system. Even though the Government still had a strong political support for Vision Zero as a long-term goal, there was less political support how this long-term goal should be achieved and if and what interventions are needed to be put in place in order to attain the intermediate target for 2007. Thus, it seems that road safety politics is not about goals but rather more about how these goals and intermediate targets should be accomplished. Despite some differences in nuance, all political parties agreed upon a stronger focus on individual road user behavior in order to achieve Vision Zero and short-term targets. This is a potential challenge to one of the core aspects of Vision Zero, namely, it is the system designers who are overall responsible for road safety. The biggest difference between the different parties seemed to be how important speed interventions are, compared to investment in infrastructure. The Government with support of the Left Party and the Green Party seems to be more in favor of speed reduction intervention. The right wing parties would instead like to see more investments. It seems that the road safety measures that the political parties prefer and prioritize have a strong correlation with other transport policy priorities. If the political parties put more emphasis on environment, there is a tendency to assign a higher priority to speed reduction interventions. If the political parties give more priority to mobility, primarily for motorized traffic, it is a tendency to prefer investments. Based on these analyses of two political decision processes, it could be concluded that there is a strong political consensus about Vision Zero; however, the path forward is highly sensitive, at least in the short run, and what route to choose depends very much on other transport policy goals. Therefore it is a risk that safety becomes a pseudo argument for something else. For example, motorways are comparatively safe however also good from a mobility perspective. However they are very expensive, and the same safety level could be reach with the 2+1 roads. Increasing the compliance of speed limits will improve the safety and also improve the air quality; however, this solution might not be a solution for a safe system without any health losses in the long run. The ongoing Vision Zero policy process is summarized in Fig. 3.

Epilogue

The target for 2007 to halve the number of fatalities from 1998 was missed by more than 200 fatalities, compared to what the target stipulated. In 2006, the Social Democrat Party was voted out of office, and Mr. Fredrik Reinfeldt (https://en.wikipedia.org/wiki/Fredrik_Reinfeldt), leader of the Moderate Party, becomes Prime Minister, and for the first time since 1991, a center-right wing Government was set up. Ms. Åsa Torstensson (https://en.wikipedia.org/wiki/%C3%85sa_Torstensson), from the Centre Party, became Minister for Infrastructure. The road safety work was evaluated thoroughly (Breen et al. 2007; Swedish Road Administration 2008) however politically, even with the new center-right wing Government who when they were in the opposition had been critical of the former Government and its policies, retained Vision Zero as a long-term goal and they concluded, among other things, that Sweden is in the 'establishment' phase of its journey towards Vision Zero. The next challenge, in view of Sweden's highly ambitious goal, is to achieve rapid 'growth' in the delivery of accountable, well-orchestrated, and effective Vision Zero activity. In addition a new intermediate target for 2020 was adopted – a 50% reduction which meant no more than 270 fatalities per year by 2020. Despite the failure to attain the intermediate 2007 target, from 2002 until about 2013, Sweden

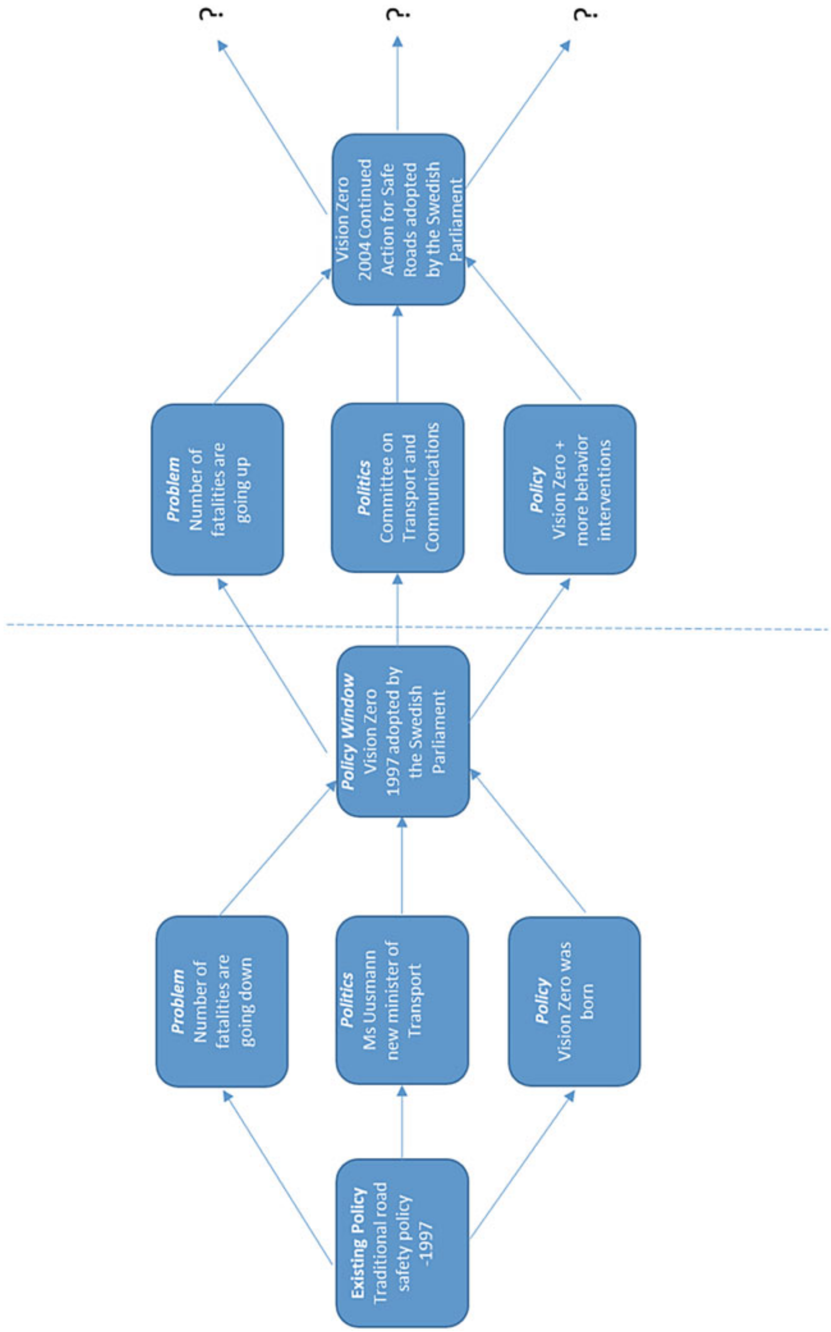

Fig. 3 Vision Zero a continuous public policy process

experienced a downward trend, and the number of fatalities was reduced by more than 50%. Investment in the 2+1 roads, automated traffic safety cameras, lower speed limits, and safer vehicles, together with other interventions, contributed to this downgoing trend (Fridtjof and Vadeby 2007; Strandroth 2015). However, even though Sweden was affected to a lesser extent by international standards, the economic crisis of 2008 and adjustment of the official statistics to separately report suicides in 2010 also contributed to this positive trend. Fairly immediately after the new Government took office in 2006, they initiated a large organizational reform work in the transport sector. This work seems to be guided on at least three important principles, integrated transport system, strict Government mandate, and market-driven production (Swedish Transport Administration 2015). First out was the formation of the Swedish Transport Agency responsible for regulation and inspection activities of all transport modes. The Swedish Transport Administration responsible for planning of the whole transport system and building and maintaining road and railway infrastructure was set up in 2010. Probably due to the fact that road safety was continuously improved, Vision Zero and how to organize an effective institutional arrangement for safety were not on the reform agenda. Even the road safety inspectorate, which was a fairly new organization, was dissolved. No lead agency for safety was designated or pointed out by the Government. In 2014, the Social Democratic Party returned to power however this time together in a Government collaboration relying on the Green Party. This new Government had a rather weak position within the Parliament, and when the whole opposition was united they could topple the Government. Since 2010, there was a tendency that the steady downward trend was plateauing, and the new Government decided to draft a new policy document, renewing their commitment to Vision Zero. In 2016, the Government announced its decision to re-launch Vision Zero (Swedish Government 2016), an intensified initiative for transport safety in Sweden. Based on this policy document, they also commissioned the Swedish Transport Administration to leading the road safety collaboration to achieve Vision Zero. This is the first more comprehensive discussion about Vision Zero and its direction from the Government since 2004. However this new policy document was never directly formulated into a Governmental proposal and sent to the Parliament for consideration. The reason for this might be that the Government would like to avoid the risk that this strategy would end up as a political discussion in the Parliament which they could lose. In any event, this is an important step in an ongoing policy process in the shaping of Vision Zero as a public policy and its implementation.

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Vision Zero in Norway

9

Rune Elvik

Contents

Abstract

This chapter describes the adoption of Vision Zero in Norway and some of the impacts on transport safety policy that can be traced to it. These impacts concern the following:

1. the demand for improved knowledge about the effects of road safety measures,
2. the creation of a new forum for developing road safety policy,
3. the adoption of quantified road safety targets and a system for management by objectives based on road safety indicators,
4. the identification of roads suitable for conversion to motorways or to 2+1 roads based on the Swedish model,
5. the revision of speed limit policy and
6. the revision of standards for the design and use of guardrails.

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It is argued that the adoption of Vision Zero has had a major impact on road safety policy in Norway and may have contributed to speeding up the decline in the number of traffic fatalities and serious injuries after the year 2000.

Keywords

Norway · Quantified targets · Policymaking · Fatality trends · Evidence base

Introduction

In 2000, the National Transport Plan for Norway for the term 2002–2011 was presented. The plan was the first of its kind, i.e. the first long-term plan that included all modes of transport. Previously, separate plans had been made for each mode of transport, with no attempt to coordinate policy for all modes of transport. In the National Transport Plan (Samferdselsdepartementet 2000), the Ministry of Transport stated:

> The Ministry will give higher priority to road safety measures in the 2002–2011 planning term. The basis for doing so is a vision of no fatalities or permanent injuries in road traffic.

Before the adoption in The Parliament (Stortinget), the Transport and Communication Committee stated (Stortinget 2001):

> The Committee notes that the Government will base road safety policy on a vision of no fatalities or permanent injuries in road traffic. The Committee shares this vision.

Stortinget approved Vision Zero in February 2001 as part of the first National Transport Plan (Stortinget 2001). It has later been clarified that Vision Zero applies to all modes of transport in Norway. Vision Zero has unanimous political support. All political parties endorse it.

Fatality Trends Before and After Vision Zero

Figure 1 shows the annual number of traffic fatalities in Norway from 1970 to 2019. The highest number ever recorded was 560 in 1970. In the years before the adoption of Vision Zero, there was an irregular downward trend, corresponding to a mean annual decline of 2.1% in the number of fatalities.

After the adoption of Vision Zero, the annual decline in the number of traffic fatalities in Norway has accelerated to 6.1%. The lowest number of fatalities recorded before the adoption of Vision Zero was 255 in 1996. In the 19 years from 2001 to 2019, the number of fatalities has been lower than 255 in 14 years, including all years after 2008.

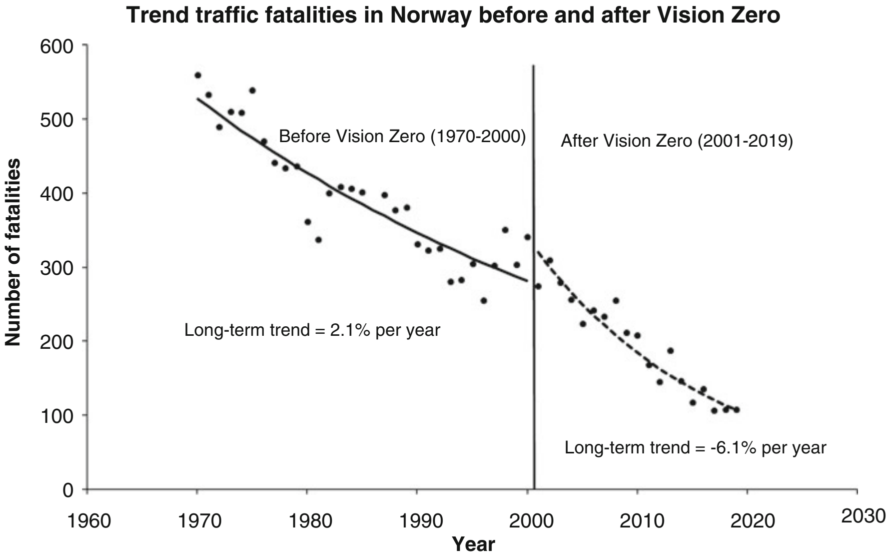

Fig. 1 Trend in traffic fatalities in Norway before and after Vision Zero

Obviously, these numbers by themselves prove nothing. However, they at least show that progress in improving road safety in Norway speeded up after Vision Zero became the long-term ideal for transport safety. It may be noted that the annual trend in the period before the adoption of Vision Zero was the same, a decline of 2.1% per year, even if the trend refers to data for the last 19 years of the period, 1982–2000, rather than 1970–2000. Is it possible to identify specific policies or measures taken that may explain the more rapid decline in fatalities after 2001 than before?

Demand for Updated Knowledge

The Institute of Transport Economics published the first edition of the *Handbook of Road Safety Measures* (Pedersen et al. 1982) in 1982. Updated editions were published in 1989, 1997 and 2012. Since 2000, an online edition of the *Handbook* is continuously being updated. To make road safety policy more evidence-based, the *Handbook* has been supplemented by a report written specifically to serve as input in the development and revision of the National Transport Plan, a catalogue of effective road safety measures. The catalogue of measures was, in its current form, first published in 2002 (Elvik and Rydningen 2002). Updated editions were published in 2006 (Erke and Elvik 2006), 2011 (Høye et al. 2011) and 2017 (Høye 2017).

This means that updated estimates of the effects of road safety measures are now systematically produced to serve as a basis for planning these measures. Particular emphasis is put on showing effects on fatalities and serious injuries, as these are the types of injuries that Vision Zero seeks to eliminate. The regular updating of the catalogue of effective road safety measures provides a basis for an evidence-based road safety policy. Many of the road safety measures implemented after 2001 have clearly been evidence-based; at the same time, some measures for which evidence of effects is less clear continue to be used (more on this in the next section).

A New Forum for Road Safety Policymaking

The National Transport Plan does not describe road safety measures in great detail. Moreover, it includes only measures for which road authorities are responsible, not education and training or police enforcement. A need was therefore felt for creating a new forum for road safety policymaking in addition to the system set up for developing the National Transport Plan.

Starting in 2002, detailed road safety programmes for four years have been developed as a supplement to the National Transport Plan. The lead agency for developing and following up of the plan is the Norwegian Public Roads Administration. The current plan, covering the years 2018–2021 comprises 136 road safety measures (Statens vegvesen et al. 2018). The plan has been developed by the Public Roads Administration, the Police, the Norwegian Council for Road Safety, the Directorate of health, the Directorate of education, the Association of municipalities and representatives of large cities and counties in Norway. All these bodies have signed the plan. Implementation is monitored annually.

The plan embodies the system of management by objectives created for road safety in Norway. This system is presented in the next section. The measures included in the current road safety plan are a mixture of very specific measures for which expected impacts can be estimated and more general measures whose effects are more difficult to quantify. Examples of measures belonging to the first group are as follows:

> Measure 101: During 2018–2021 approximately 192 km of four lane divided motorways will be built.
>
> Measure 102: During 2018–2021 median guardrails will be installed on 40 km of road with two or three lanes.

Examples of measures of a more abstract nature include the following:

> Measure 17: The police will consider using the method "conversations about matters of concern" together with municipal social workers as an element of advice to and treatment of repeat offenders.
>
> Measure 123: Counties and major cities will encourage active cooperation between public agencies and organisations in order to join forces and work towards improving road safety at the regional and local levels.

While these measures may have value, they are somewhat vague and non-committal (the police will 'consider'; counties and major cities will 'encourage'), and the results expected by implementing the measures are not described.

It is nevertheless reasonable to assume that, by (1) establishing a broad consensus on road safety policy, (2) involving as many stakeholders as possible, (3) asking each stakeholder to commit itself to implementing at least one road safety measure and (4) establishing annual monitoring of progress, it becomes more likely that effective road safety measures will be implemented than if road safety policy lacks one or more of these elements.

Quantified Road Safety Targets and Management by Objectives

For a long time, Norwegian politicians were opposed to setting quantified targets for reducing the number of fatalities and serious injuries. This has changed after the adoption of Vision Zero. In the most recent National Transport Plan (2018–2029), a target has been set of reducing the number of killed or seriously injured road users to a maximum of 350 by 2030. Figure 2 shows the actual number of killed or seriously injured road users registered by the police from 2000 to 2019 and the targeted decline until 2030.

There were 673 killed or seriously injured road users in 2019. The target for 2024 is a maximum of 500 and the target for 2030 a maximum of 350. As can be seen from Fig. 2, the recorded number of killed or seriously injured road users during 2014 to

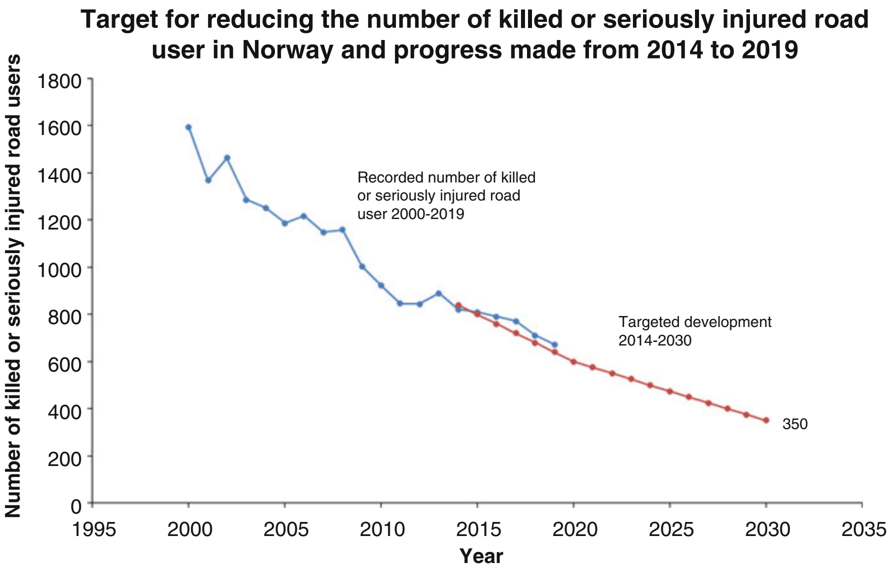

Fig. 2 Quantified road safety target for Norway for 2030

2019 was slightly above the target numbers. The trend is, however, closely parallel to the targeted development.

In addition to the overall target for reducing the number of killed or seriously injured road users, a comprehensive set of safety performance targets has been set based on safety indicators. These targets include amongst others compliance with speed limits, compliance with blood alcohol limits, seat belt wearing, wearing of bicycle helmets and use of reflective devices. These targets reflect high ambitions for improving road safety, and progress has been made in realising some of them. More specifically, compliance with speed limits has increased from 45.6% in 2006 to 62.1% in 2019 (Statens vegvesen et al. 2020). Seat belt wearing in front seats of passenger cars has increased from 89.8% in 2004 to 97.4% in 2019. However, it should be noted that (1) there are very many targets and (2) it is not always clear what action must be taken to realise the targets (Elvik 2008). The guidance provided by the system of management by objectives could be enhanced if, for each target, an analysis of the measures that should be implemented to realise the target was also included.

Converting Roads to Motorways or 2+1 Roads

An innovative road safety measure, inspired by Vision Zero and first tested in Sweden, is 2+1 roads. When Vision Zero was adopted in Norway, an inventory was made of roads that could either be converted to motorways or to 2+1 roads. The 2+1 solution was judged as suitable for 1340 km of road, of which 340 km had been built by the end of 2018 (Statens vegvesen 2019). Motorways (four-lane divided roads) were judged as suitable for 1100 km of road (this included motorways that had already been built). The building of motorways has expanded considerably in Norway after Vision Zero was adopted. Figure 3 shows how the length of motorways has developed from 1962 to 2018.

It is seen that growth in motorway length has been more rapid after 2000 than before. The rapid growth in the length of motorways will continue in the coming years. An evaluation study (Elvik et al. 2017) concluded that a new motorway in the county of Østfold reduced the number of fatalities and serious injuries by 75%.

2+1 roads are considerably more difficult to build in Norway than in Sweden. Sweden had a large network of the so-called “13 metre” roads that could easily be converted to 2+1 roads by means of road markings and wire guardrails. Norwegian roads are narrower. To allow for 2+1 lanes, most of these roads need to be widened, which adds to the cost and complexity of the projects. There are median guardrails on a few two-lane roads, but the use of median guardrails on two-lane roads is restrictive, as there is a risk that the roads gets blocked in case of an accident, making it difficult for police and rescue services to get to the site of the accident.

New Speed Limit Policy

According to the biomechanical foundations of Vision Zero, speed limits should be no higher than 30 km/h in places where pedestrians can be struck by motor vehicles, no higher than 50 km/h in places where side impacts between cars of equal mass may

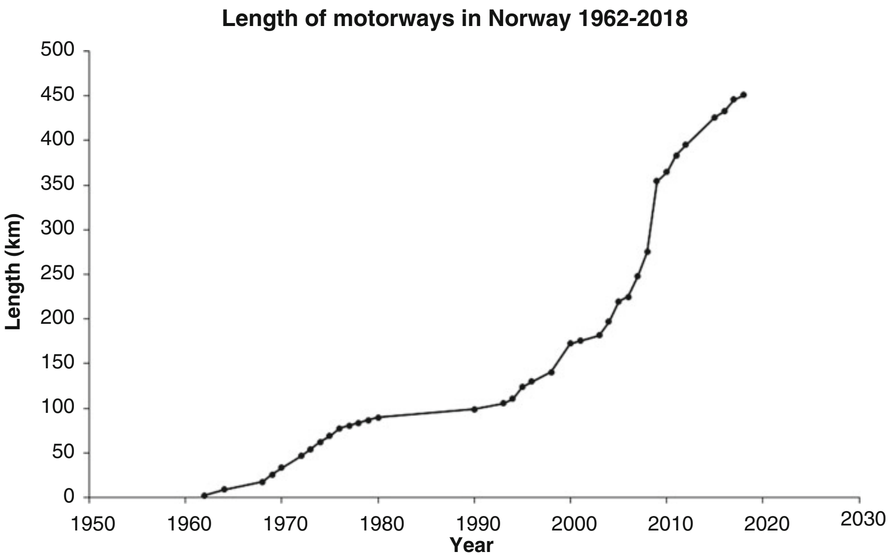

Fig. 3 Length of motorways in Norway 1962–2018

occur (junctions) and no higher than 70 km/h in places where frontal impacts between cars of equal mass may occur. On roads where there are no pedestrians or cyclists, no at-grade junctions and a physical separation or safety barrier between opposite directions of travel, Vision Zero allows for higher speed limits, like 90 km/h or more. When Vision Zero was adopted in Norway, speed limits were 50 km/h in urban areas and 80 km/h outside urban areas.

A review of speed limit policy was initiated. As a basis for the review, a new approach to estimating road safety was introduced. This was the empirical Bayes approach to road safety estimation, based on accident prediction models first developed in 2002 (Ragnøy et al. 2002) and updated in 2014 (Høye 2014) and 2016 (Høye 2016). Road sections that had a high expected number of fatal or serious injury accidents were identified. In 2001, speed limits were lowered on these road sections, from 90 to 80 km/h on 393 km of road and from 80 to 70 km/h on 741 km of road (Ragnøy 2004; Christensen and Ragnøy 2007). The mean speed of traffic was reduced, respectively, from 85.1 to 82.2 km/h and from 75.3 to 71.2 km/h. The number of fatalities was reduced by 34% on roads where the speed limit was lowered from 90 to 80 km/h and by 29% on roads where the speed limit was lowered from 80 to 70 km/h. It can be estimated that lowering the speed limit from 80 to 70 km/h reduced the annual number of fatalities by about 7. The reduction of the speed limit from 90 to 80 km/h was estimated to reduce the annual number of fatalities by about 2. The use of 70 km/h on rural road sections with a high expected number of fatal or serious injury accidents is now an integrated part of speed limit policy in Norway.

Speed limits of 30 or 40 km/h are increasingly introduced in urban areas (Bjørnskau and Amundsen 2015). On some motorways, speed limits have been increased from 90 to 100 or 110 km/h. There has been a tendency for the mean speed of traffic to go down in Norway after 2006. Based on updated estimates of the relationship between speed and road safety (Elvik et al. 2019), the tendency for speed to go down may have reduced the number of fatalities by close to 20% from 2006 to 2019.

Criteria and Design Standards for Guardrails

An important element of roads that came under scrutiny early following the adoption of Vision Zero was guardrails. Formal criteria for the use and design of guardrails have long existed. In 2001, a research project was carried out to revise these criteria (Elvik 2001). The criteria for using guardrails were liberalised, meaning that installing guardrails would be warranted at more sites with the new criteria than with the old.

An important change in the design guidelines concerned guardrail end design. Before the change, the most common design in Norway was the so-called turned down design, shown in Fig. 4 (Gjerde 2008). This design could act as a launching pad for a striking car. The car would climb up the slope of the guardrail and be launched into the air, landing perhaps far away from the point where the guardrail was struck. This design of guardrail terminals has been found to be associated with a high share of fatal and serious injuries (Elvik 2001).

As a result of the revision of the design standards for guardrails in Norway in 2001, the turned down design is no longer permitted on new roads or when replacing

Fig. 4 Turned down guardrail terminal. (Photo: Marianne Gjerde (2008))

Fig. 5 Flared out guardrail terminal attached to backslope. (Photo: Marianne Gjerde (2008))

guardrails on existing roads in rural areas. Guardrail ends should be flared out and attached to a backslope or designed to redirect a vehicle to a safe zone outside the road. This design is shown in Fig. 5.

Other Developments

There have been a number of other developments in road safety policy in Norway after 2001 that most likely have contributed to reducing the number of killed or seriously injured road users. The use of speed cameras and section control (two or more connected speed cameras monitoring a road section) has expanded. These measures are highly effective in reducing the number of killed or seriously injured road users (Høye 2015a, b).

Per se limits for the concentration in blood of medicines and illegal drugs were introduced in 2012 and expanded in 2016. Roadside surveys (Furuhaugen et al. 2018) show that the amount of driving with illegal concentrations of medicines or illegal drugs was reduced from 2009 to 2017.

In-depth studies of fatal crashes started in 2005 and are made both by the Public Roads Administration and the Accident Investigation Board of Norway. The reports on fatal crashes contain recommendations for safety measures, whose implementation may reduce the chances of similar crashes in the future.

A Road Safety Inspectorate was created in 2012. Its mandate is to monitor the compliance with safety standards for roads, as given, for example, in design standards and guidelines for the use of traffic control devices. It publishes inspection reports where deviations from safety standards are noted and recommendations for improving compliance are given.

Discussion and Conclusions

When Norway adopted Vision Zero in 2000–2001, progress in improving transport safety appeared to have stagnated. The number of road traffic fatalities in 2000 was 341, the second highest number in 10 years and considerably higher than the annual average for 1990–1999, which was 306. A major ferry accident in late 1999 killed 16 people. A major train crash in early 2000 killed 19 people. The crash of a Russian flight on Svalbard in 1996, killing 141 people (all of whom were Russian mine workers), was still fresh in memory. A pressure was felt for taking bold initiatives to reinvigorate transport safety policy.

Sweden had adopted Vision Zero in 1997, and doing the same in Norway was widely regarded as an attractive idea. When the Ministry of Transport proposed to adopt Vision Zero as the long-term ideal for transport safety, there was unanimous political support for this. Within the two first years, this had an impact on speed limit policy and on criteria for use and design of guardrails. Other policy innovations took somewhat longer to materialise. The four-year road safety programme was first developed in 2002. The system of road safety management by objectives was developed at the same time, but quantified targets for reducing the number of fatalities and serious injuries did initially not get political support. A quantified target for reducing fatalities and serious injuries was approved in the National Transport Plan for the 2010–2019 term and has had political support since then.

On the whole, after the adoption of Vision Zero, road safety policy has become more evidence-based, based on quantified targets, based on a more detailed planning of road safety measures and embedded in an institutional framework ensuring consensus on goals and measures. Was this just a coincidence or was it brought about by the adoption of Vision Zero? History, unfortunately, does not produce a control group. It is impossible to know what would have happened in Norway if Vision Zero had not been adopted. It is a fact that road safety in Norway has been greatly improved after 2000. A complete account of the factors contributing to this improvement cannot be given. However, it is not unreasonable to think that it can, at least in part, be credited to a better-informed road safety policy, inspired by Vision Zero.

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Sustainable Safety: A Short History of a Safe System Approach in the Netherlands

10

Fred Wegman, Letty Aarts, and Peter van der Knaap

Contents

Abstract

Although it has never been a real top priority, road safety is an important issue in the Netherlands and much progress has been made. In the last 50 years, the country experienced an enormous growth in population (+30%) and in kilometers travelled (+300%), but the mortality rate dropped by 80%. Many effective interventions were taken. Over time, new insights in traffic risks and causes of crashes led to the adoption of a new road safety vision in the early 1990s: Sustainable Safety, the first attempt worldwide of a Safe System approach (1992). This vision was inspired by the UN-Brundtland report Our Common

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Future (1987) and applied to road safety. Its basis originated in the knowledge and experiences in the decades before.

In a sustainably safe road transport system, risks of crashes and serious injuries are drastically reduced or even eliminated by an infrastructure that is adapted to the limitations of human capacity by proper road design, by vehicles fitted with ways to simplify the tasks of man and constructed to protect the vulnerable human being as effectively as possible, and by road users who are adequately educated, informed, and, where necessary, controlled. If crashes still do occur, serious injuries must be excluded. The vision Sustainable Safety has been translated into a set of characteristics and into Sustainable Safety principles.

Sustainable Safety was welcomed by Dutch road safety professionals and received great political support. A massive implementation program was initiated and carried out as from 1995. Many stakeholders were engaged. An evaluation study covering the period 1998–2007 revealed a 30% reduction in the number of fatalities. Benefits of the investments were four times higher than costs. Sustainable Safety empowered and strengthened the Dutch road safety research community and heavily influenced the discourse on road safety in the country.

As from 2000, several developments (a different planning structure of road transport, less political priority for road safety – perhaps as a result of successes in the past – and decentralization of policies) caused that Sustainable Safety became less prominent and safety effects less visible. However, the vison and the principles remain a solid basis for making progress towards a casualty-free road transport system and to respond to new developments, such as a changing demography, changing transport modes and traffic patterns, and new technologies. Two more editions have been published (2005 and 2018). Results and impacts are being discussed.

Keywords

Safe system approach · Crash causation · Safe system principles · The Netherlands · Implementation

Introduction

The rapid reconstruction of the Netherlands after World War II was accompanied by an annual economy growth of about 4% (1950–1975). A similar growth was also to be observed in other Western European countries. This prosperity growth was accompanied by a growth in car mobility. On a population of ten million, the number of passenger cars increased from about 150,000 in 1950 to 500,000 in 1960, and to nearly 2.5 million vehicles on a 13 million population in 1970 (Harris 1989). The number of cars has now grown to 8.5 million, which means that 1 in 2 people in the Netherlands owns and drives a car.

In the twentieth century, the main transport modes in the Netherlands were cycling, walking, or public transport, but gradually the car took over public space.

The Netherlands has traditionally been a bicycle country and now has more bicycles than inhabitants: there are 23 million bicycles on a 17 million population. Almost 40% of the bicycle kilometers are for recreation and sport; the remaining more than 60% are for commuting, cycling to and from school (the vast majority of high school students – 12–18 years old – cycle to school), and for shopping (Harms and Kansen 2018). In 1950, one in two Dutch people owned a bicycle and that share remained constant until well into the 1960s. The passenger car became increasingly popular during this period and displaced the bicycle. Somewhat exaggerated we could say that in the 1960s, the bicycle was only used by those who could not or were not allowed to drive a car: school children, housewives, elderly, and those who did not (yet) have a driving license.

The growing popularity of the car led to a demand for more space for cars. This was found in expanding the street and road network, particularly the extension of the motorway network. The length of the motorway network enjoyed explosive growth and, in the densely populated Netherlands, is longer per square kilometer more than anywhere in the world. After the British motorways, the motorways in the Netherlands are the most heavily used worldwide.

But remarkably, public space being increasingly dominated by passenger cars led to a social reaction as early as the early 1970s. The car required more space (for driving and parking), but in the historic cities of the Netherlands (which experienced spectacular growth in the seventeenth century, when the Netherlands was an economic and political “world power”), the extra physical space could hardly be found and citizens were increasingly opposed to making the necessary changes. The tension between traffic and livability in towns and villages became an issue. It was the period in which civil society organizations did not want to subject to the passenger car becoming increasingly dominant, at the expense of the space for cyclist and pedestrian. Organizations dedicated to making school routes and the school environment safer could count on strong support. It was the period when cities prioritized the use of public transport and a start was made with the construction of tram and bus lanes. It was the period when “woonerf’s” were created in the Netherlands, later followed by traffic calming (30 km/h) zones. The social developments outlined here were certainly not dominated by road safety considerations, but they certainly played a role.

Recent decades have been characterized by further growth in mobility, although the growth rate has fallen significantly and we observe hardly any growth in the last decade (KiM 2019). Congestion, particularly on the motorways, is perceived as worrying, but by citizens do not consider congestion as a major problem in Dutch society (KiM 2020). The Netherlands is a country of cyclists with more bicycles (23 million) than inhabitants (17 million). More than 25% of all trips are cycle trips (Harms and Kansen 2018). Separate cycling facilities are very popular and the expansion of these facilities, both within and outside cities, is impressive (Harms and Kansen 2018). Use of public transport was growing with 10% between 2010 and 2018 (KiM 2019). Freight transport by road increased dramatically over the years, with, for example, by almost 50% in kilometers travelled between 1999 and 2008 (Tavasszy and Ruijgrok 2013) and 12% between 2010 and 2018 (KiM 2019).

This is the context in which the history of road safety in the Netherlands is studied: a country with high population density, a high-quality and greatly expanded road infrastructure, where the available space is shared by motorized traffic, vulnerable road users (pedestrians and cyclists), and public transport. Road congestion, environmental problems (emissions and noise), and road safety require political attention and funding. This chapter discusses road safety development in this drastically changing road transport environment in recent decades.

This chapter starts with a brief outline of road safety in the Netherlands. We will then go deeper into the causes of road crashes as an introduction (and explanation) of the Netherlands opting for a Safe System approach in the late 1980s/early 1990s. In the Netherlands, the name Sustainable Safety was given to this approach. The Sustainable Safety vision will then be discussed according to the three editions of the vision that have so far been developed and published (1992, 2005/2006, and 2018). The development, as well as the implementation and evaluation results of the vision will be discussed. The chapter concludes with a reflection on almost 30 years of Sustainable Safety in the Netherlands.

Road Safety in the Netherlands: A Success Story

The number of road fatalities increased from about 1000 road deaths in 1950 to 3264 fatalities in 1972, a record height. This negative development was certainly cause for concern in Dutch society. It is striking that it was not the government that called for action, but civil society organizations, particularly the Dutch Touring Club ANWB (Bax 2011). The government did not join until later. This striking phenomenon is not so easy to explain. The following reasoning may, however, be plausible: the growth of motorization was considered a positive development because it went hand in hand with an intended growth of prosperity and well-being among the Dutch population. Negative consequences such as the growth in the number of road crashes and the number of road casualties were considered an unavoidable price that had to be paid.

In addition, there may have been another argument for the government not to intervene. It was generally accepted that road crashes were dramatic, but exceptional incidents, the cause of which was to be found mainly in humans who were inattentive and careless. More careful behavior was believed to result in fewer crashes (Asmussen 1983). Campaigns were used to call on the Dutch road user to act as “A gentleman in traffic” and thus to contribute to reducing the number of road casualties. Until the 1970s, a classic difference of understanding can be observed between “left-wing” and “right-wing” politicians: the political “right” primarily considered road crashes as a responsibility of the individual. Policy should call on road users to take that responsibility using laws and regulations and their enforcement. There was limited need for intervention from the government. The political “left” saw road crashes as a problem for vulnerable citizens (pedestrians and cyclists) who suffered from the behavior of “strong road users,” mainly drivers of passenger vehicles.

In the 1960s and 1970s, the scale of the problem of road safety certainly became clear in the Netherlands and a multitude of activities were developed to improve the situation. It is remarkable, however, that in a comparison between Sweden, the United Kingdom, and the Netherlands (the SUN countries, the best-performing countries in the world in the field of road safety) which was carried out in the SUNflower project (Koornstra et al. 2002), the Netherlands had a mortality rate of around 25 road deaths per 100,000 inhabitants and Sweden and the United Kingdom of around 15. This difference was eliminated in the following 20 years. There are a couple of possible explanations: the Netherlands was rather late to improve road safety or, secondly, road safety policy in the period 1970–1990 was more successful in the Netherlands than in both other countries. We tend to the first explanation, but whatever the explanation: in the period 1970–1990, the number of road deaths, mortality (deaths per 100,000 inhabitants), and traffic risk (deaths per motor vehicle-kms travelled) decreased significantly (60% fewer annual road deaths in 20 years). A third explanation, however, might be that the introduction of mandatory helmet use for riders of motorized two-wheelers (1972/1975) reduced not only the risk to be injured but also the exposure. In a relatively short period of time, the number of mopeds decreased with two-thirds, as did the number of moped fatalities (SWOV 2007).

During the same period (1970–1990), the policy interest in road safety increased considerably which was mainly reflected in a substantial amount of legislation (alcohol, speed limits, seat belts, helmets for motorcyclists and moped riders). A separate Road Safety Agency was set up at the national level, after an initiative from Dutch Parliament, a Road Crash Registration Department was established within that Agency and an independent Road Safety Council, led by Prof. Pieter van Vollenhoven, was established. Through an annual government subsidy, SWOV also acquired considerable leverage and acted as a driving force to support road safety policies.

In the late 1980s, however, the decrease in the number of road deaths did not continue and new initiatives were considered necessary. The national government drew up strategic plans with great frequency. It is worth noting that one of those plans announced that it was necessary to work with a quantitative target (−25% for the period 1985–2000). Not much later, it was decided to aim for −50% in the period 1986–2010. Road safety was on the rise in the Netherlands. In 1989, a book (Wegman et al. 1989) was published which drew up the balance of a large number of road safety issues. It also indicated where further profits could be made. However, one of the comments was that these were all isolated road safety issues and proposed measures that lacked a fundamental understanding of road crashes. Road safety plans at the time were basically a long list of individual measures and interventions. There was no cohesion between the various road safety issues and interventions and they also lacked a general vision of how proposed measures could be effectively implemented.

In this period (the late 1980s), road safety was given less policy priority by the Dutch government. This might be related to the impressive reduction in the number of road casualties in the 1970s/1980s after which policy attention could shift and actually did shift to other issues, such as combating congestion. In an interview in the staff magazine of the Ministry of Transport and Water Management in May 1992, the then director of road safety in the Netherlands, Paul Hamelynck, says: “In the notes and speeches that end up on my desk, my field gets too little attention. In a whole series of notes on traffic and transport, I didn’t even once come across the word road safety.”

SWOV Institute for Road Safety Research was then invited by the Ministry’s Road Safety Agency to develop a new vision for a road safety approach. Three issues were to be central to this vision: an in-depth analysis of why traffic leads to so many annual traffic casualties (numbers that are considered unacceptable in other transport modes such as rail transport and aviation), a vision of what significantly safer road traffic might look like, and, finally, along which lines that significantly safer road traffic could be established. Informal contacts with Swedish colleagues working on Vision Zero was a source of inspiration for both countries.

SWOV decided not to carry out this work by itself but enlisted the help of other researchers. Practitioners and representatives of government and interest organizations were invited to support this process. And together, they created a first version of a “System Approach” for road safety. The published book was named “Naar een Duurzaam Veilig Wegverkeer; Nationale verkeersveiligheidsverkenning 1990/2010” (Towards a Sustainably Safe Road Traffic; National Road Safety Outlook 1990/2010). The book was also referred to as the “Purple book,” due to the color of the cover. During the years 1990/1992, a large number of people worked on this book, and it was published on the occasion of SWOV’s 30th anniversary. It is noteworthy that the Road Safety Policy Plan which was released in 1991 (note, one year earlier!) introduced Sustainable Safety as one of the policy pillars, alongside six traditional spearheads for policy (driving under the influence of alcohol, safety devices such as seatbelts, airbags, child seats, and crash helmets, speed, hazardous situations (high-risk locations), cyclists, and heavy traffic). The authors of the Policy Plan could take a sneak preview!!

Before introducing Sustainable Safety, it is useful to take a closer look at how crash causation was looked at over the years, also in the perspective of crash prevention. This is of interest because Sustainable Safety set out to introduce a new way of thinking about crash causation and crash and injury prevention, based on literature on risk management (for example, by Jens Rasmussen) and human factors (Reason 1990). In the course of the previous century, the thoughts on road crash causation did certainly not remain unchanged. Thinking about this was crucial in developing the new vision.

Causes of Crashes

A rather comprehensive description of various road safety paradigms in the twentieth century can be found in an OECD report (OECD 1997). The concept of paradigms and paradigm shifts has been introduced by Thomas Kuhn in his 1962 publication “The Structure of Scientific Revolutions” (Kuhn 1962). He defines a paradigm shift as a fundamental change in the basic concepts and experimental practices of a scientific discipline. The concept of paradigm shift is certainly applicable when it comes to road safety. The OECD paradigms for road safety were later used in, for example, a history of road safety research (Hagenzieker et al. 2014; Hakkert and Gitelman 2014). The OECD classification has also been supplemented in order to characterize crash causation as used in road safety policies over a certain period of time. The four paradigms in the OECD report are: (1) crashes as chance phenomenon, (2) crashes caused by the crash-prone, (3) crashes are monocausal, and (4) crashes are multicausal. Two paradigms were added to these original four (Wegman et al. 2007): (5) "the road user is the weakest link and road user behaviour can be changed by education/enforcement." The sixth paradigm is the Safe System's management perspective.

According to the OECD report (1997), early last century road crashes were considered an unfortunate incident in which the person concerned had the misfortune to be involved in a crash. Attempts were hardly made to prevent crashes. In the following period (1920–1950), crashes were attributed to persons who were unfit for traffic participation. The notion of crash-prone drivers was introduced and road safety improvement was considered a matter of making this (small) group of road users perform better. From 1950 onwards, the perspective was widened with the notion that crashes were the consequence of one single cause: either the road user, or the vehicle or the road. From 1960, it was increasingly being recognized that multiple causes can play a role in one crash and that crashes and injuries can be prevented by taking all possibilities into consideration. From the 1970s, a revival of "the road user is the weakest link" could be observed and more training, education, and enforcement of rules were believed to be the solution. This also contributed to a more integral approach being followed from 1990 onward: multiple crash causes and multiple possibilities to intervene. Adapting the "road traffic system" to humans and not, vice versa, trying to adapt humans to the system was more central in this approach. Johnston et al. (2014) suggests that these different paradigms reflect how a society feels about road crashes and road safety.

Not only the culture of a society is embedded in these paradigms, they also reflect the knowledge present or, perhaps better, the lack of knowledge. Knowledge is acquired from research and crash analyses. They provide a number of ways to detect crash causes (e.g., Shinar 2019). Data collected by the police after a crash is frequently used to assess crash causes. It must, however, be noted that the police task is not really to determine the causes of a crash, but to determine whether and to what extent a traffic offence has been committed (illegal behavior) and who was the guilty or the innocent party in the crash or the (vulnerable) party that is extra protected by law. This information is also used to determine whether behavior was inappropriate and if a person involved could be held liable for the crash consequences. Therefore, it is not surprising that "human error" emerged as a cause in the databases based on police registration of crashes: more than 90% of crashes involved a human error. This approach is sometimes called "a blame the victim-approach," and this view on crashes is a rather dominant and stubborn view (source).

This view on crash causation was reinforced by two in-depth studies from the 1970s, one from the United States and the other from the United Kingdom. Both are much quoted to this day when it comes to causes of crashes. Rumar (1985) presented the results of both studies side by side and they are surprisingly similar (in 94–95% of crashes the human factor is involved, in 28–34% the road is involved, and in 8–12% the vehicle is involved). These findings are surprising, because the two research teams did not use the same definitions and studied crashes in rather different situations. These results seriously contributed to the often heard statement: “almost all crashes are caused by road users, and roads and vehicles play only a minor role.”

Present in-depth studies, however, look not only at the events just before and at the time of a crash, they also try to consider the context of a crash and to understand the underlying circumstances. This perspective is rather common when analyzing industrial safety or, for example, causes of shipping and aviation crashes (Davidse 2003). This perspective tries to understand human behavior and, if opportune, human error. Road crashes are not the result of a series of unsafe road user actions but also of gaps in the traffic system. These gaps are also called latent errors (Reason 1990). This also led to the understanding that if a human factor is found as a cause, a solution is not necessarily found in humans, but in the surroundings of humans (Hauer 2020). For example, a head-on collision on a motorway due to fatigue can be prevented by an adequate median.

In addition to knowledge about the causes of road crashes, another dimension is relevant to conclude whether an idea develops into a road safety paradigm: expectations about the possibility of using policy to eliminate or mitigate causes of crashes. Dutch researchers made important contributions to the international discussions on the causes and the prevention of road crashes.

Erik Asmussen, SWOV’s first managing director, was one of the first road safety professionals in the Netherlands who considered unsafe traffic conditions not to be only a problem of the individual road user, but as a problem of the road traffic system. Asmussen (1983) and a scientific working group of the OECD (1984) he chaired built on the previous work of William Haddon. Haddon, the first director of the American National Highway Traffic Safety Administration, introduced a public health model within road safety. This model is known as the Haddon matrix (see, for example, Haddon Jr. 1972).

This matrix contains two axes: one axis for the crash process (pre-crash, crash, and post-crash), and the other axis for the components of road traffic: humans, vehicles, and roads. The matrix consists of three times three cells, and in each cell, road safety problems and/or solutions to those problems can be identified. The great value of the Haddon matrix is that it describes the entire playing field of road safety and not just the field (humans) in which until then problems and solutions were described: the cell “pre-crash – humans.”

Asmussen spoke of a dynamic system approach (he used “the phase model” describing how transport and traffic processes, which can result in crashes, and the crash process are regarded as a chronological – the dynamic aspect – complex of successive, increasingly critical combinations of circumstances and events) which he considered to be a tool to structure the road safety phenomenon. In his approach, Asmussen also discarded the idea that crashes have just one cause or solution: road crashes are the result of a combination of factors. If these factors reach a decisive point, a crash will occur. SWOV had already acquired this insight in the 1970s.

Another SWOV researcher, Matthijs Koornstra, the second SWOV managing director, also discarded the idea that road crashes were mainly caused by crash-prone road users. In an analysis, Koornstra (1978) showed that there are no crash-prone road users, but that one may refer to unlucky persons.

This evolution of road safety paradigms discussed in this paragraph is important to understanding the considerations regarding the Safe System approach; after all, the Safe System approach can be seen as the last in a series of paradigms until now. In addition to Matthijs Koornstra, Fred Wegman, SWOV's third managing director, also played a role in the development of the Safe System approach together with Letty Aarts, and more specifically in this new paradigm being further elaborated and accepted as a basis for road safety policy in the Netherlands.

Peter van der Knaap, the managing director since 2013-2021, set out to revitalize the by then 25-years-old approach. Building upon the evident successes and good benefit-cost ratios, together with Letty Aarts, he put special emphasis on the notion of "system responsibility" and the need for continuous policy-oriented learning, including the use of new data (see also Van der Knaap 2017).

This evolution in paradigms, or paradigm shifts, is important to understand the paradigm shift towards the most recent one: Safe System approach.

Start of the Dutch Safe System Approach: Sustainable Safety. National Road Safety Outlook for 1990–2010

As explained before, several good reasons emerged in the late 1980s to develop a new road safety strategy for the Netherlands based on a new paradigm. First of all, there was a strong ambition to further reduce the number of road fatalities, as expressed in road safety targets: minus 25% fatalities in 2000 (compared with 1985) and minus 50% fatalities resp. minus 40% hospitalizations in 2010 (compared with 1986). Secondly, the downward trend was not that impressive anymore and it was concluded that the 2000-target could not be reached by simply extrapolating trends. Thirdly, it was not expected that the then current set of additional measures and interventions would be sufficient to reach road safety targets. And last but not least, Dutch road safety professionals, more specifically the research community, supported the view that we could not rely anymore on the dominant view at the time: "to blame the road user for a crash and to carry out further training and education to reduce road risks."

The road safety research community developed a new road safety vision for the Netherlands under the leadership of SWOV-researchers (Koornstra et al. 1992). This report is also called "the Purple book." Two elements in this attempt were critical. The research community agreed on a new vision. Secondly, close contacts were established with road safety policy makers and practitioners in order to have them on-board while developing the new vision. As a consequence, we could observe positive responses to this new initiative: a willingness among policymakers to work with the results of this work and the work was welcomed by politicians, by the professional community, by representatives of all tiers of government, and by interest groups.

The choice was made to name the new vision *Sustainable Safety*. This was not the first name to be considered. Initially two working names featured: “inherently safe” and “intrinsically safe.” These “safety by design” approaches (avoiding hazards instead of controlling them) were seen as appropriate for road traffic as well. However, these terms were considered as too technocratic to be sufficiently appealing for this paradigm shift. Several Dutch politicians whispered Sustainable Safety in our ears as a strong brand name for this new approach. This was at the time that “sustainability” was a notion for the forefront of the environmental movement only!

The objective of Sustainable Safety is to prevent road crashes from happening, and where this is not feasible (yet), to reduce the incidence of (serious) injury whenever possible. This can be achieved by a proactive approach in which human characteristics are used as the starting point: a user-centric system approach. This approach refers on the one hand to human physical vulnerability to forces in crashes and on the other hand to human (cognitive) capacities and limitations.

The most important features of sustainably safe traffic are that gaps in the road transport system that result in human errors or traffic violations are prevented (as far as possible) and that road safety depends as little as possible on individual road user decisions. The responsibility for safe road use should not be placed solely on the shoulders of road users, but also on those of who are responsible for the design and operation of the various components of road traffic (infrastructure, vehicles, legislation/regulation). This means that a Sustainable Safe road traffic has an infrastructure that is adapted to the human limitations, vehicles that are designed to support road user tasks and to protect the human body in a crash, and road users that are adequately trained, informed, and when needed, controlled.

Three guiding principles were developed in “the Purple book” of 1991:

- Functionality of roads: monofunctionality of roads as through roads, distributor roads or access roads in a hierarchically structured road network and prevention of unintended road use.
- Homogeneity: equity in speed, direction, and mass at medium and high speeds in order to reduce levels of kinetic energy under tolerable levels for the human body.
- Predictability: predictability of the road course and road user behavior by recognizable road design using consistency and continuity as a design approach.

In order to prevent serious crashes on the road, the three guiding principles were operationalized into a set of practical principles which were used to design measures to be implemented. Large-scale implementation of these measures were realized through the Start-up Programme of Sustainable Safety (Ministerie van Verkeer en Waterstaat 1997).

It was evident that this new approach required a top-down approach to influence decisions of autonomous stakeholders, and a massive investment was envisaged, mainly in the road infrastructure. To illustrate this, we can use the predictability principle: if different road authorities treat similar design issues differently, road users cannot predict from the road layout what to expect on the road’s course. The idea behind the predictability principle is that road users are not aware of any difference between road authorities. Because hundreds of autonomous road authorities in the Netherlands design and maintain the road infrastructure, guidance must be given to road authorities as a binding legal instrument is not appropriate. Another approach was therefore chosen. It was decided to revisit all Dutch design manuals (with the exception of the manual for Dutch motorways) and, based on Sustainable Safety a couple of new design manuals for regional flow roads, for distributor roads and for access roads were developed (and published in Dutch by Knowledge Platform CROW in 2013). And Dutch road designers were found to use their design manuals!

The Dutch national government expressed a clear ambition to bring the Sustainable Safety ideas to implementation. Because the vision relied heavily on a better planned and designed road infrastructure, mainly for municipalities and provinces, the national government built a strong coalition with all road authorities. Furthermore, the national government was willing to co-fund investments to make existing roads and streets meet Sustainable Safety principles. Initial estimates indicated that a full treatment of the whole road network would cost dozens of billions of euro's, and this frightening perspective resulted in attempts to develop "low cost solutions." But it was not fully clear whether these low-cost solutions would be effective enough. Because of this, a three-step approach was designed: demonstration projects (for learning by doing), a Start-up Programme (the first couple of years of implementation, co-sponsored by the National Government), and a final phase of an integral and complete implementation (Ministerie van Verkeer en Waterstaat 1997).

After a couple of successful demonstration projects had been implemented, in 1997 an agreement for a so-called Start-up Programme Sustainable Safety was signed by the Association of Netherlands Municipalities, the Association of Waterboards, the Association of the Provinces of the Netherlands and the Ministry of Transport, representing all tiers of government and all road authorities. The agreement contained 24 measures and actions. The national government made a financial subsidy available and other governments were expected to supplement the subsidy with at least an equal amount. The Start-up Programme also contained an outline of intentions concerning the decision-making process required for the second phase, a full-scale implementation of Sustainable Safety. However, this second phase did never get off the ground, due to reasons that are not related to road safety as such. It was decided to fundamentally change the relationship between the national government and provinces and municipalities resulting in decentralization of policymaking and implementation.

Many actions in the Start-up Programme were aimed at improving road infrastructure, more specifically at a functional categorization of the whole road network (functionality principle), guidelines on road type dependent road markings and the construction of 30 and 60 km/h zones. Furthermore, actions were taken related to enforcement, public campaigns, education, and vehicle safety (for an overview, see Weijermars and van Schagen 2009). Quite some attention in the Start-up Programme was spent on sharing information with road safety professionals. For example, an information point was established. This information point turned out to be a key-feature in supporting practitioners and was highly appreciated by them.

Table 1 Distribution of road length of 30 km/h and 60 km/h in 1998, 2003, and 2008 (SWOV 2009)

	1998	2003	2008
Urban area			
30 km/h	8.900 (15%)	29.000 (45%)	50.300 (70%)
50 km/h	50.600 (85%	36.500 (55%)	21.600 (30%)
Total urban	59.600 (100%)	66.400 (100%)	71.900 (100%)
Rural area			
60 km/h	2100 (3%)	+/− 10.000 (15–20%)	35.400 (57%)
80 km/h	63.300 (97%)	54.000 (80–85%)	25.500 (43%)
Total rural (excl. motorways)	65.400 (100%)	64.000 (100%)	62.100 (100%)

An example to illustrate the implementation process: during the period 1998–2002, which was extended in the years thereafter, nearly all road authorities drew up a categorization plan in which all roads and streets were functionally classified (first principle). Taking this as a starting point, it is estimated that more than 41,000 km of 30 km/h-roads and more than 33,000 of 60 km/h-roads were constructed (Weijermars and van Schagen 2009). See Table 1 for more details. Initially these streets and roads had a speed limit of 50 km/h or 80 km/h. This included not only a change in speed limit but also a redesign according to Sustainable Safety design principles. In other words, in 10 years time, a dramatic change in urban roads in Dutch cities and (secondary) rural roads took place. Traffic calming, not only urban but also rural, began to be the rule and not the exception in the Netherlands. A questionnaire study among road authorities (Doumen and Weijermars 2009) showed more about the quality aspects of implementing Sustainable Safety. The main conclusion was that a substantial amount of the redesigned roads met Sustainable Safety guidelines to a large extent, although further improvements were recommended to benefit fully from this approach to reduce the number of (serious) crashes.

Weijermars and Van Schagen (2009) assessed safety effects of individual measures and they also estimated combined effects (see also Weijermars and Wegman 2011). They compared actual developments on road fatalities (using police statistics) making use of an extrapolation scenario based on developments 1988–1997. The fatality rate (fatalities per kilometers travelled) dropped 5.3% per year between 1998 and 2007 compared to 1.8% in the 10 preceding years. Based on these earlier developments, fatality numbers in 2007 were about one-third lower than expected. A cost-benefit analysis revealed that the benefits were almost four times higher and all individual measures showed a benefit-cost ratio higher than one. Based on a comprehensive overview of the implemented interventions, the researchers made it plausible, that the fatality reduction was due to interventions that were derived from or inspired by Sustainable Safety.

It is worthwhile to notice that the set-up of the funding scheme for infrastructure, €200 million from the central government for a 4-years period, and raising the same amount from the other road authorities, worked excellently. A case study for the year

2007 (Wijnen and Stroeker 2009) revealed that on Sustainable Safe infrastructure €350 million (mean value per year) has been invested. Substantial amounts of money were also spent on safer vehicles and on police enforcement, and more limited amounts of money on public information, on education, and on research, advice, and policy. The estimate of infrastructure investments for a 10 years period (1998–2007) is 10 times €350 million, 3.5 billion euros. It is important to observe that these budgets were not "road safety earmarked" budgets, but regular budgets for road investments.

The main conclusion of the evaluation of its implementation was that Sustainable Safety was a great success: it resulted in a substantial reduction in the number of fatalities, considerable improvement of a major part of the Dutch road network, and in positive effects of increased and improved enforcement. For example, automated speed enforcement and enforcement on red light violations increased with more than a factor of three between 2001 and 2007 and violations went down most probably. Vehicle improvements also contributed to the success (SWOV 2009).

It is important to observe that interventions and measures were never targeted at the public as components of a road safety vision, but regular consultations took place with communities on interventions and measures. We limited the discussion on the vision Sustainable Safety to decision makers and road safety professionals. The interventions and measures, derived from and/or inspired by Sustainable Safety, were presented and discussed without generally disclosing the wider perspective of Sustainable Safety.

We learned a lot from the implementation of interventions and measures, and it is fair to say that several question marks arose. One example is the so-called "grey roads." The functionality principle proposes to give a road or street only one function to: access, distributor, or through function. However, sometimes it turned out to be inevitable to combine the access function and the distributor function. How to design for this combination, the "grey roads"? Another issue that arose: Sustainable Safety relied heavily on improving road infrastructure, but how about using modern (vehicle)technology instead of costly infrastructure investments? Could it be preferable to wait for new technologies?

Year after year the Start-up Programme was extended beyond the intended period 1997–2000 and as a consequence, the more fundamental decision what to do in the future was postponed. At that time, a couple of important developments occurred in Dutch public administration which led to issues far bigger than road safety. The national government decided to decentralize the implementation of policies to other tiers of government, such as provinces and municipalities. Furthermore, the Dutch government decided to move some tasks to civil society organizations and to the private sector. This was a major reform in Dutch society. In this process, the Dutch national government also delegated road safety tasks to other parties, but it became obvious that those who were supposed to take over these tasks were not yet prepared and equipped to do so. Hence, a period of uncertainty and ambiguity about the implementation of road safety policies began. This period (the late 1990s) is characterized by a high level of ambition (ambitious road safety targets) and no clear ideas of how to realize the ambitions. In the first decade of the new millennium, it was therefore time to draft a second edition of Sustainable Safety trying to respond to these challenges and to new opportunities.

Advancing Sustainable Safety: National Road Safety Outlook for 2005–2020

Because unfortunately the Start-up Programme Sustainable Safety was not followed by a second phase, several new initiatives were developed. A collection of essays by experts was published in *Denkend over Duurzaam Veilig* (Thinking about Sustainable Safety) (Wegman and Aarts 2005). The Foreword title of this collection of essays, "Inspiration, commitment and synergy," reflected the spirit of that time. Sustainable Safety was considered to be a sound basis for future policy development on road safety and all authors of the book were in support of this. It was inspiring to learn about the many excellent recommendations, either based on the implementation so far, or anticipating on new opportunities, or just presenting creative new initiatives.

In the same year, a new "Purple book" titled *Door met Duurzaam Veilig* (Wegman and Aarts 2005) was published as the follow-up to *Naar een duurzaam veilig wegverkeer* (Towards Sustainable Road Traffic Safety) (Koornstra et al. 1992); the English translation *Advancing Sustainable Safety* was published in 2006. In this advanced edition, adaptations were made where necessary, based on what we had learned from our first steps towards a sustainably safe road traffic. The Sustainable Safety vision was also updated in accordance with new insights and developments. We chose a broader perspective for this book than we did in 1992. This broader perspective is justified, because we had been able to evaluate the results of our efforts to date. Moreover, there was high demand from practitioners to develop Sustainable Safety for specific problem areas or problem groups. Furthermore, the institutional settings for implementing governmental policies in the Netherlands, also for road safety, changed drastically (Wegman et al. 2008). Finally, this perspective offered the opportunity to "position" the vision again, to eliminate any misunderstandings and to create a new momentum for effective implementation.

The Dutch version of the second "Purple book" was presented to the Dutch Minister of Transport at the time, Mrs. Karla Peijs, and was welcomed by her. It is of crucial importance to notice that this book did not just address the Minister of Transport but also addressed representatives of institutions such as municipalities, provinces, water boards (road authorities in the western part of the Netherlands with an important road authority task), judicial authorities, police, car industry, etc.

We identified the following key approaches for this second edition (see also Wegman 2010):

- An ethical approach: we do not want to hand over a road traffic system to the next generation with the current casualty levels, but considerably lower ones.
- A proactive approach: we do not need to wait for crashes to occur before taking action, because we have a stock of knowledge that can be used.

- An integral approach: integrate man, vehicle, and road into one safe system; cover the whole network, all vehicles and all road users, and integrate with other policy areas.
- Man is the measure of all things: human capacities and limitations are the guiding factors together with the vulnerability of the human body in road crashes.
- Reduction of latent errors (system gaps) in the system: in preventing a crash we will not fully be dependent on whether or not a road user makes a mistake, commits an error or violation.
- Use criterion of preventable injuries: if we know the cause of a crash, if we know the cure, and if the cure is cost-beneficial for society.

As we illustrated earlier, a crash is rarely caused by one single unsafe action; it is usually preceded by a whole chain of poorly attuned occurrences. This means that it is not only one or a series of unsafe road user actions that cause a crash; also gaps in the traffic system contribute to the fact that unsafe road user actions can result in a crash. These gaps are also called latent errors (Reason 1990). It is also known as the Swiss cheese model of accident causation. The holes in the slices (of Swiss cheese) represent weaknesses. In summary: crashes occur when latent errors in the traffic system and unsafe actions during traffic participation coincide in a sequence of time and place (Fig. 1).

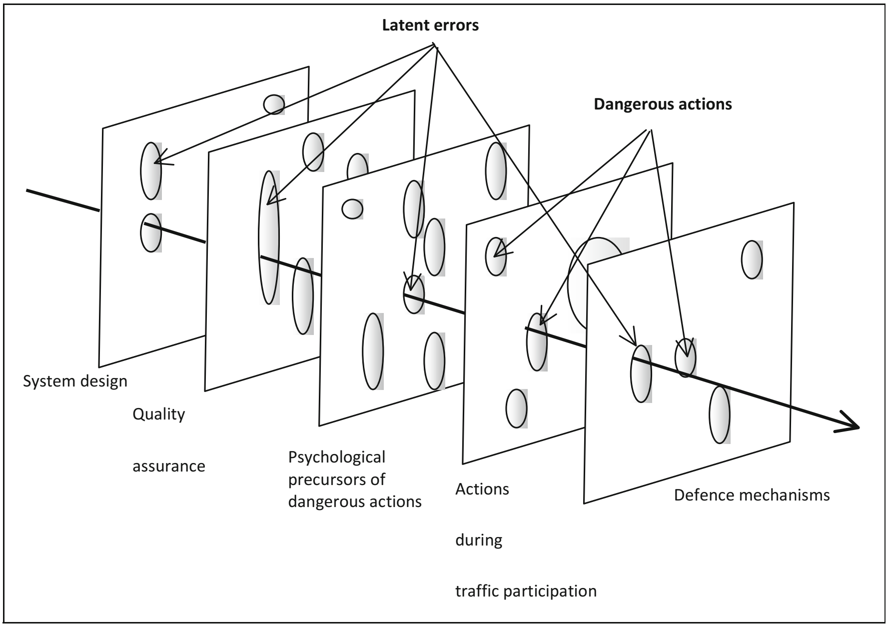

Fig. 1 Diagram showing the development of a crash (bold arrow) as a result of latent errors and unsafe actions in the different elements composing road traffic (based on Reason 1990). If the arrow encounters "resistance" at any moment, no crash will develop

As unsafe actions can never entirely be prevented, the Sustainable Safety vision aims at banishing the latent errors from traffic: the road traffic system must be *forgiving* with respect to unsafe actions by road users, so that these unsafe actions cannot result in crashes. The sustainable character of measures mainly lies in the fact that actions during traffic participation are made less dependent on momentary and individual choices. Such choices may be less than optimal and can therefore be risk-increasing.

Adjusting the environment to the abilities and limitations of the human being is derived from cognitive ergonomics, which in the early 1980s made its entry coming from aviation and the processing industry. In all types of transport other than road traffic, this approach has already resulted in a widespread safety culture. Further incorporation of the Sustainable Safety vision should eventually lead to road traffic that can be considered as "inherently safe" as the result of such an approach.

The fundamentals remained the same in the second edition of Sustainable Safety. The objective of Sustainable Safety was and remained to prevent road crashes from happening, and, where this is not feasible, to reduce the incidence of (serious) injuries whenever possible. This can be achieved by a proactive approach in which human characteristics are used as the starting point: a user-centric system approach. On the one hand, these characteristics refer to human physical vulnerability, and to human (cognitive) capacities and limitations on the other.

The principles of the first edition (functionality, homogeneity, and predictability) were reformulated where appropriate, and two new principle were added. This resulted in five principles:

- Functionality of roads.
- Homogeneity.
- Forgivingness (of the environment and other road users).
- Predictability (of the road course and road user behavior by recognizable road design).
- State awareness by the road user.

The forgivingness principle makes it possible to pay explicit attention to road side design and to the interaction between different types of road users. This "new principle" was in fact already embedded in the first edition of Sustainable Safety, but it is appropriate to position it explicitly.

The predictability principle, also already in the first edition, deals with a road environment and road user behavior which support road user expectations through consistency and continuity in road design. A road is self-explaining (Theeuwes and Godthelp 1993) if the design itself is made enough standardized and predictable. One of the main issues is to reduce speed variance between drivers, and also to minimize speed adaptation to prevailing conditions.

The state awareness principle is derived from the task-capability model as developed by Ray Fuller (Fuller 2005). In his model, Fuller compares road user task demands or task difficulty with the task capability to perform a task safely. Task capabilities is a combination of the competences of a road user minus the situation dependent state (for example, influenced by fatigue, distraction, impairment). Driving speed is the most distinctive factor in relation to decreasing or increasing task difficulty. The state awareness principle makes eliminating distraction, drinking and driving, fatigue, etc. explicit components of the Sustainable Safety approach.

The Dutch vision Advancing Sustainable Safety as presented by Wegman and Aarts (2005, 2006) has been translated in numerous ideas for practical proposals concerning road infrastructure, vehicles, intelligent transport systems, education, regulations and their enforcement, speed management, drink and drug driving, young and novice drivers, cyclists and pedestrians, motorized two-wheelers, and heavy goods vehicles.

The final part of the publication (Wegman and Aarts 2005, 2006) pays attention to various components of implementation. We learned a lot during the introduction of Sustainable Safety, and the new thoughts on organization of policy implementation, on quality assurance, on funding, and on accompanying policy are discussed in this part of the handbook.

The authors of the second edition acknowledged that, unlike the first edition, Sustainable Safety could no longer be regarded as the basis for a national road safety plan to be implemented. The environment changed with more decentralized responsibilities, with many different and more or less autonomous stakeholders and without a strong top-down push from the national government. Sustainable Safety was expected to flourish more when used as a guiding concept for a multi-stakeholder setting. This different view on implementation did not really come about because the designers of Sustainable Safety expected better results. This was due to the fact that policy making and implementation, also in the field of road safety, changed because the Dutch public administration changed.

Decentralization became en vogue in the Netherlands some 20 years ago. Basically, this reform refers to the transfer of powers and responsibilities from the central government to elected authorities at a subnational level. The consequences for Sustainable Safety were huge. It resulted in an increase in mutual dependence between parties in the implementation context and it was necessary to base the implementation of the next phase of Sustainable Safety on the perspective of implementation as a coordination process in a multi-stakeholder environment, as presented in Table 2.

This new perspective became a very serious hurdle for road safety improvement and further implementation of Sustainable Safety. Decentralization is a major reform in many countries, such as the Netherlands, and certainly not a panacea for all problems in society. An OECD-report (OECD 2019) developed 10 guidelines for a successful implementation of decentralization, some of which were not met when decentralizing the implementation of road safety in the Netherlands. To name a few: no adequate subnational capacity building, insufficient funding for various road safety responsibilities, and no adequate coordination mechanisms across levels of government.

The next phase of Sustainable Safety did not come into being. A strong and leading Road Safety Agency was missing and moreover, at a regional and local level road safety professionals, who were familiar with Sustainable Safety, left because of

Table 2 Two visions on the implementation of Sustainable Safety

Implementation as rational programming	Implementation as co-ordination process in a multi-stakeholder setting
Sustainable safety is an effective concept that has to be implemented as completely and uniformly as possible.	Sustainable safety is not static. It is about realizing uniformity and an adequate adaptation in dialogue with executive organizations.
Central control is the best guarantee for a complete and uniform implementation.	Central control leads to adaptation problems and alienates potential partners, whereas central administration failed as an ally in the past.
Area-orientated policy and faceted policy are detrimental to uniform and complete implementation.	Area-orientated policy and faceted policy offer opportunities for adaptation of sustainable safety at decentralized level and proactive involvement of related policy areas.
Success is the extent to which the realized measures comply with the ideals of sustainable safety.	Success is comprised of road safety benefits relative to existing situations.
Research institutes contribute to the content of sustainable safety based on their scientific knowledge.	Knowledge about sustainable safety facilitates decentralized administrations and other actors in the preparation of measures with road safety impacts.

budget reductions or because of (early) retirement. The assumption behind decentralization (more effective and efficient policies and implementation) failed to be true for road safety. Unfortunately, from a perspective of road safety, it is unavoidable and sad to conclude that Sustainable safety was not strong enough to survive in a climate of reduced political interest in road safety starting at the end of the first decade of the twenty-first century; there was no longer a decent "road safety plan." Some people concluded that Sustainable Safety became a weary vision and something new was needed.

Sustainable Safety the Third Edition: The Advanced Vision for 2018–2030

In 2013 and 2014, the annual amount of road deaths in the Netherlands reached its lowest number since decades, and for the seriously injured, this point was reached in 2016. The years thereafter, however, the number of casualties increased. Furthermore, discussions were emerging about "who is responsible" for societal results such as safety. The question was raised whether people could be made more responsible for their contribution to societal needs, and this was illustrated in several examples such as citizens contributing to better neighborhoods. It was, however, maybe too easy to put this idea further towards other domains such as road safety where the most recent insights were not to put the responsibility for crashes on the road user, but far more on the designers and operators of the road transport system This was also a general approach that got international support from road safety experts (ITF/OECD 2016). This development, together with the observation that still a number of effective measures were not yet implemented, provided the breeding ground for Sustainable Safety third edition.

The third edition of Sustainable Safety (SWOV 2018) builds upon the success of the earlier Sustainable Safety philosophy (Koornstra et al. 1992; Wegman and Aarts 2006) but aligns itself to several developments, such as the change in demography, increasing urbanization, and technological developments. In addition, ways were explored to "revitalize" the vision also inspired by discussions on the role of government, the role of citizens, civil society, and the private sector when it comes to relevant themes for society, like road safety.

International elaborations of what is considered as a "Safe System approach" (OECD/ITF 2008, 2016) also provided inspiration for the third edition of Sustainable Safety, for example, the concept of "responsibility." The third edition of Sustainable Safety makes use of new opportunities and recommends completion of several effective, yet unfinished measures with the ultimate aim to move towards a casualty-free traffic system. At a national level, the third edition of Sustainable Safety provided a substantiated framework for further development of the national road safety policy of the Netherlands as written down in the new Strategic Road Safety Plan (Ministry of Infrastructure and Water Management et al. 2018).

In brief, the following elements of the third edition can be highlighted:

- More focus on new and still frequently occurring serious crashes in the Netherlands, such as bicycle crashes without involvement of motorized traffic.
- A more explicit vision on what to accept in road traffic, what needs to be mitigated, and what needs to be eliminated.
- The road safety principles are more often linked to more than one type of measure (e.g., infrastructural measures and vehicle measures). They provide the opportunity to achieve similar results through a combination of complementary measures.
- The road safety principles are expanded and divided into three design principles and two organization principles.
- A more explicit emphasis on the specific responsibilities of different road safety stakeholders in realizing a sustainably safe road traffic system. Traffic professionals are crucial in this respect, even if the problem is the behavior of road users. Responsibilities are made more explicit in one of the organization principles, "effectively allocating responsibility," and in this respect links more clearly with the international vision of an inherently safe traffic approach.
- In order to better assist traffic professionals in making the traffic system structurally safer, not only are data on common crash types and casualties used as the basis of policy but also the use of surrogate safety measures in traffic (risk factors or road safety performance indicators, SPIs in short). The most important risk factors can serve as significant intermediate goals and offer deeper understanding of the underlying problems. These risk factors are necessary for assigning roles and responsibilities to the various road safety stakeholders.

In the revised Sustainable Safety vision, the ideal for the future is to make road use as inherently safe as possible by taking into account the demands and possibilities of road users now and in the future. The vision acknowledges the mobility demands of various groups in our society, the importance of satisfactory accessibility by road, and the need for a personal freedom of choice. It is a fact that certain modes of transport are inherently less safe (i.e., two-wheeled vehicles) and certain road users are more prone to traffic injury than others (e.g., children, teenagers, elderly). With these facts as a starting point, Sustainable Safety's third edition aims at maximum safety for all, that is: as safe as possible.

To reach maximum safety, a Safe System approach builds on the following implementation stages, in accordance with the societal context:

- Elimination: ideally, dangerous situations are made physically impossible so that people do not find themselves in such situations.
- Minimization: the number of dangerous situations is limited, and certain modes of road transport are made unattractive to limit people's exposure to risks.
- Mitigation: where people are exposed to risks, their consequences should as far as possible be mitigated by taking appropriate mitigating measures.

The third edition of Sustainable Safety emphasizes that "the human dimension" is not only relevant in relation with human beings as road users but also in relation with the professionals who design, implement, and/or manage elements of the traffic system (roads, vehicles, information, control systems, etc.). The same human characteristics that apply when they are road users are also more or less valid when they act in a professional capacity. This implies that in the further development and maintenance of a Sustainable Safe system, it is necessary for the professionals to organize all the processes involved to take maximum account of the human dimension.

The elements of Sustainable Safety complement and reinforce one another, making it as fail-safe as possible. If one element in the system fails, it is to be substituted or compensated for by other elements. This applies for unsafe situations – such as temporary malfunctions – as well as for human behavior. It applies to the process of traffic participation as well as to the work processes of traffic professionals.

Road Safety Principles of the Third Edition

In the third edition of Sustainable Safety, five principles are essential: three design principles (1, 2, and 3) and two organization principles (4 and 5).

- Functionality of roads.
- (Bio)mechanics: Limiting differences in speed, direction, mass, and size, and giving road users appropriate protection
- Psychologics: Aligning the design of the road traffic environment with road user competencies.
- Effectively allocating responsibility.
- Learning and innovating in the traffic system.

The functionality of roads remains a solid basis for the vision, although the third edition pays attention to the earlier mentioned criticisms on, for instance, roads that do not fit well in a monofunctional approach (the so-called “grey roads”). Solutions are found in the concept of “safe speed” in case monofunctionality cannot be met.

The second design principle – (bio)mechanics – is a combination of the old principles of homogeneity (edition 1 and 2), physical forgivingness (edition 2), and new elements added that specifically apply to the safety of two-wheeled vehicles, especially bicycles. This last issue turned out to be a large and growing problem in road safety in the Netherlands. We discovered this by linking police data and hospital data to get a complete picture of “serious injuries” (SWOV 2019). According to the (bio)mechanics principle, ideally, traffic flows and transport modes ideally are compatible with respect to speed, direction, mass, size, and degree of protection. This is supported by the road design, the road environment, the vehicle, and, where necessary, additional protective devices. For two-wheeled vehicles, it is important that the road and the road environment contribute to the stability of the rider. Besides paying attention to the huge problem of single bicycle crashes in the Netherlands, this second design principle applies to infrastructure, speed, vehicle design, and protective devices.

The third and last design principle incorporates the old principle of predictability (edition 1 and 2) and state awareness (edition 2), and adds to it a number of other psychological issues which have turned out to be relevant for safe road user behavior. The principle of psychologics states that the design of the traffic system should be well-aligned with the general competencies and expectations of road users, particularly the elderly. This means that for them as well as others, the information provided by the traffic system is perceivable, understandable (“self-explaining”), credible, relevant, and feasible.

Nevertheless, road users should be capable to carry out their traffic task and should be able to adjust their behavior according to the task demands for safely participating in traffic under the prevailing circumstances. This applies for drivers (skilled and fit for the driving task) as well as for nonmotorized road users (skilled in dealing with traffic and fit to participate in traffic).

New in the third edition are principles for the organization of a Safe System. It starts with the principle of responsibility and states that this is allocated and institutionally embedded in such a way that it guarantees a maximum road safety result for each road user and optimally integrates with the inherent roles and motives of the parties involved. In principle, road users follow the rules and set a good example for children and teenagers. Thanks to a forgiving traffic system, road users will not be punished for their errors and weaknesses with crashes and serious injuries.

As the world changes continuously, this requires that a safe traffic system and the professionals who design, implement, and maintain the system to adequately adapt to these changes. Therefore, the last organizational principle of the third sustainable safety vision is about learning and innovating the traffic system. The Deming cycle is relevant here: it starts with the development of effective and preventive system innovations based on knowledge of causes of crashes and hazards (Plan). By implementing these innovations (Do), by monitoring their effectiveness (Check), and by making the necessary adjustments (Act), system innovation ultimately results in fewer crashes and casualties.

In order to design countermeasures that are feasible and practical, it is important to further operationalize principles into "Requirements for a Sustainably Safe Road Traffic System." In addition, it is also important to draw up a Sustainable Safety Knowledge and Research Agenda that will strengthen further development of Sustainable Safety.

A number of measures that fit in a Sustainable Safety are illustrated below.

Illustration 1: Exposure of vulnerable road users to motorized traffic where vulnerable road users share road space with motorized traffic, the road clearly has an exchange function (functionality principle). From the principle of (bio)mechanics, major differences in speed should be avoided. In order to prevent crashes with serious injuries, it is important that motorized traffic is limited to a maximum speed of 30 km/h. This can be realized by adapting road design, vehicle, information provision, and enforcement to these traffic conditions and to the needs of the prevailing road users' groups

Aim: Maximum speed of 30 km/h at locations where there is interaction between vulnerable road users and motorized traffic. Types of solution ranging from full freedom of choice, just informing to safety by design in relation to speeding behavior (and thus an increased level of Sustainable Safety):

- Mandatory open ISA (Intelligent Speed Adaptation) and fines: continuously inform motorized road users about the legal speed limit and fine them when they drive too fast.
- Credible road design: physically nudge motorized road users to maintain a maximum speed of 30 km/h by providing a road layout that is appropriate for no more than this speed. This can be achieved by limiting the length of tangents (straight road sections), by providing physical speed reduction measures (e.g., speed humps or raised junctions), a narrow cross-sectional profile, an uneven road surface, or by placing buildings or vegetation close to the road.
- Mandatory closed intelligent speed adaption: eliminate high speeds by limiting the speed of all motorized traffic to 30 km/h.

Illustration 2: Single-bicycle crashes. Cyclists form a significant proportion of the seriously injured traffic casualties, many of them being seriously injured in a single-vehicle (bicycle) crash. The bicycle infrastructure plays an important role in these single-bicycle crashes. In particular, obstacles (lack of forgivingness) and balance-disrupting road elements (combined in the principle of (bio)mechanics) are sources of concern. To substantially reduce hazardous situations on the cycling infrastructure, special attention should be given to these crashes in the future

Aim: Cyclists do not fall, do not hit obstacles, and are physically protected in case something goes wrong. Types of solution within the traffic system and for the road user, again with an increasing amount of safety by design (less opportunity for unsafe choices) and thus an increasing level of Sustainable Safety:

- Physical protection of the cyclist: as long as the road infrastructure and the road environment do not offer sufficient protection against injuries in the event of a crash, protective cycling gear provides some level of protection to the cyclist.
- Obstacle-free, spacious, and skid-resistant bicycle infrastructure: create a bicycle infrastructure that is forgiving and therefore free from slippery substances (loose sand/gravel/leaves), obstacles, and vertical edges and ridges that can cause cyclists to lose their balance, fall, and injure themselves. Additionally, create a bicycle infrastructure that is wide enough to provide cyclists with the space for natural lateral movement and is sufficiently skid-resistant to prevent cyclists from skidding in bends.

Illustration 3: Distracted motor vehicle drivers, distraction among drivers, for instance, because of the use of the smartphone, contributes to a 3–4.5 times' higher crash risk compared to normal, undistracted driving. Causes and solutions are mainly found in the Sustainable Safety third edition principle of psychologics

Aim: Distraction of motorized vehicle drivers does not result in serious casualties. Types of solution with a decreasing amount of chances to make unsafe choices and consequently an increasing level of Sustainable Safety:

- Warning system: the car warns the driver against unsafe situations and gives priority to the most important information to prevent the driver from being overloaded with information.
- Restricting use of electronic devices: electronic non-traffic devices are automatically switched to a safe mode which prevents the driver from using them while behind the wheel. Other vehicle occupants can still use their devices.
- Autonomous (self-driving) vehicles: the vehicle undertakes the driving task without interference from occupants. The vehicle and related technology is programmed to safely deal with all types of traffic interactions. Vehicle occupants can engage in non-driving tasks, for example, reading a newspaper, operating a laptop, phoning, or participating in a meeting. The large-scale introduction of autonomous vehicles is not expected until 2030, but preparations for a safe operating system and the transition towards it are ongoing.

As we showed in this chapter, the third edition of Sustainable Safety builds on previously developed and shared principles, requirements, and measures. A primary recommendation is therefore also to complete what has proven to be effective. Past Sustainable Safety measures have had great success despite not being fully implemented. Examples of measures that should be finalized to have even more effect are the full implementation of credible road layouts, sufficient separation of high-speed traffic (especially with vulnerable road users), and evidence-based education.

The third edition of the vision also provides a framework for elaboration, operational requirements, and measures that may be developed in the future or that already exist but cannot as yet be applied to accomplishing a sustainably safe road traffic. For example, policy makers may consider vehicle safety and protective measures, road and vehicle technology, responsibility of professionals and the role of education, regulation and enforcement for road safety professionals, as well as for road users. In other words: the Sustainable Safety vision incorporates and provides a framework for effectively dealing with new challenges and making effective use of new technologies.

The updated vision also looks back at the results that have already been achieved – fully or only partially. For instance, effective interventions focussed on the prevention of serious road injuries were insufficiently incorporated in the previous editions of Sustainable Safety. Also, further road safety improvements for vulnerable road users deserves more attention from the perspective of current insights. The problems encountered in the past stemming from the implementation of minimally designed 30 and 60 km/h zones should no longer impede the realization of maximum road safety. Road safety would also benefit from correcting flaws that stem from failing to sufficiently account for the human dimension as a basis for design and guidelines.

For the further implementation of a sustainably safe traffic system, it is beneficial to collaborate with other organizations and stakeholders. The elaboration of operational requirements clearly calls for collaboration with organizations that are active in the field of regulation, guidelines development, publication, and professional education, but also with interest groups representing groups such as motorists, cyclists, and traffic safety advocates. With respect to implementing measures, road authorities and other traffic professionals have the most important role. They are invited to reflect on how the updated vision may be relevant for their policy and how it may help them in taking new steps.

Current initiatives also offer opportunities in the Netherlands to implement a Sustainable Safe road traffic system. A number of civil society organizations invited the Dutch government to put road safety higher on the political agenda and proposed to make higher budgets available for road safety investments. The insight that investments in road safety measures are likely to be cost-beneficial and can contribute to stimulate economical developments is helpful here. The increasing numbers of people killed and seriously injured in Dutch traffic in recent years is considered as an undeniable signal. The Strategic Road Safety Plan 2030 (Ministerie van Infrastrutuur en Waterstaat et al. 2018) responded to this initiative and includes new directions such as a risk-based, proactive approach (based on the use of Safety Performance Indicators), the chain approach to implementation, and the reflection on the "governance" of road safety policy and ambitions to get to zero (serious and fatal) road casualties. Sustainable Safety's third edition provides a framework to realize the formulated ambitions with maximum safety by adopting the following, most important policy aspects:

- Make clear choices when it concerns the functionality of roads.
- Take vulnerable road users as a basis from the perspective of (bio)mechanics.
- Adjust the traffic system to the competencies of the elderly.
- Further reflect on an effective allocation of responsibilities.

• Perform in-depth research into all fatal crashes and implement a risk-based approach with Safety Performance Indicators as the basis for learning and innovating.

Epilogue

We conclude this chapter with a couple of thoughts on looking back and looking forward.

Reflections on 30 Years Sustainable Safety

The Netherlands, along with Sweden, was one of the first countries to implement a Safe System approach. In 1992, the vision on a Sustainable Safety was conceptualized (Koornstra et al. 1992); in 1995, a small number of demonstration projects were launched; and in 1997, this culminated in the adoption of the Start-up Programme Sustainable Safety. The Start-up Programme was a milestone involving the adoption of a formal covenant, signed by all the public road authorities. Even before the formal adoption of the Sustainable Safety vision, and parallel to the Start-up Programme covenant, measures had been taken in the spirit of this vision, such as: building high-quality motorways, providing footpaths for pedestrians and separate bicycle tracks for cyclists. The Start-up Programme not only created a financial incentive for the further roll-out of Sustainable Safety measures, it also facilitated a coordinated approach to redress the growing road safety problems. Since implementation, these measures have proved to be cost-effective and reduced the number of road deaths. This systematic approach set an international example and certainly made a firm contribution to making the Netherlands a top-ranking player in the field of road safety.

In 2005, the second edition of the Sustainable Safety approach was presented with Advancing Sustainable Safety (Wegman and Aarts 2005, 2006). This generated renewed interest in the philosophy, partially attributable to two new principles: forgivingness and state awareness. Road authorities and policymakers continued with the implementation of measures in accordance with the outlines of the Start-up Programme. However, a lack of political priority for road safety, less effective coordination between different stakeholders and reduced resources prevented Sustainable Safety from being completed.

We have unfortunately seen that due to various developments (Weijermars et al. 2013), the number of road deaths has held constant and the number of serious road injuries has been increasing. Evaluation results learned that implementing Sustainable Safety has been very successful in reducing the number of fatalities, but not successful in reducing the number of serious injuries, and more specifically in reducing the number of serious road injuries in crashes not involving motorized vehicles. Almost all of these seriously injured are cyclists (Weijermars et al. 2013). Because speed reduction is a key element of Sustainable Safety, it is not surprising that implementation is more effective in reducing fatalities than in reducing injuries.

However, it is alarming that an increasing trend in single-cycling crashes has been observed. This leads to the important conclusion that the idea of forgiving infrastructure to prevent single-cycling crashes must be added to Sustainable Safety.

The need for a third edition of a Sustainable Safe road traffic (SWOV 2018) coincided with the increase of the number of road casualties. It tries to respond to developments regarding demography, urbanization, and technology, and national as well as international discussions on the organization of and responsibility for societal benefits such as road safety. The third edition gave room to these developments, making the vision “future proof” again, also by adding organizational principles like “effective allocation of responsibilities” and a renewal principle of “learning and innovating.” The vision incorporated new insights based on an analysis of road crashes (e.g., single bicycle crashes causing a large number of serious injured) and taking especially the competencies of elderly road users as a reference point. The five principles of the third edition provide the framework for a casualty-free road traffic system the Dutch government is aiming for. At least, they are presented as such. The focus on a risk-based approach and making use of safety performance indicators (SPI’s) may help in closing the gap between the vision and the pragmatic approach of a road safety plan. This process is expected to go on the coming years.

The Future of Sustainable Safety in the Netherlands

The third edition of Sustainable Safety is on its way. It is a matter of a stubborn continuation of effective measures and interventions and trying to reach “100%.” Furthermore, it is a matter of trying to use new opportunities, especially those provided by technology: to prevent risky road use (fatigue, distraction, impairment), to support drivers to prevent dangerous behavior (application in enforcement), and to support in prevention of crashes by speed management. Three challenges lie ahead of us:

Challenge 1 – Decentralization: maintaining national standards and road layout uniformity. Since the early 2000s, decentralization has led to more tasks and responsibilities for local governments. One particular risk of decentralization is the loss of a uniform road layout and design.

Challenge 2 – Policy integration: discovering win-win opportunities for integrated policy initiatives while staying focussed on safety. Policy programs that work according to an integrated approach which not just includes road safety objectives but also objectives in, for instance, health, urban, and climate policies may yield substantial benefits. Whether or not these benefits are actually achieved depends on the quality of “connective” agenda setting and cooperation.

Challenge 3 – Wise spending: calculating the optimal cost-benefit ratio of the Safe System approach. Calculating the expected benefits of road safety investments ex ante can empower road authorities and other actors to make better investments in road safety. An even stronger “business case” for Sustainable Safety requires better evidence on the optimal results that (only) a well-designed use of infrastructural, technical, and behavioral measures can yield.

Sustainable Safety in International Perspective

Sustainable Safety is used in the Netherlands as a name for its Safe System approach. Vision Zero is the name chosen in Sweden and in many other countries. The OECD used Towards Zero (2008) and later "Zero road deaths and serious injuries." These different names do not really reflect major differences in approaches as the core idea how to reach these aims starts from the idea that the system needs to be tuned to the competences of traffic participants. It requires real understanding of the human component and how the system can deal with it safely. Whereas the Netherlands and Sweden were starters in developing a Safe System approach, other countries, regions, and cities have been showing a growing interest in developing their own version of a Safe System approach (OECD 2008, 2016). Four starting points have to be adapted everywhere: (1) people make errors, (2) the human body has a limited physical ability to tolerate crash forces before harm occurs, (3) improving road safety is a shared responsibility, and (4) all parts of the road transport system must be strengthened, and if one part fails users are still protected (OECD 2016). Many policy documents in the world use Safe System or Vision Zero in their name these days; however, the presented measures and interventions are not always really reflecting the genes of Safe System thinking. That is confusing.

Differences in conceptualization of the Safe System approach in practices and tools and in Safe System management between countries can be observed. Speed management is a key principle for Safe System and takes literally a very central role in the Australian approach (safe roads, safe vehicles, safe people, and safe speeds). These differences basically reflect differences in "structure and culture" between countries (see also Koornstra et al. 2002) and perhaps differences in "taste" of policy designers. Further (evaluation) research have to show us how these differences affect road safety.

Sustainable Safety: Fourth Edition or a Next Paradigm?

The current paradigm in road safety – Sustainable Safety as an example of a Safe System approach – has a solid basis in scientific knowledge and recognizes that the responsibilities to make road traffic truly safe (without serious injuries) is shared between individuals and a wide range of stakeholders. The individual road users remain a critical part. But a key feature of the Safe System approach is not to blame the road user when failing to behave safe. The Haddon matrix (1972) clearly depicts the many areas and fields to improve road safety. And it is a given that many different (autonomous!) stakeholders have responsibilities, not just different tiers of government, but also the private sector and civil society. As long as individual road users make decisions in traffic and the context of these decisions will be shaped by the many stakeholders involved, the Safe System approach will remain a valid and effective approach. Strong leadership and institutional management remain needed.

Of course, Sustainable Safety have to adapt itself to new developments and opportunities in society. From this perspective we conclude that Sustainable Safety 4.0 is sooner to be expected than a paradigm shift. If a game changer like self-driving vehicles ("level 4 or 5 of driving automation") will be a reality, the question will be answered differently, perhaps. If we will ever reach that state in the Netherlands with the many bicycles everywhere, is still questionable. Time will learn.

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Vision Zero in Germany

11

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Abstract

Vision Zero has a central role in traffic safety in Germany. Finally, it was even a relevant point in the coalition treaty from the Federal Governing Parties in the year 2018.

It is a unifying theme for safety measures taken on the federal, state, and local levels and in private, nonprofit traffic safety organizations. In later years, cooperation between these different agents has been intensified. Evaluation and measurability are essential in the German approach to Vision Zero. One example of this is the statistical work performed every year to identify "zero cities," i.e., cities that had zero road fatalities the previous year. A yearly award puts focus on cities that have a particularly long string of zero years, in relation to their size. This is performed on an international level, and cities around the world are incentivized by these recognitions. Munich is used as an example of a city that has recently stepped up its traffic safety work. The city has adopted Vision Zero and followed up this with intensified traffic safety work, including improved data collection, the identification of accident black spots, targeted measures to improve safety in these black spots, safety audits of new infrastructure plans, etc. Before the introduction of new traffic technologies which may have an impact on safety, in-depth technology assessment has to be performed. This is illustrated by an example in which sufficient prior technology assessment did not take place, namely the introduction of e-scooters in Germany. After their introduction, they have turned out to be significantly more dangerous than bicycles, as can be seen from the statistics of fatalities and severe injuries. Proposals are made for measures are needed to reverse this trend, including obligatory use of helmets. The dialogue with neighbor states is also essential. Here the Traffic Expert Society of Medical and Technical Biomechanics, gmttb (Germany, Austria, and Switzerland= D A CH), has initiated to discuss and bundle basic principles of the Vision Zero in three neighbor countries. To promote Vision Zero, gmttb also organizes interdisciplinary yearly conferences with experts from Austria (Vision Zero is a state philosophy) and Switzerland (here named Via Sicura) to bundle strength and adopt ideas together with Swedish and multinational experts. As well as a yearly gmttb Vision Zero Safety Award is granted to motivate people, organizations, and manufacturers to promote good ideas for better traffic safety.

Keywords

Accident black spot · Driver's education · E-scooter · Electric micro-vehicle · Federal Republic of Germany · Helmet · Munich · Technology assessment · Vision Zero · Zero city

Adoption and Basic Principles (Christian Kellner, Ute Hammer DVR)

Vision Zero had early supporters in Germany. For instance, the "Traffic Club Germany" (VCD) developed a plan for Vision Zero in 2004, (https://www.vcd.org/themen/verkehrssicherheit/vision-zero/) and the Federal State of North Rhine-Westphalia included Vision Zero in its road safety program in 2005. The idea gained further impetus on the federal level in September 2007 when the executive board of the German Road Safety Council (DVR) resolved to align its road safety activities to the Vision Zero strategy.

As a nonprofit association with more than 200 member organizations throughout Germany, the DVR includes many stakeholders. Among these are employers' liability insurance associations (BGs), the public sector accident insurers, the federal government and the federal states, the German Road Safety Volunteer Organization (Deutsche Verkehrswacht), the automotive and automotive supply industry, and many more. Many other institutions soon joined and explicitly committed themselves to the Vision Zero strategy. Due to the proximity of the DVR to the employers' liability associations, Vision Zero also received considerable support in the area of occupational safety, as it has also done in many other parts of the world.

The DVR's decision was based on the conviction that the death toll on German roads was unacceptable. The number of road accident victims in Germany has been recorded by the Federal Statistical Office since 1953. Since then, a total of 736,000 people have been killed in road accidents in Germany. This is more than the number of inhabitants of the city of Frankfurt am Main. Even now, when the number of road accident fatalities has reached an estimated historic low of 3,090 in 2019, on average 8.5 people die in road accidents in Germany every day.

Let us imagine that cars had not yet been invented. Someone then came and explained to politicians, the media, and the general public in Germany that they had invented an entirely new technology which puts personal mobility on a completely new basis thanks to motorized, individually controlled vehicles. However, the introduction of this technology would entail a new type of accident, namely road accidents. According to their estimate, this would involve a daily average of 8.5 fatalities. It should be obvious that this new technology would never be introduced, and that the inventor's proposal would be rejected and perhaps even cause outrage. Who could justify introducing a technology that would cause 8.5 fatalities every day? Politicians, society, and the media would be unanimous in their rejection.

The decision to adopt Vision Zero also has a constitutional background. The right to life and physical integrity, which is precisely what Vision Zero demands, is a central concept in the constitutional law of the Federal Republic of Germany. Protection of this right is the responsibility of state bodies. The legislature and the executive are required to do all that is necessary to prevent infringement of this constitutional right. In view of the many options which are available, it is questionable whether the traditional traffic safety policy, which accepts a considerable number of deaths and severe injuries as unavoidable, provides such protection.

Road users cannot achieve traffic safety on their own. It is the duty of the state and industry to develop a safe traffic system. However, this does not eliminate individual responsibility. Each and every one must be aware of the risks which they create for others by their actions or failure to act. Individuals are responsible for compliance with laws and regulations, while the developers of the system must ensure that the system as a whole is safe. Developers of the system primarily include the authorities that are responsible for building and maintaining roads, vehicle manufacturers, transport operators who transport goods and passengers on a commercial basis, as well as politicians, the legislature, the judiciary, and the police. This systemic view in Vision Zero is perhaps the most important change as compared to the previous view, which considered individual road users to bear the primary responsibility.

The German Road Safety Council cannot pass legislation, and it does not build roads or vehicles. However, it can make demands with regard to these points. Together with its member organizations, the DVR has developed the following list of ten top measures to be implemented by government, municipalities, and industry. The DVR is convinced that these measures will rapidly reduce the number of deaths and serious injuries due to road accidents. Some of these measures will take some time, whereas others can be rapidly implemented.

Increase in Targeted Traffic Enforcement

- Appropriate improvement of the financial and personnel resources of the police and the corresponding state organizations, including improved training
- Increased prevention and prosecution of traffic violations by means of better cooperation between authorities
- Implementation of model trials with section control (a speed control system that measures the average speed of vehicles over a road section of typically 2 km or more)

Adaptation of Maximum Speeds

- Reduction of the maximum speed on rural roads with widths up to and including 6 m to 80 km/h
- Enforcement of overtaking prohibitions on rural roads in areas with restricted visibility for overtaking

- Implementation of trials for the reduction of urban speed limits from 50 to 30 km/h
- Introduce general speed limits for all vehicles on German motorways; promote the expansion of intelligent traffic systems

Prevention of Accidents with Trees

- Design of roadsides of rural roads without obstructions
- In the case of existing trees, increased use of passive protection in critical areas
- Reduction of the maximum speed limit for tree-lined roads and efficient monitoring of compliance

Improvement of Safety for Motorcyclists

- Extensive implementation of the information leaflet for improvement of the road infrastructure for motorcyclists (MVMot 2018) in all federal states
- Improvement of the visibility of motorcyclists

Increased Safety Through Improvements of the Infrastructure

- Consistent application of proven infrastructure measures
- Ensurance of the use of the instruments of road safety inspections, accident commission, auditing of the status quo, and safety audits
- Improvement of safety at intersections, road junctions, and roundabouts

Promotion of Driver Assistance Systems, Automation, and Networked Driving

- Consistent promotion and installation of safety-enhancing driver assistance systems in vehicles
- Utilization of the proven safety potentials of automated driving functions and networked driving

Increased Safety for Pedestrians and Cyclists

- Improvement of the infrastructure for pedestrians and cyclists
- Improvement of the visibility of pedestrians and cyclists
- Promotion of helmets for cyclists and riders of electric bicycles
- Development and mandatory use of turning assistance systems
- Promotion of the “Dutch Reach”

Prevention of Driving Under the Influence of Alcohol and Drugs

- Enforcement of the prohibition of driving under the influence of alcohol
- Introduction of alcohol interlock programs
- Introduction of a traffic offence for cyclists with a blood alcohol level of more than 1.1

Improved Qualification of Novice Drivers

- Promotion of the accompanied driving scheme
- Introduction of mandatory extensions of learning times for novice drivers
- Development and mandatory introduction of a curriculum for driver training

Reduction of Hazards Due to Distractions

- Promotion of a change in behavior in the use of information and communication systems (including smartphones)
- Exploitation of all technical options for reducing risks due to distractions

Political Implementation (Guido Zielke BMVI)

Since the 1950s, traffic trends in Germany have been heading in one direction only – upward. With the fall of the "Iron Curtain" and German reunification, this trend was given a further boost. Thus, for instance, freight traffic on German roads increased by over 27% from 2000 to 2010. In the same period, there was a rise of over 6% in the volume of private motorized transport.

An end to this trend is not in sight. The Federal Ministry of Transport's traffic forecast predicted an increase in road haulage by 39% from 2010 to 2030, and at the same time an increase by 10% of passenger traffic. This seems to become true, judging by current trends. In the last ten years alone, the number of motor vehicles in Germany has increased by around 14%.

However, in spite of the increased intensity of road traffic, German road safety has improved considerably. The federal government, federal states, and local authorities have for decades undertaken major and successful action to reduce the number of people killed and severely injured. In 1970, over 21,300 people lost their lives on the roads, whereas that figure had fallen to 3,046 by 2019. That is a drop of more than 85%.

This success in improving road traffic in spite of intensified traffic has been based on two working principles: First, concentrating on measures whose effectiveness have been proved by academia and, secondly, focusing on what is most likely to be successful. An example can show what this means. Newly qualified drivers are by their very nature a high-risk group, not just in Germany. In many cases, the risk inherent in being a novice driver is compounded by the risk inherent in being a young person. In other words, they are involved in far more fatal accidents than what would be assumed given their share of the population. It was thus obvious that there was a requirement for action here. One approach to solving the problem was to lengthen the learning phase of normal driver training.

However, although driving schools are naturally keen to sell more driving lessons, many young people cannot afford them. So, what about parents and other experienced drivers helping out by acting as lay instructors? As an incentive to allow themselves to be accompanied while driving, a kind of “advanced driving license” could be obtained earlier. However, the minimum age of 18 years for driving unaccompanied would remain unchanged. That was the idea.

In 2004, the first trial schemes for what was known as “accompanied driving from seventeen” were launched. The Federal Highway Research Institute evaluated the trials and reached an opinion that, for academics, was surprisingly unanimous. In the first year of unaccompanied driving, drivers who had taken part in the scheme were involved in 17% fewer accidents and committed 15% fewer traffic offences. If mileage is taken into account, the risk of being involved in an accident fell by 22% and the risk of being caught committing a traffic offence fell by 20%. In purely mathematical terms, the scheme prevented around 1,700 personal injury accidents in 2009.

Following this unambiguous outcome, the Federal Ministry of Transport acted. Since 1 January 2011, accompanied driving from 17 has been part of permanent legislation. Participation in the “Accompanied Driving” scheme is voluntary and has to be explicitly applied for. The normal minimum age at which a driving license can be obtained remains 18 years. The scheme has been a continuous success story, as the academic study predicted. The federal government and the federal states have now joined forces in an attempt to encourage more young people who wish to drive unaccompanied as soon as they reach the age of 18 to participate in the “Accompanied Driving” scheme.

Thus, the academic-based approach and the concentration on the most important fields of action have proved very successful. This is also the approach that the Federal Ministry of Transport applies in developing a new vision for the future of road safety activities in Germany.

On the global level, the 2010s were declared the “Decade of Action for Road Safety” in the “Moscow Declaration.” The European Commission followed suit with its “Policy Orientations on Road Safety 2011-2020.” Both documents contained an undertaking to halve the number of road deaths. The EU’s long-term goal is now to move close to zero fatalities by 2050. Its third Mobility Package set the interim target to reduce the number of road deaths by 50% between 2020 and 2030. In the “Valletta Declaration,” Germany, along with the other EU Member States, expressed its support of this target. Given what has already been achieved, the efforts involved in achieving further reductions will increase disproportionately as each further advance is made. There are no easy solutions any more.

The federal government is leading the way in the work to reduce fatalities and serious injuries on German roads. In its new road safety program, which covers the period from 2021 to 2030, it will set out measures that are within its remit. However, an important lesson from the past ten years is that is it not sufficient for each of the federal government, federal states, and local authorities to consider only its own measures. The new vision for the future of road safety is therefore linking together all stakeholders in jointly establishing the overarching objectives and determining the specific fields of action. This gives rise to effective measures that complement and build on one another. Against this background, the federal government is currently compiling its own measures in the next road safety program, which will cover the period from 2021 to 2030. The federal states and local authorities are also engaged in similar processes. This approach was supported in the 2018 Coalition Agreement, in which the federal government committed to Vision Zero in the medium term. Vision Zero refers to a shared responsibility. The German aspiration is to bring all parts of society together in the interests of common road safety activities and to unite them in a common strategy with a common vision. This includes the federal government, federal states, local authorities, and all other key stakeholders in road safety. Towns and cities, in particular, are key players, especially with regard to vulnerable road users such as pedestrians and cyclists. Trade associations, industry, and individual businesses can also make most valuable contributions.

The fields of action on which all road safety stakeholders in Germany agree include to tackle accident blackspots and to address all road users. Important measures are improving the road safety of cyclists, pedestrians, and the elderly, and mitigating the effects of accidents. It will also be necessary to deal with the increasing automation of motor vehicle traffic, as well as other megatrends, such as the digital revolution, globalization, and connectivity, which are transforming society, and thus also mobility. Each field of action can be bolstered by far-reaching measures taken by different players. The objective is to enhance road safety in each field of action by means of measures that are dovetailed as closely as possible and complement one another in the spheres of infrastructure, automotive engineering, or human behavior. With regard to safe cycling, for instance, the infrastructure at junctions is crucially important. Another infrastructure challenge is the increasing speed of cycles as a result of electric mobility. As far as the objective of preventing accidents involving turning vehicles is concerned, the focus will continue to be on the use and the developments in the field of automotive engineering. At the same time, there will consistently be a need to adapt the law governing road user behavior, for instance, to cover new forms of mobility such as the electric scooter. The objective is to decouple the trend in the accident and casualty figures from the desired trend in the volume of cycling as an ecological, active, and modern form of mobility. In the field of cycling, greater consideration has to be given not only to actual objective risks but also to cyclists' subjective feeling of safety. This is just one example of how broad-based and complex the measures involved in a field of action can be.

With the specific fields of action, Germany is breaking new ground in addressing target groups and issues. In addition, the federal government is increasingly focusing on improving the measurability of road safety. In the next decades, new indicators will be added to existing ones, such as the seat belt wearing rate and the percentage of cyclists wearing helmets. In addition to indicators relating to the vehicle fleet and the infrastructure, an indicator of road user culture will be developed. The new measures will provide information on the effectiveness of different measures that the current official accident statistics does not deliver. This approach represents the continuation of the course of action practiced for years of a road safety policy based on evidence and academic research.

The new vision for the future of road safety in Germany will also bring another new feature. Supported by additional data produced in part by the new indicators, the federal government will conceive its road safety program as a living system. If we think of the electric scooter or automated and connected driving, it becomes clear that the changes to our mobility are occurring at an increasingly rapid pace. The German Federal Government wishes to be able to take action at any time to promote Vision Zero. Necessary adaptations of the measures are to be continuously reviewed. The guiding principle that every fatality is one too many will not only be confirmed but also receive new impetus in the new decade as a result of the actions described above.

Research for Safe Cities (Clemens Klinke DEKRA)

For almost 100 years, DEKRA, the German Motor Vehicle Inspection Association (Deutscher Kraftfahrzeug-Überwachungsverein), has been working for safety on the road. This is the purpose for which it was founded in 1925, and it still has not changed. Although the scope of DEKRA's efforts for a safe world has widened over the decades, improving road safety is still – and will continue to be – its central objective. Its major purpose is to help all stakeholders in road safety with concrete recommendations for improvements and solutions. DEKRA was one of the first signatories of the European Road Safety Charter, and it has supported Vision Zero from the beginning.

Some have argued that Vision Zero is a utopia, an illusion, a goal that cannot realistically be reached. While this should never be an argument for not even trying, DEKRA's approach has been that like other major projects, Vision Zero should start with first steps. What if every institution concerned with road safety set their own "small" target? For example, should not a trucking company set the target for itself to get through the year without any crashes involving physical injury? Should not a regional council strive to reduce the number of crashes, tackling one accident black spot at a time? The combination of all such targets would take us gradually closer to Vision Zero. The 2014 DEKRA Road Safety Report specifically focused on urban mobility and asked the question: Would Vision Zero be achievable within the comparatively manageable framework of one town or one city? (DEKRA Road Safety Report 2014 Urban Mobility, Strategies for preventing accidents on European roads, Stuttgart (Germany), 2014 – available from www.dekra-roadsafety.com)

DEKRA Accident Research, working closely with members of the OECD's International Traffic Safety Data and Analysis Group (IRTAD), has been analyzing crash statistics from towns and cities with more than 50,000 inhabitants. The figures from the years 2009 to 2012 for 17 European countries showed even then that no less than 48% of the 971 towns and cities with over 50,000 inhabitants had achieved the goal of no road fatalities in at least one year. Among them were also larger cities with a population of more than 100,000 or even 200,000. The conclusion in the 2014 DEKRA Road Safety Report was that, although there is still quite some distance to go in order to achieve Vision Zero as a whole, there were millions of Europeans already living in towns and cities without any deaths caused by road crashes in built-up areas.

To make this fact known, an interactive online map was created, which has been updated and expanded over the past years with more and more data. (DEKRA Vision Zero Interactive Map, www.dekra-vision-zero.com) Today, it features 26 countries, with its scope expanded beyond Europe to include data from, among others, Australia, Canada, Japan, Mexico, and the USA. Of the 2,975 cities analyzed worldwide, a total of 1,197 – or 40% – have achieved the goal of zero road fatalities at least in one year since 2009.

With the interactive map, users can filter results by country, by city population, by calendar year, by the number of zero years, or any combination of these criteria, giving in-depth insight into the degree to which Vision Zero, in terms of road deaths, is being achieved in cities around the world.

Results vary considerably from region to region and from country to country. In Mexico, the share of “zero cities” is just 6%, in Japan it is a little over 20%, in the USA 24%, and in Australia some 28%. The European picture looks better, as a whole, with 68 % of cities over 50,000 inhabitants having achieved zero road fatalities at least once. While in some European countries the percentages are comparable to those in the USA or Japan, there are others where a very large majority of 50,000+ cities have already been successful – e.g., the UK (68%), Switzerland (70%), France (75%), Germany (79%), Spain (83%), the Netherlands (86%), and Sweden (95%). The percentages are based on available data within the period from 2009 to 2018 or 2019, respectively.

Many cities have achieved zero road fatalities more than once, 147 of them even in six or more years. The largest share of these cities is to be found in Europe, but also Mexico (1), Japan (1), and the USA (3), among others, have cities with six or more zero years. Among the “zero cities” around the world, there are almost 270 with a population over 100,000 and almost 40 with a population over 200,000.

By far the largest city with one zero year is Gothenburg (Sweden) with almost 550,000 inhabitants. Other large cities who have reached the goal at least once are Espoo (Finland), Aachen (Germany), Granada (Spain), Rennes (France), Jerez de la Frontera (Spain), and Mainz (Germany). The UK has a particularly large number of “zero cities” with a population of over 200,000, e.g., Nottingham, Newcastle, Derby, Southampton, Portsmouth, Brighton and Hove, Reading and Northampton, as well as the London Boroughs of Wandsworth and Bexley. Most of the successful 200,000+ “zero cities” are European, but some can also be found in other world regions, such as Fuchu (Japan), Buenavista (Mexico), and Oxnard (California, the USA).

To honor especially successful cities for achieving zero road crash fatalities, and to draw attention to Vision Zero as a concept, the DEKRA Vision Zero Award has been presented every year since 2016 to a city with a string of zero years. Recipients so far have been Kerpen (Germany, 6 zero years in a row), Torrejón de Ardoz (Spain, 7), Bad Homburg (Germany, 8), Lüdenscheid (Germany, 7), and, most recently, Siero (Spain) with no less than 11 "zero years."

The award recipients, as well as almost 1,200 other towns and cities around the world, are testament to the fact that, 20 years after its conception, Vision Zero can by no means be called an illusion or a utopia never to be reached. Of course, it has not yet been completely turned into reality. However, the analysis shows that the goal can be achieved within an urban context and is in fact already being achieved year after year in hundreds of cities across the globe.

This should provide extra motivation among all road safety stakeholders not to give up their efforts to edge ever closer to Vision Zero. This applies to cities that have not yet been able to register any zero years, as well as nonurbanized areas in other contexts of traffic. It also includes going beyond road deaths to also cover severe injuries.

In the future, automation will play an ever-increasing part in our vehicles and in traffic as a whole. Some have claimed that given the high share of crashes caused by human error, automated driving will be the solution of all road safety problems. This might seem plausible at first glance – however, things will probably not be just as simple as that. No doubt, automated driving has the potential to help avoiding accidents and to reduce the number of deaths and severe injuries on our roads. Sensor technology as well as vehicle-to-vehicle and vehicle-to-infrastructure communication can play out their strengths where human drivers might reach their limits. However, automation will only be beneficial if both the vehicle itself and its communication with other vehicles or the surroundings work reliably throughout its life cycle. This needs to be monitored and tested independently.

In the past and up to today, human drivers have been tested and regulated: They need a driver's license, they are restricted in terms of alcohol consumption and other factors, and professional drivers are required to undergo regular further training and tests. At least the same degree of thoroughness will have to be applied to testing and regulating the "virtual driver," i.e., systems of automated driving, if we do not want to compromise road safety. This will have to be part of the homologation of new vehicles, as well as periodical technical inspections (PTI). In both these processes, systems of automated driving will have to undergo in-depth checks to make sure they work safely. DEKRA and other organizations have made the case that, especially for PTI, inspectors need to have independent and unfiltered access to vehicle data relevant for the inspection. Building the legal framework for this will be one of the major tasks for regulators in the coming years.

With regard to automated driving, road safety is at a crossroads, so to speak. If handled sensibly and responsibly by all parties concerned, automation has the potential to improve road safety quite significantly. If decision-makers let things slide, however, automated driving can be rather counterproductive and predominantly create new dangers. Nobody advocating Vision Zero should be willing to let this happen.

Munich: A City on Its Way to Vision Zero (Matthias Mück and Martin Schreiner, Mobility Department, City of Munich)

Munich is a rapidly growing city with around 1.5 million inhabitants. Its surroundings have a population of around 3 million people. The road safety level is close to the national average: 46.000 accidents took place in 2018, 17 persons died, 619 were seriously injured, and 5.891 slightly injured. To improve this situation, the Munich City Council decided (on the recommendation of the municipal road administration) on April 25, 2018, to adopt the Vision Zero according to the recommendations of the German Road Safety Council (Deutscher Verkehrssicherheitsrat) as the official fundament and strategic goal of the road safety work of the City of Munich. This decision included the political mandate to develop an ambitious program improving and modernizing the municipal road safety work fundamentally. Essential basis for this challenge was an expert's report compiled by PTV Transport Consult GmbH, and supported by the Institute of Forensic Medicine of the Ludwig-Maximilians-University Munich. Both analyzed the current road safety work in detail and developed comprehensive recommendations to improve it. This measure had been subject to several city council decisions in 2019, including the allocation of resources for its long-term implementation. The most important action fields and measures are:

Improvement of the Data Basis

One key element of the Vision Zero implementation is the improvement of the accident data analysis by using new software products. As of now, police accident data can be analyzed in detail according to accident severity, type, location, and constellation of accidents, but also combined with several further criteria, such as time, weather, or specific target groups. This creates conditions for a more thorough local accident analysis and for the development and implementation of specific and effective measures.

This software is also able to combine accident data with further traffic and infrastructure data, allowing the identification of risk areas within the existing road network that are in need of preventive measures. Additionally, the evaluation of planned infrastructure measures with respect to expected accident consequences is an essential innovation to consider road safety issues at a very early planning stage of networks, sections, and all kinds of infrastructure.

A weakness of the current data analysis is that only accidents registered by the police are used. This excludes accidents that are not registered by the police, but only by, e.g., hospitals or insurance companies. Therefore, the City of Munich launched a pilot project in cooperation with hospitals and insurance companies to investigate the high number of unreported accidents (especially in cycling), which is still a largely unknown field of road safety.

Systematic Mitigation of Accident Black Spots

In addition to the activities of the municipal accident commission that intervenes after fatal accidents or noticeable accumulations of accidents at specific locations, the 50 most dangerous intersections will be identified in regular rotation and monitored in the abovementioned data analysis with up-to-date police accident data. They will be subject to mitigation measures that may include speed reduction and optimized traffic control, as well as a complete reconstruction of crossings in order to obtain clear sight lines and a more understandable road design.

To highlight one important example: Turning accidents are a dominant accident type, especially at intersections. At this point the administration itself serves as a model. Currently, 90% of all municipal trucks have turning assistance systems to prevent turning accidents with cyclists and pedestrians. In addition, subcontractors using trucks are bound by contract to have such a system.

Strong Prevention Work

Prevention is a crucial pillar in the Munich road safety work and necessary requirement for the successful implementation of the Vision Zero concept. Within the first years we prioritize our prevention work on clear focus areas with a high safety potential.

- *Setup of a safety audit entity:* Main objective is to evaluate every infrastructure plan by a certified road safety auditor to ensure the involvement of road safety aspects in the earliest possible stage of infrastructure planning. Furthermore, the systematic evaluation of existing infrastructure concerning road safety aspects will be also part of the foreseen audit entity. Therefore, we will hire and train extra staff in the near future.
- *Implementation of safety performance indicators (SPIs):* The assessment of the road safety situation, as well as its development on the basis of casualties and/or accidents, is not without problems. Accidents are influenced by a number of factors (e.g., weather effects) and these influences can also overlap. Hence, assessing the causal relationship between road safety measures and the occurrence of accidents is limited. This also applies to the timeline. Certain measures might show their effects only after a longer period of time. Safety performance indicators reflect a mediating level between road safety measures and the final result of road safety efforts in the form of accidents, injuries, or fatalities. In 2021 the City of Munich will develop first suitable indicators (i.e., speed measurements to determine the effectiveness of speed limits) to ensure comprehensive measure evaluation.
- *Public relations:* A permanent road safety campaign will be implemented in 2021 as part of an overall communication concept for promoting sustainable mobility.

The road safety campaign will focus on special topics, such as collisions between a cyclist and a motor vehicle's door, but also on general issues such as a more respectful behavior on the road and a more relaxed collective spirit. It will be combined with a city-wide target group–oriented information, consulting, motivation, and training program. Main focus groups are vulnerable groups like school children and elderly people.

Safety on the way to school: A new digital portal for planning safe ways to school is available since the end of 2020. The portal provides information about school locations, school districts, signalized intersections, and the positions of available assistants on the way to school, helping school children crossing the street.

Fortunately, the Munich City Council did not only approve the Vision Zero as the new official strategic objective, it also launched a concrete implementation program and provided necessary resources. Altogether 15 new jobs in road safety have been created, and a yearly budget of 2.5 million Euros was established. Moreover, programs and resources in other fields of activity within the mobility sector will focus more on road safety.

There are four major reasons why Munich was able to implement this ambitious Vision Zero program.

1. Motivated, competent, and personally engaged people in the city administration with good contacts to science, consultancy, and policy. They prepared the topic in the background over several years and took any arising opportunity.
2. The City of Munich had excellent consultants, who worked out the foundations of the described concept.
3. In 2016 the Department of Safety and Public Order got a new head, who put road safety very high on his agenda.
4. Finally, and unfortunately, some very serious accidents occurred. Following media reports and public pressure also prepared the ground for a resolute political decision.

Main task in the upcoming two to three years will be to get this program fully started. Specialists have to be employed, software has to be fully implemented, and trainings have to be conducted. New working structures and processes have to be implemented. External support has to be organized. Considering the very special environment of a public administration, the high number of tasks in a rapidly growing city like Munich, and the high expectations of politicians and the public, the implementation of Vision Zero is a major challenge. That is why the City of Munich systematically seeks for external cooperation and support, especially for a close exchange of experiences with comparable cities and interested institutions.

The Need for Technology Assessment: E-scooters as an Example (Kurt Bodewig DVW)

The Need for Technology Assessment: E-scooters as an Example

Technology assessment (TA) originated in the 1960s in the USA. It "serves to identify and evaluate the consequences of the use of technology for society through scientific analysis. It is concerned with the systematic identification and assessment of technical, environmental, economic, social, cultural and psychological effects that are associated with the development, production, use and exploitation of technologies. The idea of TA is to be able to anticipate in advance the consequences of technical actions and thus to make the thorny path of trial and error at least less painful, if not to avoid it completely." (Wirtschaftslexikon24.com 2018 p.1.) Within the framework of the policy of humanizing work, technology assessment was also applied in Germany in the beginning of the 1970s. Scientists and TA institutions in Europe have joined forces to form the European Technology Assessment Group (ETAG). Since 2005, ETAG has supported corresponding technology assessment projects on behalf of the European Parliament for the STOA Committee (Science and Technology Options Assessment) since 2005. In Germany, this task is carried out by the Office of Technology Assessment (TAB) at the German Bundestag.

Technology assessment is important for many political decisions. Especially with a strategy of Vision Zero, every change in the mobility system should be precisely analyzed for its effects and checked in terms of Vision Zero. This is exemplified by the introduction of electric micro-vehicles on urban streets and roads of Germany.

In urban agglomerations, there is a high volume of traffic. For this reason, mobility offers must be expanded to provide alternatives, especially for users of private cars. In addition to bicycles, so-called micromobility is seen as a solution, whereby commuters, for example, leave their cars at home and cover the "first and last mile," i.e., the journey from home to public transport and from public transport to work, with a much smaller and more economical vehicle. This is the role of the e-scooter, a battery-powered, single-track vehicle with a handrail. Its approval in the Federal Republic of Germany was published in the Federal Gazette (Federal Gazette Part I 2019 No. 21) on June 14, 2019, by the Electric Micro-Vehicles Ordinance (eKFV). It came into force on June 15, 2019. (Bundesministerium der Justiz und für Verbraucherschutz – Bundesamt für Justiz: Verordnung über die Teilnahme von Elektrokleinstfahrzeugen am Straßenverkehr (Elektrokleinstfahrzeuge-Verordnung – eKFV)) With this decision, the prerequisites were created for electric micro-vehicles with steering or holding rods to participate in road traffic. The vehicles must be equipped with two independent brakes, a lighting system, and an acoustic warning device (bell). The drive power must not exceed 500 W, and the maximum driving speed is 20 kph. For operation in Germany, the vehicles must have a general operating permit from the Federal Motor Transport Authority (Kraftfahrtbundesamt, KBA). In addition, users must take out liability insurance and affix an appropriate insurance plate to the vehicle. The allowed traffic areas are cycle paths and roads, and the minimum age is 14 years. The use is also subject to further regulations for driving vehicles, such as strict restrictions against driving under the influence of alcohol and drugs.

Despite criticism of individual regulations, the road safety associations agreed unanimously to the proposed approval on the basis of its risk/opportunity assessment. A draft ordinance was introduced into the legislative procedure just one month later. It was weakened in terms of road safety, in ways that significantly increased the potential danger. At the hearing in the German Parliament (Bundestag), criticism was correspondingly strong. Although negative experiences from other countries, including road deaths, serious injuries, greatly increased aggression, and displeasure in the population, were pointed out, they had no discernible effect on the federal government. Following protests by the DVR and DVW and other associations, some attempts to weaken safety rules, such as the planned use on footpaths and lowering of the age of use to 12 years, were withdrawn in consultations with the states.

However, the technology assessments of the Federal Highway Research Institute (BAST) were not sufficiently taken into account. Parliamentary technology assessment was not carried out because the regulation did not require a parliamentary decision. A proposal by traffic safety associations to require drivers to be suitable to drive motor vehicles was rejected. It would have led to a minimum age of 15 years and to a requirement of proven knowledge of the rules of the road, shown, for example, by means of a moped license. Since this proposal was not adopted, the current legislation allows 14-year-olds to drive a motor vehicle without special requirements.

The exact regulations for the introduction of electric micro-vehicles were not sufficiently communicated to the public in advance, and there was widespread ignorance of which e-scooters were allowed and how they could be used. There were already many privately owned electric micro-vehicles that did not have a permit and were therefore not allowed on public roads. Many believed that they were legalized by the regulation, and so vehicles without handlebars, sometimes self-balancing, were driven, often on pavements and at considerably more than 25 kph, without insurance coverage.

Vehicles that complied with the technical regulations were not privately owned at first but were offered by rental companies in large cities and in large numbers. In Berlin alone, six national and international suppliers of e-scooters were represented by the end of 2019. Since Berlin had not set an upper limit like other large cities, after half a year there were more than 15,000 scooters in the city area, mainly near the center.

The number of users was correspondingly high, and after 6 months of registration of e-scooters in Germany, there was a massive deterioration in the traffic climate and an increase in the number of accidents with injured people, some of which were seriously injured, an extremely high increase in alcohol offences and a massive increase in rule violations. This was confirmed in accident reports from the police and in news media.

- In Berlin, 176 traffic accidents were registered by the police from the introduction of the e-scooters until September 30, 2019, alone. In these accidents 131 people were injured, 21 of them seriously. By October 16, there were more than 1,200 proceedings concerning traffic violations in connection with e-scooters. In 108 cases the drivers were under the influence of alcohol, in 22 cases under the influence of other drugs. In addition, by the end of November 2019, there were more than 1,200 reports of incorrectly parked e-scooters in the Berlin-Mitte district alone. Almost all of these were violations of the road traffic regulations.
- In North Rhine-Westphalia, a total of 116 accidents have been recorded since the official permit for e-scooters was issued. Almost 1,500 administrative offences have been registered.
- In the Saxon state capital of Dresden, e-scooters are now responsible for more than half of all alcohol offences on the road. Between August and October 2019, the authorities counted 217 offences committed by e-scooter drivers involving alcohol.
- By the end of 2019, the police in Erfurt, the capital of Thuringia, had reported almost 170 cases of scooters being driven under the influence of alcohol. One in two of these cases was a criminal offence with over 1.1 per mille. Sixteen people had been caught under the influence of drugs.
- A sanction was imposed by the district court of Hanover against an e-scooter driver (age 22) for drunk driving. The young man had driven through the pedestrian zone with 1.2 permille. He lost his driving license and has to pay an additional penalty of 1,250 €.
  – MDR (20.12.2019): "E-Scooter in Mitteldeutschland-Viele Alkoholverstöße und Unfälle mit E-Rollern"
  – WDR (09.01.2020): "Schwerverletzte bei E-Scooter-Unfällen in NRW"
  – RBB (12.11.2019): "Rund 15.000 E-Scooter rollen durch"
  – Berlin- Tagespiegel (20.11.2019): "Mehr als 1200 Anzeigen in Berlin-Mitte gegen E-Scooter"
  – dpa/Redaktionsnetzwerk Dtschl.- RND (12.01.2020): "Studie: E-Scooter Unfälle führen oft zu Kopfverletzungen" [USA]
  – UDV-Blog (08.07.2019): "E-Tretroller: Laufen lassen oder intervenieren?"

These breaches of the rules not only lead to administrative costs, but also threaten the safety and protection of people, especially the drivers themselves, and also crowded pedestrians with injuries that are often more severe for elderly people. Statistically, e-scooter accidents are not recorded separately.

According to a newspaper article, serious head and face injuries occur, especially when alcohol is involved. This was reported by Marc Schult, a chief physician at the Clinic for Trauma Surgery, Hand Surgery, and Orthopedics in Hanover: "According to my observations," he said, "the number of pedestrian accidents is currently higher for e-scooters than for bicycles. Since mid-September we have treated around 50 patients in my clinic alone." Typical injuries in e-scooter accidents are fractures of the wrist, elbow, and ankle. "In the case of drunken drivers, we find more serious injuries, in particular craniocerebral trauma and fractures of facial bones, such as the nose, zygomatic bone or jaw." Schult pleads for compulsory wearing of helmets to reduce the dangerous head injuries.

This is confirmed in a recent study from the USA published in the medical journal *Jama Surgery*. ("Jama Surgery" 2019, dpa 11.01.2020) It showed that the number of injuries and hospital admissions after accidents with e-scooters has increased dramatically. About a third of the patients suffered head trauma, twice as many head injuries as cyclists in the USA. More than a quarter suffered fractures, similarly frequent bruises and abrasions, and one in seven suffered cuts. The authors of the study admit that there is probably a high number of unreported accidents. They strongly recommend a helmet, since only 2–5% of the users, which were treated in hospitals, wore a head protection and whoever provides e-scooters should promote helmets and make them more accessible.

In addition to accidents, there are other effects, such as the increasing aggression in the traffic climate due to the reckless behavior of e-scooter drivers, who crowd pedestrians and leave the vehicle on sidewalks. Pedestrians, especially old and disabled people, are left with a feeling of insecurity. At the parliament's hearing, the German Federation of the Blind and Partially Sighted rightly warned of the dangers.

Since January 1, 2020, the involvement of e-scooters has been separately assessed and recorded when reporting accidents. This is the first time that valid data on perpetrators, victims, and serious consequences of accidents have been collected. The police, who have already recorded e-scooter accidents in various regions, now produce these reports according to a uniform system.

The Federal Statistical Office (Destatis) published first statistical data for 2020. There were 2,155 accidents recorded throughout Germany involving e-scooters, which harmed people. Most of them caused slight injuries, 386 people were seriously injured, and 5 e-scooter-users lost their lives. In comparison to other vehicles these numbers seem to be less alarming but keeping the special conditions of e-scooters in mind, there is a reason for worrying. We assume that there is a higher number of unreported incidents and the e-scooters are a rather new form of mobility with fewer vehicles in use. Also due to the Corona pandemic in 2020 significantly less tourists visited cities, who are the main target group for the rental services. This made the rental companies to reduce their fleets temporally. It means, we have to presume, that under "normal" conditions and development the number of accidents would be a lot higher.

But from these data we could already see that there is a higher accident risk for e-scooter users in comparison to bicycles, which are the nearest group of road users. They both are unprotected, traveling with a similar speed, use the same road types such as bike lanes, and do not make any kind of driving license necessary. E-scooters also injure more often other persons – especially pedestrians – involved in relevant accidents than cyclists do.

One of the reasons is that e-scooter users violate important regulations more often, which is also attributed to the special circumstances of the rental system. It aims predominantly to a spontaneous decision to drive – mainly by tourists. We guess that they are less experienced in safely driving the scooters and/or there is an ignorance of the local regulations such as the prohibition to use the sidewalk. Some want to save money while renting and use the vehicles with two person or they carry heavy luggage. Especially party-seeking tourists see the rental system as an opportunity to manage shorter distances faster than by foot and more convenient than using the public transport – while anything else but sober. Most frequent cause of accident in 2020 was the influence of alcohol in about 18% of the cases. Furthermore, visitors are not equipped with protective gear as a helmet and rental companies do not provide them.

These indications contrast with the usage of e-scooters in everyday life and regular frequency like for commuters. Here we expect another age structure, more driving experience, more reasonable and right behavior, higher potential for using a helmet, etc. So, there is an appropriate implementation of e-scooters, if we use it as a replenishment to our mobility to ease traffic congestion while keeping sustainability in mind.

With these findings, a (lesser) form of TA will be carried out retrospectively. Whether and when these findings will lead to a necessary change in the legal situation is not yet foreseeable.

All this could have been avoided with an appropriate technology assessment. We can learn this from the experience of technology assessment in Montreal (Canada). When Montreal was faced with the decision whether to approve e-scooters, a technology impact assessment was carried out. It was based on a pilot project in which rental of e-scooters was allowed on a limited scale.

The evaluation of the pilot project showed that hardly any e-scooter driver adhered to the traffic rules. An extra police unit would be needed to cope with the many rule violations. Although the drivers were required to wear a helmet, almost none of them did so. In 80% of the cases, the e-scooter driver finished the rental by parking the e-scooter illegally. Based on this real experience and its scientific evaluation, it was decided not to perform any additional pilot projects. The small electric vehicles were again banished from the cityscape again. Instead, it was decided to improve the supply of rental bicycles and to introduce additional licenses for e-bike rentals. The resulting income will be reinvested in the city's bicycle traffic infrastructure. (CTV News Montreal Wednesday, February 19, 2020.)

The design of the e-scooters results in high demands on safe handling. At the same time, the rental system means that many people are on the road for the first time without having practiced before. For this reason, the Deutsche Verkehrswacht (German Road Safety Association), with the support of the Federal Ministry of Transport, has included the topic in one of its target group programs and offered to give test courses.

The e-scooter is a sensible means of mobility for the journey between home and daily employment in order to bridge the so-called "last mile." Either in the combination of bus and train with e-scooter locations at stops and stations as a rental system or transportation in public vehicles, such as subways or regional trains or in buses. This also allows helmets to be carried, but also requires specific solutions. However, in order to avoid hazards, the carriage of electric vehicles in public transport buses is subject to special conditions. Only if the criteria for taking e-scooters on public buses are met, it is possible to transport them safely in local public transport vehicles. This should also be part of a TA.

Public platforms such as JELBI, which connects different rental platforms with Public Transport in Berlin, uses an app to sell tickets and rent complementary micro-electric vehicles for individual mobility chains. By the obligatory proof of the driving license for the receipt of the app access is also, e.g., the proof of the driving rules knowledge necessary for traffic safety reasons likewise documented.

Furthermore, the DVW advocates the following measures:

Cities that allow e-scooters will have to put stringent demands on providers of e-scooter rental. Reasonable measures to reduce accident risks include:

- A prohibition to park e-scooters outside of clearly defined parking spaces. This is needed to avoid accident risks for pedestrians.
- In order to make effective traffic-safety prosecution possible, rental companies should be required to collect the necessary user data and make them available to the law enforcement.
- Helmets should be mandatory in order to prevent severe head and brain trauma.
- The police must enforce compliance by building appropriate capacities (including building or expanding police bike teams).
- Alcohol controls, also with a focus on e-scooters, must become part of police activities. Previous cases of drunk e-scooter driving clearly show the necessity.
- The infrastructure needs to be significantly improved and expanded in order to reduce competition between cyclists and e-scooters.
- The technical equipment of e-scooters needs to be improved, among other things, by bindingly equipping future single-track, standing miniature electric vehicles with direction indicators.
- Other vehicle classes that pose a higher risk, such as self-balancing micro-electric vehicles or vehicles without a handrail, have to be banned.
- Additional scientific data are required to target accidents. The federal government should commission its research institution (BASt) to provide this data.
- All of this must be accompanied by road safety prevention that offers training for safe use and critically monitors developments.

In conclusion, if a sound technology assessment had been carried out prior to the entry into force of the regulation on the electric micro-vehicles, the current situation with serious accidents and chaos in the inner cities of urban and tourist centers could have been avoided. The procedure practiced in Germany in this case, with a draft bill being approved without a prior technology assessment, is the opposite of an action in the sense of the “Vision Zero” commitment. This should be a warning to all. When a new mobility element is introduced, a technology assessment must be carried out.

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Vision Zero in Poland

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Contents

Abstract

Poland's experience of road safety work is relatively short. In the early 1990s road deaths soared to a staggering 8000 a year. A diagnosis found that Poland's lack of systemic road safety action was to blame for those figures. In response, the state set up road safety bodies and commissioned road safety programs. In 2005, Poland followed the example of Sweden and adopted Vision Zero as a far-reaching concept of changes in road safety. The work that followed helped to improve the situation and reach less than 3000 fatalities in 2015. Despite that, for years Poland has been notorious for its road accident deaths, which are some

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of the highest in the EU. Poland has had its share of both successes and failures. The results of road safety policies are still below the expectations and many problems have not been solved. Road accidents are not considered a major problem. As a consequence, they are low on political agendas and the institutions remain ineffective due to a sense of collective responsibility for road safety problems. Achieving Vision Zero will require many changes, learning from past mistakes, taking advantage of the experience of the best performing countries, and, above all, taking effective and efficient actions with their systematic monitoring.

This chapter is a summary of the last 30 years of road safety work in Poland. It presents a diagnosis of Poland's problems, an assessment of the policies so far, and the likelihood of achieving the assumptions of Vision Zero in the future. Building on this, recommendations are given on the next steps Poland should take to improve its road safety.

Keywords

Road safety · Poland · Vision Zero · GAMBIT · Program · Strategy · Scenario · Forecast

Introduction

Between the late 1980s and early 1990s a political transformation of Poland was taking place. Just as many other Central and Eastern European countries, Poland was making a shift from socialist to capitalist economy. The period was marked by an astonishing increase in road accident fatalities. People wrongly assumed that this was inevitable simply because motorization was developing dynamically. State bodies with statutory responsibility for road safety could not agree more because it justified their lack of spending on better roads. After all, there were always other more important issues, or so it seemed at the time. There was no reaction from the public, either. After years of socialism, people were willing to pay the price for growing mobility even if it meant accidents and victims. It was not until a group of World Bank experts (Gerondeau 1993) published their report in 1992 that an honest and objective diagnosis of the Polish situation was made clear – the system failed to address the problems of growing motorization leading to the high number of victims. The report paved the way for tackling road safety problems in Poland head on. The first steps were taken and they were to appoint the National Road Safety Council and develop Poland's first ever road safety program known for short as GAMBIT 96 (Krystek et al. 1996).

Since 1991, which was a peak year with the highest number of fatalities in Poland, the situation has improved significantly. Road deaths have now fallen from the catastrophic 8000 in 1991 to less than 3000 in 2019. The reduction was achieved thanks to the new socioeconomic situation, which kept improving after the transformation, road safety policies, change in road user behavior, and the delivery of national road safety programs.

An important milestone at the time was Poland's accession to the European Union (May 2004) and the development and implementation of the National Road Safety Program for the Years 2005–2007–2013, called GAMBIT 2005 (Jamroz et al. 2005). The program adopted Sweden's Vision Zero as an ethically justified vision of road safety (Jamroz et al. 2006). By adopting it Poland committed to strive for zero fatalities in road traffic. In order to achieve this, the following demands need to be met:

– Human life and health are put above mobility and other goals of the transport system.
– Both politicians, planners, road designers and builders, teachers, journalists, policemen, road carriers, rescue services and road users are jointly responsible for road accidents and eliminating their consequences.
– The road system and vehicles are designed, built, and operated in such a way as to minimize and compensate road users' errors.
– The traffic safety management system has procedures and tools to meet the challenges posed.

The moment of adopting Vision Zero as a far-reaching vision of road safety can be recognized as the start of systemic road safety action in Poland (Jamroz and Michalski 2005; Jamroz et al. 2017).

Poland's experience of road safety over the last three decades has had its ups and downs. For years Poland has been notorious for topping the EU's most dangerous country rankings. The risk of becoming a fatality in Poland was 50% higher than the EU average and double that of the United Kingdom, Sweden, the Netherlands, and Denmark. The results of road safety treatments are below the expectations. Many problems remain unsolved such as excessive speed or a high number of pedestrian fatalities. Road accidents are still not seen as a major problem in Poland or given political priority. In addition, the relevant institutions do not produce results because responsibility for road safety is collective (Krystek et al. 2013).

While the country has had successful road safety policies, more needs to be done (Wegman 2007; Jamroz et al. 2019). As it works its way toward Vision Zero, Poland will have to make many changes, learn from its mistakes, and take advantage of the experience other countries have with tackling road safety problems. This sets the context for Polish road safety research (Jamroz et al. 2006, 2016; Jamroz 2011, 2013; Krystek et al. 2013; Gaca and Kiec 2016). It aims to:

– Evaluate the approach to road safety programs in Poland
– Identify the conditions and efforts which have significantly improved road safety
– Identify barriers to the full implementation of measures
– Identify the challenges Poland will face in the years to come
– Understand how likely Poland is to achieve Vision Zero

This chapter is a summary of the last 30 years of road safety efforts in Poland.

State of Poland's Road Safety

Changes Between 1988 and 2019

Over the last 30 years Poland's road safety has improved significantly. Since 1991, which recorded the highest number of road deaths in history at 7900, fatalities have been reduced nearly threefold to 2900 people killed in 2019 (Table 1).

Compared to other EU countries, the changes have not been quick enough with Poland topping EU lists over the last 18 years several times. In 2018, Poland was number four among the EU's most dangerous countries (Fig. 1). The risk of becoming a fatality in Poland is still 50% higher than the EU average (which is 49 fatalities per one million population in 2018) and double the risk in the United Kingdom, Sweden, the Netherlands, and Denmark (Fig. 2). The total number of fatalities in Poland, Germany, France, and Italy represented half of the entire European Union's road deaths in 2018.

The Situation in 2018

Based on the police road safety database SEWIK, in 2018 there were 31,700 road accidents on Polish roads with 2865 people killed and 37,300 people injured of which 10,900 were seriously injured. The most frequent causes of serious accidents (involving pedestrians and serious injuries) included: hitting a pedestrian, side collisions, and head-on collisions; serious accidents happened most often on national roads, junctions, at nighttime, at pedestrian crossings and involved speed and hard roadsides (Fig. 3).

Road safety research in Poland (Jamroz et al. 2017, 2019) shows that:

Table 1 Changes in Poland's road safety from 1988 to 2019 compared to socioeconomic changes

	Population	Number of vehicles	Vehicle travel distance	Gross domestic product per capita	Number of fatalities	Road fatality rate		
Year	P (m)	V (m)	VKT (b vkm)	GDPPC (thous. ID/year)	F (victims)	RFR_P (victims/ 1 m. inhab.)	RFR_M (victims/ 1 m. veh.)	RFR_T (victims/ 1 b. vkm)
1988	37.8	6.9		8.20	4851	128.3	703.0	
1991	38.2	8.6	94.6	7.57	7901	206.8	918.7	83.5
1997	38.6	12.3	127.4	10.22	7312	189.4	594.5	57.4
2001	38.2	14.7	148.4	11.96	5534	144.9	376.5	37.3
2007	38.1	19.5	220.8	15.66	5583	146.5	286.3	25.3
2015	38.0	27.4	315	21.77	2938	77.3	107.2	9.3
2019	38.3	29.5	335	25.72	2909	75.9	98.6	8.7

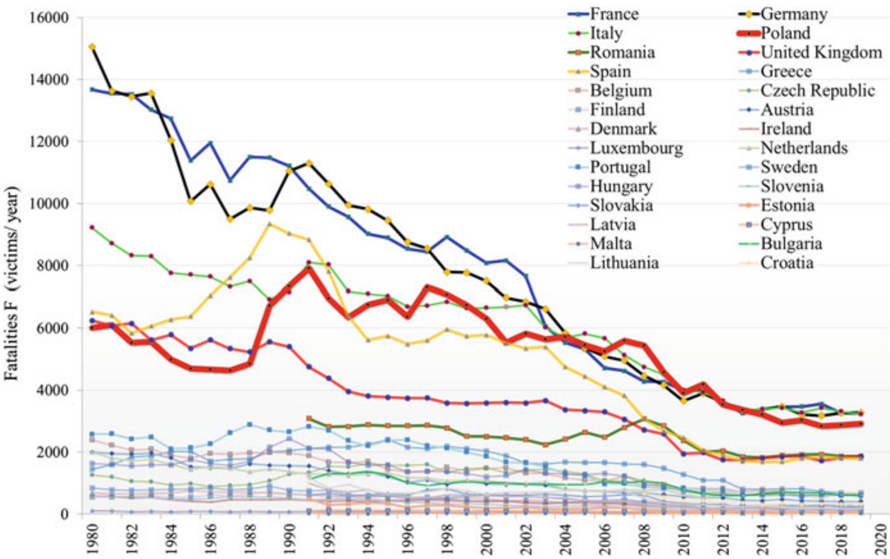


Fig. 1 Changes in fatalities in EU countries in the years 1990–2018

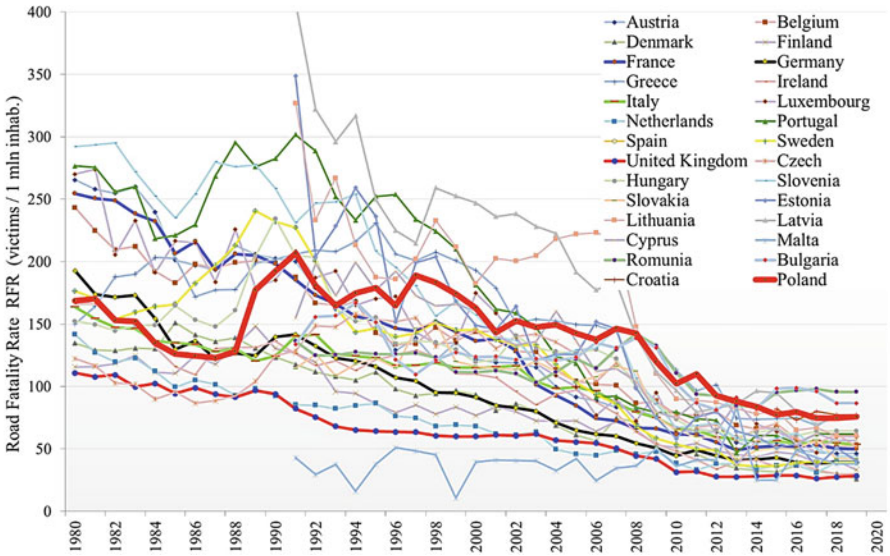


Fig. 2 Changes in road fatality rates in EU countries in the years 1990–2018

1. Vulnerable road users: pedestrians, cyclists, and young drivers continue to be at high risk of death or serious injury.
2. Poland's basic road safety problems are still the same, i.e., poor quality of some of the road infrastructure, ineffective speed management, relatively poor road safety behavior.

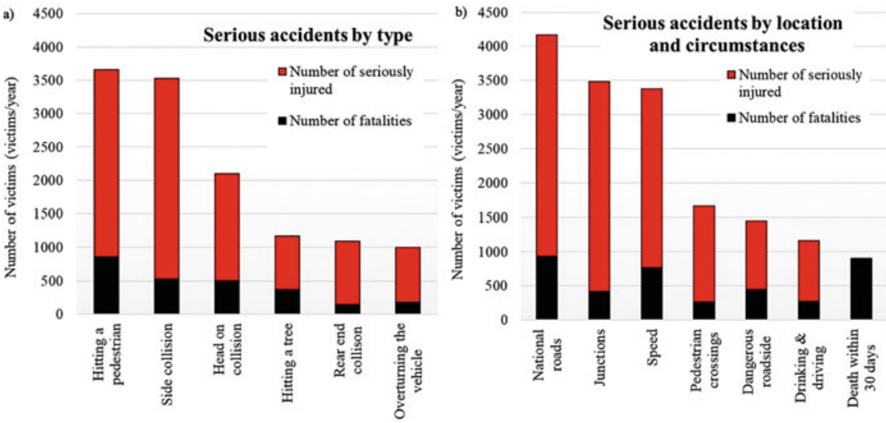


Fig. 3 Distribution of fatalities and serious injuries in Poland's serious accidents broken by type (**a**) and accident location and circumstances (**b**)

3. Simple road safety measures are no longer working and soft measures are not enough; what is needed is an integrated and knowledge- and research-based approach with the right resources and funds.
4. The road safety management system is weak: there is no lead at the central or regional level, programs are poorly funded, access to accident databases is poor, and the scope of data is limited.

Key Road Safety Problems

An analysis of Poland's road safety data has helped to identify nine problems which generate a particularly high number of road accident deaths. The road accidents in question occur on national roads and involve pedestrians, speeding, nighttime, running-off-the-road and hitting a tree, high severity (death at the scene or within 30 days), drink-driving, and accidents at junctions and pedestrian crossings. Despite a significant drop in fatalities in the last 20 years (1999–2019) (Fig. 4), fatal accidents remain a serious risk.

Speed Excessive, dangerous, or not adequate for the driving conditions, speed is the risk factor of about 30% of fatal accidents. Between 1999 and 2019 fatalities in these accidents fell by 61%. This is mainly thanks to the speed camera system (CANARD) (Jamroz and Michalski 2005; Jamroz et al. 2005), building a network of safe roads and introducing traffic calming zones in urban areas (Gaca and Kiec 2016). Sadly, other decisions were also made which went against fatality reduction in speed-related accidents such as reducing the coverage of the speed camera system (2015) and increasing motorway speed limits from 130 km/h to 140 km/h (2010).

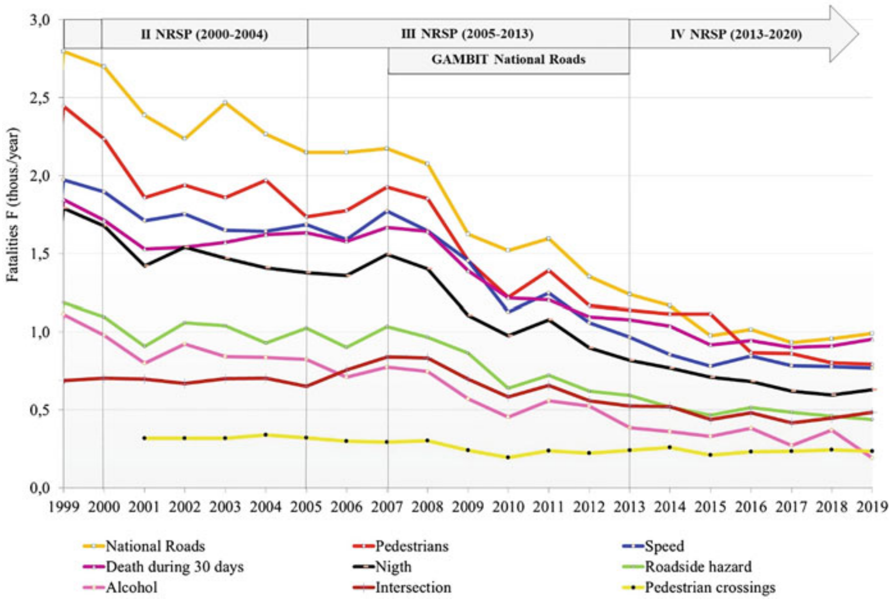


Fig. 4 Changes in the number of road fatalities in Poland in the years 1999–2019 and in the periods of National Road Safety Programs (NRSP), broken by selected road safety problems

National Roads (managed by National Road Administration) carry more than 25% of overall traffic. Nineteen percent of all accidents happen on these roads with fatalities representing as much as 33% of all road deaths. The years 1999–2019 saw the introduction of a number of systemic policies such as the development and implementation of GAMBIT National Roads (Jamroz et al. 2008), construction of new motorways and expressways (between 2002 and 2019 nearly 3500 km of new sections were completed), and a steady improvement of safety standards. As a result, fatalities on national roads dropped by 65%. Certain problems, however, persist: too few good quality roads (motorways and expressways), lack of ring roads, roads with wrong cross-sections, underdeveloped and unsafe roadsides, lack of protection for vulnerable road users, road safety standards not met during road improvement works, and poor progress on ITS delivery for road traffic management.

Pedestrians For many years Poland has been one of the European Union's most dangerous countries for this (31% of all fatalities) with the highest number of pedestrian fatalities among EU countries. Between 1999 and 2019, pedestrian fatalities fell by 68%. The reduction has been particularly strong since 2007. Eighty-five percent of pedestrians are killed in built-up areas and 15% in non-built-up areas. The following are sites of fatal pedestrian accidents:

– Built-up areas: 48% at pedestrian crossings, 42% on the road, and 3% on the pavement

– Non-built-up areas: 87% on the road, 8% at pedestrian crossings, and 2% on the roadside
– National roads: 11%, regional roads: 17%, municipal and county roads: 29%, and county capital streets: 43%.

The main problems regarding pedestrian safety include: unregulated pedestrian priority on the road (work is under way to change the law), lack of pedestrian safety devices (pavements, refuge islands, traffic control devices on multilane carriageways), pedestrians poorly visible during nighttime, and drivers' behavior (excessive speed, not giving priority to pedestrians) (Jamroz et al. 2016, 2019). There are measures designed to improve pedestrian safety. These include: pedestrian and cycling paths being built along rural sections of national and regional roads and the Manual for organizing pedestrian traffic (Jamroz et al. 2014a), now the basis for improving standards of pedestrian infrastructure safety, especially at the local level. The aforementioned problems of pedestrian safety are also indicated in the new Polish guidelines for the design of pedestrian devices, which is under preparation.

Death Within 30 days Between 1999 and 2019 the number of people dying within 30 days from accident date fell by 48%. This is the result of elimination of hard obstacles in the roadside, using protective devices (i.e., road barriers), changing the car park (i.e., airbags as standard car equipment), and developing a rescue system. Nonetheless, high accident severity is still an important problem in Poland. The factors contributing to high accident severity (10 fatalities per 100 accidents) include: high vehicle speed on roads with unsegregated directions of traffic and hard roadsides, rescue system deficiencies, and problems of the health care system. Efforts must be taken to reduce accident severity by improving infrastructure, organization, and management, and implementing a better road rescue system and post-accident help for victims.

Nighttime Between 1999 and 2019 the number of fatalities in nighttime accidents fell by 65%. The factors contributing to nighttime fatalities include: higher speed during the night in built-up areas (60 km/h 24.00 to 6.00), limited perception of the road by road users on rural roads (pedestrians, drivers), vertical and horizontal markings not meeting reflectivity requirements, and poor lighting (in particular junctions, pedestrian crossings). It is common practice to switch off traffic lights at night. A contributing factor which is frequently underestimated, especially on motorways, expressways, and other transit roads is driver fatigue or driver drowsiness and a poor network of places where drivers can rest (Jamroz and Smolarek 2013a).

Dangerous (hard) Roadside About 25% of rural accidents and nearly 16% of all of Poland's fatalities involve vehicles running off the road which roll over or hit a roadside object. Between 1999 and 2019 the number of fatalities when a vehicle hit a hard roadside went down by only 63%. The main cause of the situation is that roadside design and maintenance are not adequately regulated. In addition, conflicts arise when roadside trees are to be cut down (another area without proper regulation). Steps are taken, however, to improve roadside safety such as tree felling when roads are built or improved, when new road sections are built running parallel to sections with protected tree lines, containment structures are used together with a new approach to safety barriers.

Drinking and Driving In the late 1990s, alcohol was one of Poland's main road safety problems. Between 1999 and 2019 the share of fatalities in drink-driving accidents dropped from 22% to 10% and fatalities in drink-driving accidents fell by as much as 83%. Poland has one of the lowest share of drink-driving fatality accidents, a result of intense and systematic enforcement (Police, Road Transport Inspectorate), education, awareness raising, and a change of alcohol consumption culture in Poland.

Junctions The primary problem of junctions has to do with the road infrastructure and increasing traffic. With a high number of simple junctions giving priority to the main road traffic and a growing demand for entry from side streets, drivers force their way across the junction causing more and more serious side crashes and head-on collisions. If fatalities are to go down, safer junctions should be used (roundabouts, signalized junctions), with better visibility, clarity, and easier to cross. In 1999 the share of fatalities in accidents at junctions compared to all fatalities was about 10% to increase in 2018 to 14%. Fatalities within this period went down by 30%. More efforts must be taken, in particular building modern and safe junctions, to eliminate side crashes and head-on collisions. Equally, more needs to be done to improve enforcement (speed control and running the red light), compliance, and partnership among drivers).

Pedestrian crossings Crossing the road is one of the highest risk behaviors of road users in Poland. Pedestrian accidents usually happen on the road 60%, at pedestrian crossings 30%, and on pavements 4%. Crossing a road in Poland carries a lot of risk. The problems pedestrians face include a lack of pedestrian protection on high speed roads (lack of elevated refuge islands, ineffective protection at painted refuge islands, lack of cycle crossings, etc.) and extended pedestrian crossings, which are particularly dangerous when pedestrians have to cross four or six lanes that are not separated and sometimes even include tram tracks in the middle. The share of pedestrian fatalities in road accidents is 5–8% of all fatalities and has been at 250 annually over the years. If pedestrian fatalities at pedestrian crossings are to fall, the number, location, and type of pedestrian crossings must be verified; pedestrians should spend less time in vehicle conflict zones, conflicts between pedestrians and vehicles should be minimized and, once the conflict happens, the consequences should be minimized thanks to lower speeds in pedestrian zones.

Poland's Road Safety Programs

General Characteristics of Road Safety Programs

Poland's experience of road safety policies is relatively short. Following GAMBIT 96, there have been five national road safety programs (Table 2) of which the first four are called GAMBIT and were developed by teams headed by the Gdansk University of Technology.

Table 2 National road safety programs in Poland between 1996 and 2020

Program (years in force)	Acronym	Policy/ vision	Strategies	Actions	Responsible entity
Integrated road safety Program GAMBIT'96 (1996–1999)	I NRSP*	None	Main qualitative goal, overall fatality reduction	Grouped (integrated)	National Road Safety Council
Road Safety Program for Poland 2001–2010 GAMBIT 2000 (2000–2004)	II NRSP	None	Main target (4000 fatalities in 2010), 2 objectives	Two groups of tasks	National Road Safety Council
National Road Safety Program 2005–2007 – 2013 GAMBIT 2005 (2005–2013)	III NRSP	Vision zero	Main target (2800 fatalities in 2013), 5 strategic objectives, operational program	4E** and system development	Secretary of the National Road Safety Council
Road Safety Program 2007–2013 GAMBIT National Roads (2007–2013)	GAMBIT National Roads	Vision zero	Main target (500 fatalities on national roads in 2013); priorities, pilot program	3 eras, 4E	National Roads Administration
National Road Safety Program until 2020 (2013–2020)	IV NRSP	Vision zero	Main targets (2000 fatalities and 6900 serious injuries in 2020), 5 pillars	Safe system, 4E	Secretary of the National Road Safety Council

[a]NRSP – National Road Safety Program
[b]The 4 E's concept includes: Education, Engineering, Enforcement, Emergency

Detailed Characteristics of Road Safety Programs

Integrated Road Safety Program GAMBIT 1996 (I NRSP)

Commissioned by the Minister of Transport and Maritime Economy, Poland's first comprehensive Integrated Road Safety Program was developed between 1993 and 1996, known as GAMBIT 1996. Authored by a multidisciplinary team made up of scientists, engineers, teachers, police officers, fire fighters, and experts in many fields, the program was led by the Gdansk University of Technology (Krystek et al. 1996). Its biggest strength was that it brought together different sectors and industries around a common goal. With multiple specialists forming a single multidisciplinary team, work on the program paved the way for long-term cooperation of the different communities and helped to build the foundations for Poland's systemic policies. GAMBIT'96 was Poland's first ever integration and coming together of the sectors of education, infrastructure, enforcement, and rescue. The knowledge and experience of many foreign experts (Muhlrad 1991; Laberge-Nadeau et al. 1992; Haegi 1993; Gunnarsson 1995) helped to develop the program.

A diagnosis helped to identify the biggest problems: lack of road safety bodies, dangerous road infrastructure, high share of old vehicles in vehicle streams, and ineffective enforcement. In 1995, road accidents on Polish roads claimed the lives of 6900 people. The program did not set a target and instead gave a general goal of reducing road accident fatalities in Poland.

While GAMBIT 1996 was commissioned by central authorities, central government did practically nothing to implement the Program and seemed satisfied with just having a program and carrying out the odd ad hoc measure completely unrelated to the Program's methodology. Building on the national program, several regional programs were also developed (Gdansk, Elbląg, Katowice, Suwałki) and systematically implemented. The regional level became involved in improving road safety (Michalski et al. 1998).

Unfortunately, following the country's administrative reform (the number of regions went down from 49 to 16 and a four tier structure was established), regional efforts came to a halt in 1999.

The program's scientific outcome was the first International Road Safety Seminar GAMBIT (GAMBIT 1996), which brought together scientists, practitioners, administration, and NGOs. Since then the Gdansk University of Technology has been hosting biennial meetings of scientists from institutes and universities, engineers, producers of road safety devices, teachers, police officers, road rescue staff, doctors, and lawyers interested in protecting road users from the risk of injury or death (Fig. 5). They exchange experience, set new directions, and put pressure on central, regional, and local authorities.

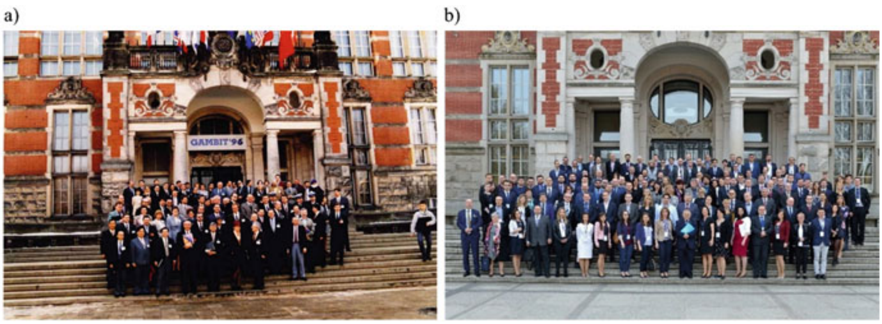


Fig. 5 Participants of the Road Safety Seminar GAMBIT in front of the Gdańsk University of Technology main building: (**a**) GAMBIT'96, (**b**) GAMBIT 2018

Poland's Road Safety Program for the Years 2001–2010 GAMBIT 2000 (II NRSP)

In 1999, a new administrative structure emerged with four tiers of governance: central, regional, county, and municipal. As a consequence, Poland's road network structure changed as well and the transport minister commissioned a new road safety program, which was called GAMBIT 2000 (Krystek et al. 2001).

In 2000, road accidents on Polish roads killed 6294 people. A diagnosis was carried out and identified the main problems: excessive speed, vulnerable road users, accident severity, transit roads passing through small towns, and high risk sites.

Taking advantage of international experience (OECD 1994; Andersson and Nilsson 1997; Broughton et al. 2000; Kroj 2001; Oppe 2001) and based on analyses of socioeconomic forecasts, GAMBIT 2000 adopted strategic goals. The main goal was to reduce road accident fatalities to 4000 in 2010 (i.e., to reduce fatalities by 36% compared to 2000). There were three objectives:

1. Implement road safety measures in seven problem areas
2. Create a basis for an effective and long-term road safety policy
3. Gain public support for road safety

The program also identified two groups of tasks:

1. Systemic action (group A) to include safety management, building databases and knowledge, safety audit, and staff training. This was designed to make road safety management more efficient following a review of the laws and adding new regulations to help with an effective delivery of the program.
2. Action to include the main problems and threats (group B) such as excessive speed, vulnerable road users, accident severity, transit roads passing through small towns, high risk sites to an extent compatible with the diagnosis and availability of funding. The program had its first short-term and long-term targets.

GAMBIT 2000 was formally adopted by the government in May 2001 as the National Road Safety Program until 2010. It was designed as the government's road safety program using direct or indirect means to change road user behavior and road safety management by the regions, counties, and municipalities. The Program was to help local authorities to create better conditions for effective road safety policies. The Program's funds were to be spent on building or improving road infrastructure. The work was considered a pilot to promote "good practice" in the area of road safety treatments (Krystek et al. 2001).

In the initial period of GAMBIT 2000 (a period of 2.5 years), fatalities compared to 2000 dropped by 10.4%. While work on delivering goal 1 (specific measures) and goal 2 (systemic measures) progressed, goal three, i.e., to gain public support for road safety never took off.

Despite the short period, GAMBIT 2000 helped to:

- Increase activity at the regional and local level (training for road safety staff, developing regional and local road safety programs, increase in using effective road safety measures)
- Build and implement systems for monitoring selected road user behaviors (speed, seatbelts) in all regions
- Prepare road safety training for central and regional staff
- Support financially central (national roads, police, rescue) and regional work (regional and county roads)
- Raise public awareness of road traffic risks
- Involve nongovernmental organizations in road safety efforts

The possible reasons why GAMBIT 2000 goals were not achieved in their entirety might be that the program did not really have a clear leader to run it and be accountable for it. Poor cooperation between central and local government was also to blame (especially between different tiers of road authorities). There was too little engagement from central bodies because decision-makers just did not think road safety was a strong enough priority. Shortage of staff and lack of scientific and technical support for road safety professionals also contributed to the poor performance. On the practical side, there were no operational programs to translate the plans into tasks and projects with specific targets, monitoring indicators, costs of delivery and contractors, all of which may have significantly boosted planning and availability of funding. With Poland lagging behind the safety standards required by the European Union in the run-up to becoming a member, a new approach to road safety was definitely called for (GAMBIT 2002).

National Road Safety Program for the Years 2005–2007–2013 GAMBIT 2005 (III NRSP)

When Poland joined the European Union in 2004, the country was required to adapt its national road safety program to the new conditions under the EU's transport policy, its strategy set out in the White Paper and the third EU Road Safety Action Program. The program aimed to halve the number of road deaths between 2000 and 2010 (European Commision 2000). The National Program GAMBIT 2005 was planned for the years 2005–2013, fitting in with Poland's first financial support period from the European Union (Jamroz et al. 2005).

In 2003, stage one of GAMBIT 2000 ended providing a baseline for GAMBIT 2005. Poland's basic road safety indicators were: 5740 people killed, 147 people killed per one million population. The rates were at a 1970s level of Sweden, the Netherlands, and England and were almost double the rates recorded in those countries at that time. Poland's basic road safety problems included: dangerous road user behavior; insufficient protection of pedestrians, children, and cyclists; poor quality of road infrastructure; and ineffective system of road safety.

While the authors analyzed the visions of a number of countries (12 original visions) (OECD 2002), the one they felt strongest about was Vision Zero delivered in

Sweden (Tingvall 1998; Tingvall and Haworth 1999), and also in Norway (Siegrist 2010), Iceland (Sigţórsson et al. 2013), Australia (Wadhwa 2001), and Switzerland (Siegrist 2010).

The new program set its strategic target at halving fatalities by 2013 compared to 2003 numbers, which meant not more than 2800 people killed in road accidents in 2013 (Fig. 6a). The program defined three time perspectives:

1. A far-reaching vision of road safety based on Vision Zero
2. A road safety strategy until 2013 (approved by the Polish government in 2005) and a strategic goal for the next period 2014–2020
3. An operational program for the years 2005–2007 (approved by Poland's new government in 2006, sadly without earmarked funding)

To achieve the quantitative goals, five strategic goals were formulated:

1. Prepare a basis for effective and long-term road safety action
2. Shape safe road user behavior
3. Protect pedestrians, children, and cyclists
4. Ensure a safe road and roadside infrastructure
5. Reduce accident severity and accident consequences

Each strategic goal set out strategic actions and tasks. There were 144 tasks in 16 strategic actions. The program adopted an extended 4E principle. It aimed to build a road safety system and improve the organizational structures, education,

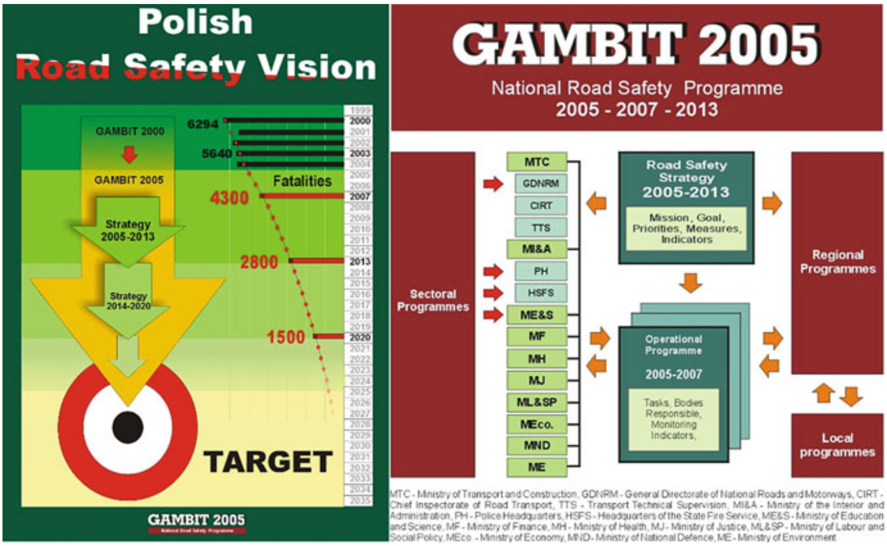


Fig. 6 National Road Safety Program for the Years 2005–2007–2013

enforcement, road infrastructure, and road rescue (GAMBIT 2006). The five areas were to be integrated at three tiers: national (ministries, administration, and central institutions), regional (regions), and local (county, city) (Fig. 6b).

GAMBIT 2005: (**a**) Polish Vision Zero, (**b**) the program's delivery structure.

As part of GAMBIT 2005 implementation, there were a number of national level activities in areas such as education, prevention, and infrastructure providing a great fit with the overall program directions. Despite that, a number of political and administrative decisions were taken which went against the program. Quite a lot was done in the area of legislation, education, prevention, and infrastructure. In the first 5 years into the Program, 84 of 144 tasks (58%) were launched. While some did not bring the expected results or were poorly performed, others worked well and helped to improve road safety. They included:

– Regional and county road safety programs were developed and implemented covering a dozen regions, cities, and counties
– Sectoral road safety programs were developed and implemented (for national roads, police programs)
– Work began on building the Polish Road Safety Observatory and two regional observatories
– Driver training and exams were changed
– An enforcement system was implemented and developed (speed control, driver working time control)
– Cycling was regulated
– A network of expressways and motorways was extended, safe junctions and traffic calming measures were built
– Road safety audit was made compulsory for some projects
– Rescue and post-accident protection systems were modernized

Unfortunately, many of the Program's important steps were never taken such as:

– GAMBIT 2005 did not have a clear leader.
– The structures of road safety bodies were not improved or made more efficient, especially the National Road Safety Council.
– No local institutions were appointed (inspectors, officers, leaders).
– No system of sustainable road safety funding was introduced.
– No monitoring system was built to keep track of strategy progress.
– Effective road safety measures were not promoted.

Evaluation of the first short-time operational program was conducted in 2007. It concluded that (Wegman 2007):

1. The road safety strategy and action plans under GAMBIT 2005 were well prepared.
2. Road safety staff were trained, increasing the number of road safety professionals at different levels of governance. Polish experts benefitted from training available

abroad (the Netherlands, France, and Sweden) and are well-informed participants of the international road safety community.
3. The actions set out in GAMBIT 2005 were not delivered fully or evaluated for their effectiveness. Funding was limited. As a result, the impacts were limited, too.
4. While regional GAMBIT programs were quite abundant and well prepared, delivery was poor and ineffective with no support from the central level, lack of solid accident databases, or a systematic evaluation of the programs.
5. The lead agencies within government structures (leaders) with responsibility for road safety did not emphasize a strong enough political will to improve road safety (lack of a political or operational leader and agencies not happy to work together).

The analyses show that Poland's approach to the problem was far from the standards normally applied in the European Union. It was clear that when the next national program is formed, the institutional setup would have to be given top priority to ensure that the program can be delivered effectively.

Road Safety Program for the Years 2007–2013 – GAMBIT National Roads
In 2007, a sectoral program was developed to address the network of national roads, called GAMBIT National Roads (Jamroz et al. 2008). For the first time the National Roads Administration acknowledged the role of partners (teachers, journalists, police officers, and fire fighters) in delivering a joint road safety vision. This was the basis for an integrated effort in a 4E approach. The program's mission followed a slogan used by many countries: **Safe roads save lives**. The program was a delivery mechanism for the National GAMBIT 2005 Program and its national roads infrastructure section. With a fairly high amount of EU funding available for road infrastructure, the main goal was defined very ambitiously, i.e., to reduce road deaths between 2006 and 2013 on national roads managed by the General Directorate for National Roads and Motorways by 75%, i.e., 500 fatalities in 2013 (Fig. 7).

Six special goals were set to reduce fatalities which are the result of: hitting a pedestrian, head-on collisions, side and rear crashes, running off the road, to reduce

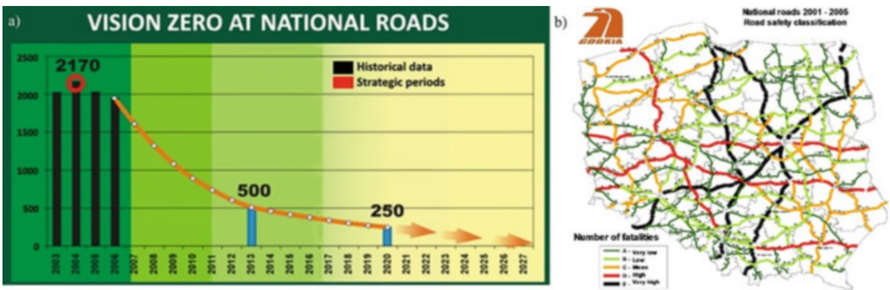


Fig. 7 GAMBIT National Roads: a) Vision Zero on national roads, b) Classification of road safety on Poland's national roads 2001–2005

nighttime fatalities, and fatalities caused by excessive speed. The tasks were organized into three groups following the 3Eras concept (infrastructure measures, safety management, and development of safety culture). Designed to ensure effectiveness and efficiency, the selection procedure consisted of the following steps (GAMBIT 2008):

1. Select sections with the highest risk of serious accidents
2. Identify hazards on high or very high risk sections (based on road safety inspection or audit)
3. Select the most effective action

The procedure made a difference in that it focused on comprehensive actions to include the following pillars: engineering, enforcement (speed cameras), emergency, education (campaigns in schools in close proximity to the roads), and the media (cooperation with national, regional, and local media) within the corridor of national road no. 8 (Fig. 8). When the road was modernized, fatalities on that road dropped by about 30%. The best solutions were implemented on another set of eight roads and then rolled out on 88 national roads; this time, however, only engineering measures were applied. Unfortunately, despite the positive outcomes of the pilot project the strategic goal was not achieved because in 2013 more than 1200 people were killed (against the goal of 500 fatalities in 2013 – Fig. 7a) on national roads which means that the assumptions were overly optimistic. More work followed in the next period. Mainly designed to build motorways and expressways, the actions helped to reduce fatalities on national roads below 1000 road deaths, but they also helped to reduce fatalities on non-national roads (secondary roads). This was possible thanks to traffic shifting from lower standard roads to better standard roads.

National Road Safety Program until 2020 – NRSP 2020 (IV NRSP)

In 2012 (a year before the previous program ended) work began on drafting a new program called the National Road Safety Program 2013–2020 (National Road Safety Council 2013). Detailed analyses showed that the main factors contributing to accidents in Poland are still the same:

- The State’s organizational and functional system (lack of political will, lack of a road safety body)
- Dangerous road user behavior (excessive speed, willingness to take risks, drivers not treating pedestrians and cyclists properly)
- Too few devices for pedestrian and cyclist safety
- The road safety management system (lack of a speed management system, lack of tools for managing road infrastructure safety)
- Quantity and quality of road infrastructure (lack of a network of high safety standard roads, few safe junctions)
- Deficiencies in the operation of the rescue and post-accident help systems

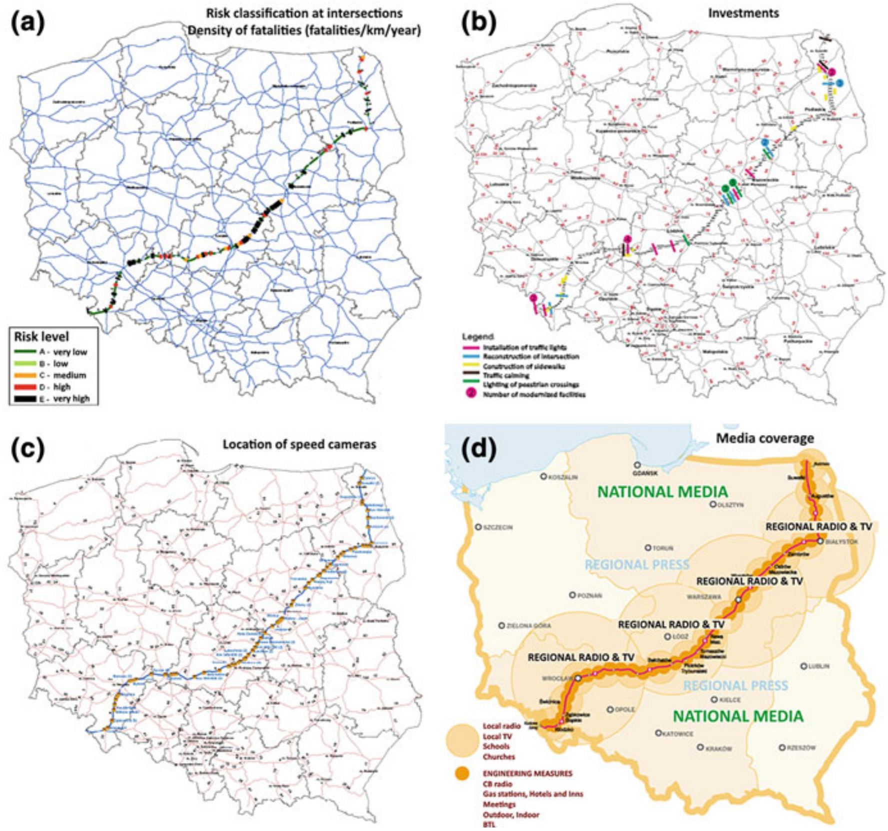


Fig. 8 Pilot project 8 + 8 + 88, national road no. 8: (**a**) risk classification on road sections, (**b**) location of proposed engineering treatments, (**c**) location of speed cameras, (**d**) coverage of regional and local media which cooperated in the pilot project

The Program builds on the assumptions of Vision Zero adopted in the previous road safety programs. It has two main strategic goals: to halve fatalities on Polish roads, i.e., to reach 2000 and to reduce serious injuries by 40%, i.e., down to 6900 in 2020 compared to 2010. Developed on the basis of the Safe System (OECD 2008; Larsson et al. 2010; Groeger 2011; Mooren et al. 2011), the Program has five pillars of action: safe people, safe roads, safe speed, safe vehicles, medical rescue and post-accident care (in accordance with the suggestions of the UN Decade). Each pillar sets out priority actions which represent Poland's basic road safety problems and how they should be tackled. Each priority is a set of measures in the areas of engineering – understood as technical measures, enforcement – understood as enforcement and control, education – understood as raising road safety awareness by understanding the risks. In addition, the Program included a section on rescue measures (4E's). While the program received the endorsement of the National Road Safety Council, it did not win the approval of the Polish government leaving it without any political or financial support. The Program is delivered by the Secretariat of the National Road Safety Council which prepares annual implementation programs made up of measures that can be delivered by central bodies using their own resources (road administration, police, fire service) and national measures such as training, studying road user behavior, media campaigns, development of road safety device design, and examples of good practice. The effects, however, are not satisfactory with cheap road safety measures no longer achieving much improvement or effect.

Role of Research

One of the main pillars of Vision Zero is facts and research in place of myths and just scratching the surface of the problem. As work on developing and implementing national and regional road safety programs began, it was clear that there is a lack of knowledge about the factors that affect road safety and a lack of tools. The available science did not include:

– An understanding of dangerous road behavior
– An understanding of the most relevant human, technical, and organizational factors and how much they affect the risks of road accidents on Poland's roads
– Methods to classify road sections for their safety
– Methods for long-term forecasts of fatalities nationally and regionally
– Methods for assessing the effectiveness and methods for selecting effective road safety treatments
– Methods for monitoring progress of treatments

Research was an important part of the implementation of the individual road safety programs. Some of it was conducted by university and research institute staff and some under national and international research grants (Jamroz et al. 2010; Jamroz 2011; Bergel-Hayat and Żukowska 2015; Gaca and Kiec 2016).

One of the first research areas was a nationwide study of road behavior carried out between 2002 and 2007 (Jamroz et al. 2016; Gaca and Kiec 2016) and continued in the periods that followed (Jamroz 2013). The first results were shocking:

– Nearly 50% of drivers drove over the speed limit with as much as 90% of drivers speeding on transit roads passing through villages and towns.
– Forty percent of drivers and front seat passengers and 60% of back seat passengers did not use seatbelts.

The results helped to intensify information and training campaigns and enforcement, including the start of building an automatic speed camera system called CANARD (Jamroz et al. 2005).

An important issue was building a Road Safety Observatory and developing a method for estimating road accident costs. Thanks to the method, it was possible to estimate Poland's annual costs of road accidents reaching more than 10 billion euro.

The next research area designed to support road safety was a study of risk-based methods for estimating fatalities and classifying road sections for accident risk (Jamroz 2011). This work helped to develop a concept of how Poland's road safety will change as a result of treatments (Jamroz et al. 2010; Jamroz and Smolarek 2013b; Wachnicka 2018). According to this concept, a country's level of road safety depends primarily on its level of socioeconomic development and population mobility. If we consider that the road fatality rate (RFR) is a normalized measure of the country's road mortality, the level of road safety changes nonlinearly depending on changes in socioeconomic development (Fig. 9).

Within the range of low and very low socioeconomic development, as people's incomes grow, so does their mobility as well as motorization and density of paved roads. Because road and vehicle standards are low, road accident fatalities increase quickly.

As gross domestic product GDP continues to grow, the rate of increase in fatalities levels off and the RFR reaches a breakpoint. This is the result of a shock when people realize the death toll of road accidents and start to think twice as drivers and pedestrians leading them to slowly change their behavior as road users (a decreasing appetite for risk: driving slower, commonly using seatbelts, no drinking and driving). National and local institutions and organizations take steps to reduce the pace of growing motorization, a safety system becomes operational (developing a system of legislation, education, appointing a leader), safety management methods are used (a more developed enforcement system, safety programs).

Once the increase in fatalities reaches its breakpoint, accident mortality drops rapidly, a situation caused by a more stable level of motorization, density of paved roads and population mobility, and more better quality roads, i.e., expressways and motorways. Key to this is also the development of state and democratic institutions

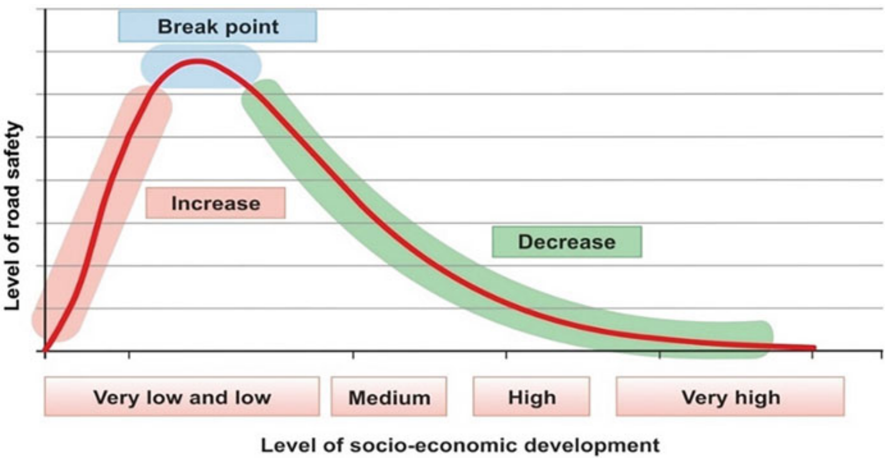


Fig. 9 Concept of a model of road safety changes in a country depending on its level of socioeconomic development

leading to less corruption, a better health care system, safety culture (use of seat belts, lower alcohol consumption).

With a growing GDP and a very high level of socioeconomic development, the fatality rate should aim asymptotically to zero. This is helped by the fact that societies increase their wealth and have more respect for each other's lives including those of road users. Adopting this concept and explaining it to those who care about road safety was very helpful with understanding the mechanisms of how a road safety system operates. The concept was used to formulate the vision and strategies in the new road safety programs (Figs. 6a and 7a) and in the proposed method for forecasting fatalities (Jamroz and Smolarek 2013b).

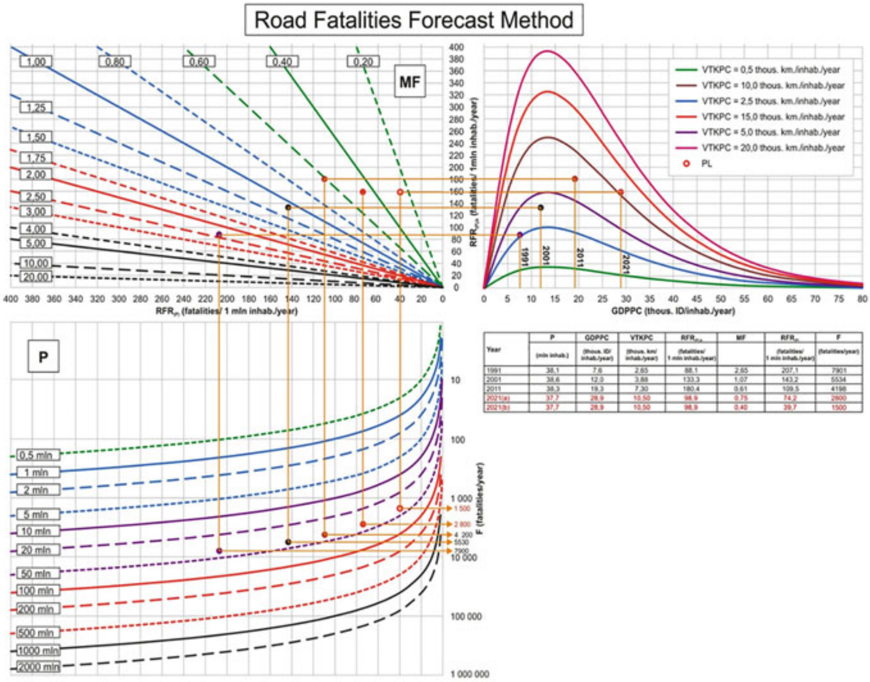
Poland did not have methods for forecasting road accident fatalities at the national or regional level. Attempts were made to use available methods and models (Smeed 1949) or the work of external experts (Oppe 2001). Simplified methods were also used. But because they were international methods, they did not account for Polish conditions or left out many important factors just as the simplified methods. As a result, the fatality forecasts were far from reality. Efforts were taken to develop Poland' own methods for forecasting road accident fatalities depending on demographic and economic factors at the national (Jamroz 2011) and regional levels (Wachnicka 2018).

To assess safety at the national level (strategic), the risk-based approach was applied which takes account of road traffic behavior of entire social groups in an area (country, region). Estimates are made of the consequences of road accidents (number of fatalities, accident costs) within a specific time period (usually over a year), which may occur as a result of dangerous incidents caused by a malfunctioning road transport system. Key to the level of the strategic risk are the country's economic development, level of motorization, social change, better education, etc.

The most commonly used measures of strategic risk are: number of fatalities F as a general measure and the road fatality rate dependent on demography RFR as a normalized measure for comparing countries for their safety levels.

A group of mathematical models was elaborated to estimate road accident fatalities F depending on gross domestic product per capita GDPPC, average number of kilometers traveled by car per capita VTKPC, number of population P, and a set of modifying factors MF (including: level of health care, level of education, level of corruption, density of road network, seat belt usage, alcohol consumption, etc.). The models were then used to develop a simplified and easy to use (by decision-makers, students, journalists) method for estimating measures of societal risk (RFR and F) shown in Fig. 10 (Jamroz and Smolarek 2013b).

A good example of how research can serve to solve road safety problems was a research program called Development of Road Innovation (RID) delivered between 2015 and 2019 by the National Centre for Research and Development and the General Directorate for National Roads and Motorways. Of the total of 15 research projects seven were dedicated to road safety problems such as: design and maintenance of safety barriers, 2 + 1 roads, the effect of advertising on road safety, speed management, the effect of ITS methods on road safety on motorways, and use of nonstandard road marking. The results of these projects are being incorporated into design practice (Gaca et al. 2018; Jamroz et al. 2018a; Oskarbski et al. 2018).



Year	P	GDPPC	VTKPC	RFR	MF	RFR	F
	(mln inhab.)	(thous. ID/ inhab./year)	(thous. km/ inhab./year)	(fatalities/ 1 mln inhab./year)		(fatalities/ 1 mln inhab./year)	(fatalities/year)
1991	38,1	7,6	2,65	88,1	2,65	207,1	7901
2001	38,6	12,0	3,88	133,3	1,07	143,2	5534
2011	38,3	19,3	7,30	180,4	0,61	109,5	4198
2021(a)	37,7	28,9	10,50	98,9	0,75	74,2	2800
2021(b)	37,7	28,9	10,50	98,9	0,40	39,7	1500

Fig. 10 Simplified method for estimating road accident fatalities F in the analyzed country

These are just some of the research projects that have helped to get a better understanding of the factors contributing to safety, develop methods for estimating accidents and casualties, and prepare tools for designing elements of roads and selecting effective and efficient solutions (GAMBIT 2016, 2018).

Role of International Cooperation

Following the development and implementation of national, regional, and local road safety programs, and III NRSP (GAMBIT 2005), in particular, Poland has seen a systematic drop in road accident casualties. Polish experts have established a stronger international presence; substantial efforts have been made to improve road safety using tried and tested solutions from other countries. There was help from many experts (the Netherlands, Sweden, Germany, and Switzerland) with training for Polish experts, road authorities, road police, etc. As a result, Poland reached the breakpoint earlier than other countries marking the start of a downward trend in fatalities thanks to lessons learned from more advanced countries (Fig. 11). By using the experience of developed countries, developing countries respond to unfavorable trends earlier and take steps to improve their road safety management

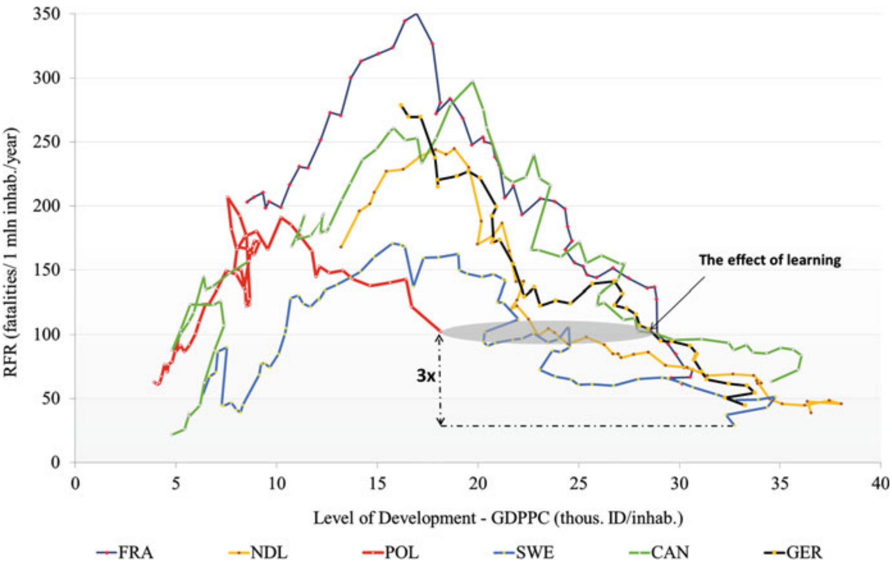


Fig. 11 Concept of a model of how experience (effect of learning) influences a country's level of safety

systems, spend more on improving road safety, implement new solutions and regulations, and are able to reduce road transport fatality rates.

Poland has benefited greatly from EU accession in 2004. The effect has been positive because (Jamroz et al. 2018b):

(a) Polish road safety strategies and programs have had to adapt to EU transport strategies and road safety programs and their requirements.
(b) Rigorous norms and standards, including those for road infrastructure safety (European Parliament and the Council 2008) have been made part of Poland's legislation and design and maintenance practice for national roads and some of local roads.
(c) With access to EU funds, Poland was able to develop a safe and modern road infrastructure such as motorways and expressways, numerous ring roads, and new links.
(d) Road safety scientists and researchers have better access to international programs and research projects, research infrastructure, and modern technologies; they are part of international teams, research projects, and conferences.
(e) Member states put pressure through their annual rankings and reports on the progress they make in achieving the strategic goals set out in road safety programs.

Poland's road safety benefitted greatly when the country joined EuroRAP's risk assessment program in 2006 (EuroRAP 2018). Using methods developed by

EuroRAP, an assessment was conducted of the risk on national roads (Fig. 7b) and compared to the level of risk in other countries. With poor results, the road authorities felt motivated to improve road safety. EuroRAP's methodology was used as a basis for developing Poland's own methods for assessing and classifying risk on national and regional roads and on street networks in major cities (Jamroz 2019).

Evaluation of the Effectiveness of Poland's Road Safety Programs

As the programs were ongoing, it was clear that road safety had improved significantly (Table 3). During GAMBIT96 the drop in fatalities was small at a mere 2.5%. During the subsequent programs, however, the effects were substantial; between 2000 and 2019 (GAMBIT 2000, GAMBIT 2005, NRSP 2020) the number of fatalities almost halved. The biggest reduction in fatalities was achieved during GAMBIT 2005; in that period (2005–2012) fatalities fell by nearly 40%.

Below are the characteristics of the most important efforts supported by the programs. Figure 11 shows how the efforts were positioned relative to the changes in fatalities in Poland between 1986 and 2018.

Period Before Road Safety Programs (1986–1995) Under planned economy (until 1989) the people of Poland had poor access to cars and fuel which was rationed (up to 30 liters per car per month toward the end of the period). As a result, population mobility was much lower and people prevalently used public transport to travel. The constraints meant that there were very few fatalities. The problem began when the political system changed (from socialism to democracy) and the economy went through a transformation (from planned to capitalist economy), which was in the second half of 1989. With the introduction of the free enterprise act, Polish citizens were able to buy cars freely (mostly second-hand cars bought abroad) causing a rapid increase in cars on Polish roads. Young drivers with very little

Table 3 Changes in people killed during individual road safety programs in Poland between 1996 and 2019

National road safety program	Program period	Population P (m)	No. of fatalities F (victims)	Change in killed DF (victims)	Rate of change in killed TF (victims/year)	Percentage drop in killed PF (%)	Road fatality rate RFR (victims/1 m pop.)
–	1995	38.6	6900	–	–	–	178.8
I NRSP	1996–1999	38.7	6730	−170	−43	−2.5	173.9
II NRSP	2000–2004	38.2	5712	−1018	−204	−15.1	149.5
III NRSP	2005–2012	38.1	3540	−2172	−272	−38.0	92.9
IV NRSP	2012–2019[a]	38.3	2909	−631	−90	−17.8	76.0

[a]currently in force

experience of driving more powerful and dynamic cars and practically no police on the roads (change of structure, staff, and forms of operation) produced an “explosive mix” with tragic consequences and an increase in fatalities at 3050 in 2 years (from 4851 in 1998 to 7901 killed in 1991), i.e., by 63%. This came as a real shock to both government and society.

In 1992, the World Bank experts were employed to study the situation. Their report identified Poland’s main road safety problems such as lack of an organization with responsibility for road safety and a very high risk to road users in Poland (Gerondeau 1993). A combination of a shocked public, refusal to accept the high road traffic risk, pressure from the media, and fast economic growth helped to overcome the trend. Following the critical peak of 1991 and the World Bank report results, Poland took steps to develop its road safety program. In 1995 there were 6900 fatalities on Polish roads (i.e., a reduction of 1000 compared to 1991) (Fig. 12).

1996–1999 A time of strong variations in the fatality trends between 1993 and 1997 as the central government made other issues its priority. Despite that, fatalities dropped significantly after 1997, a trend which continued until 2001. Because the program only lasted for a short time, it achieved a mere 2.5% drop in fatalities at 6730 victims (i.e., 170 victims less compared to 1995). With the adoption of the Road Traffic Act (1997), road traffic and enforcement were better regulated and improved. In 1999, the Act was amended to add a drinking and driving regulation making a BAC above 0.05% a crime as opposed to a misdemeanor which it was before. That was a very good start to more measures designed to reduce accidents caused by drunk drivers.

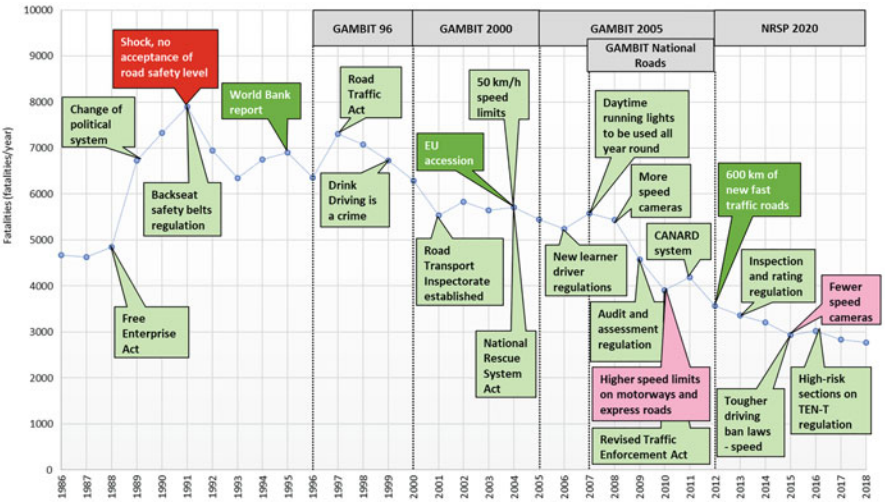


Fig. 12 Fatalities in Poland against road safety milestones

2000–2004 During GAMBIT 2000 (II NRSP) the reduction in fatalities reached 15% at 5712 (i.e., 1018 victims less compared to 1999). At the time the Road Transport Inspectorate was established with responsibility for controlling vehicles and transport companies just as the police. Despite numerous efforts, there were no quick results; however, over time a cumulative effect could be seen with a reduction in fatalities in the years that followed. One of the contributing factors was Poland's accession to the European Union, which led to more regulation and bringing Polish laws to the level of countries boasting much better safety.

2005–2012 During GAMBIT 2005 (III NRSP) the national level saw a number of legislative, educational, preventive, and infrastructural efforts. However, only 84 of 144 tasks (58%) were completed. Some did not bring the expected results or were poorly performed and a number of political and administrative decisions were taken which went against the program. Many of the measures had a positive effect on Poland's road safety. They were: new regional and county road safety programs covering about a dozen regions, cities, and counties; new sectoral road safety programs (for national roads, police); start of building the Polish Road Safety Observatory and setting up two regional observatories, new driver training, and examination rules; implementation and development of an enforcement system (speed control, control of driver working time); normalizing cycling on roads; intensive construction of expressways and motorways; construction of safe junctions, pavements, and pedestrian devices (especially on rural roads); traffic calming measures; introduction of road safety audits for some projects; and modernization and development of the rescue system and post-accident care.

The effects of the III NRSP were clear especially between 2007 and 2010, when more measures were introduced such as compulsory use of daytime running lights all year round, new speed cameras making enforcement more intense, introduction of some of the tools recommended in EU Directive of 2008 on road infrastructure safety management (audit of design documentation and assessment of newly designed roads for their safety impacts on other networks). The first sectoral program was implemented, GAMBIT National Roads, mainly focusing on infrastructure and the operational program "Roads of Trust," which involved media campaigns to inform the public about road safety problems and warned against road risks. We could see the effects of EU recommended road safety principles and standards and more funding for building safe roads in Poland. The length of safe roads increased significantly during that period (in the record year of 2012 more than 600 km of motorways and expressways were completed). Thanks to the new investments and an improved enforcement system on national roads, serious accidents (involving fatalities and serious injuries) decreased and the level of risk on the roads was clearly changing (Figs. 13 and 14). New tools suggested in the Directive on road infrastructure safety management were implemented (European Parliament and the Council 2008), i.e., inspecting existing road infrastructure and classification of hazardous sections. The speed limit in built-up areas was reduced to 50 km/h (sadly the

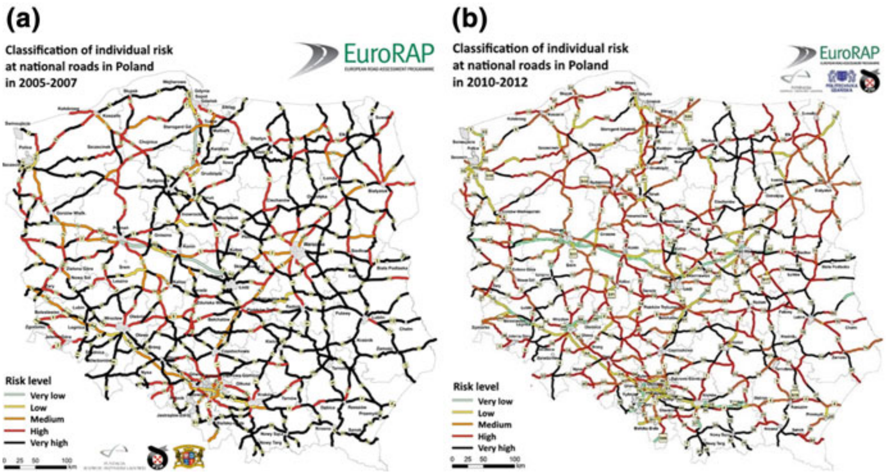


Fig. 13 Map of individual risk on the network of Polish national roads; (**a**) between 2005 and 2007, (**b**) between 2010 and 2012

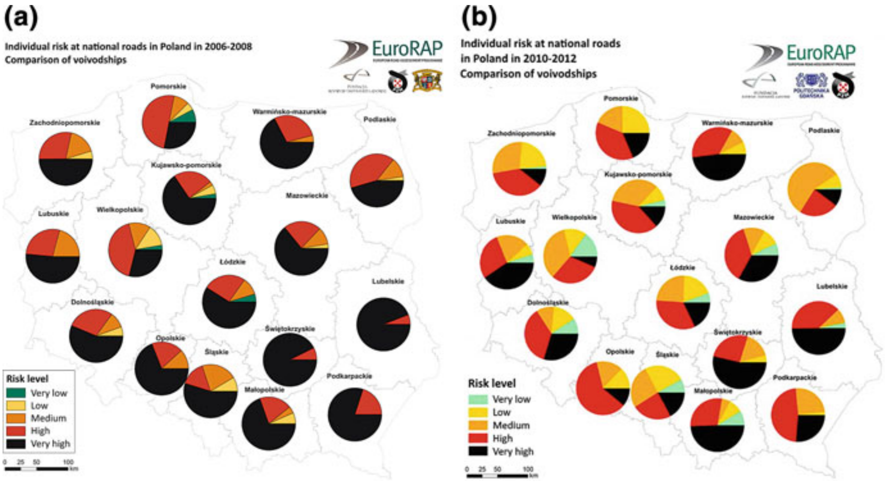


Fig. 14 Map of individual risk on the network of Polish national roads by the regions; (**a**) between 2006 and 2008, (**b**) between 2010 and 2012

nighttime speed limit was left at 60 km/h, work is under way to change this regulation in 2020) and driving tests were amended. It is estimated that thanks to the program within 8 years fatalities dropped by 38% to 3540 (i.e., fatalities went down by 2172 compared to 2004), about 6000 people were saved from death in a road accident and about PLN 34.5 billion was saved.

Road accidents, however, were still not seen as a major problem in Poland. They did not become a political priority and the institutions proved ineffective because responsibility for road safety was shared (collective). Unfortunately, many of the key actions set out in the program were never launched. No one was appointed to a lead role regarding GAMBIT 2005 delivery, the country's road safety bodies were not improved, in particular the National Road Safety Council, no appointments were made at the local level (inspectors, officers, leaders), funding for road safety was not secured, the strategy was not monitored for its progress, and good road safety practice was not promoted. Another setback came in 2010, when the motorway speed limit was raised to 140 km/h and the expressway speed limit went up to 120 km/h. In 2011 the automatic speed camera system underwent restructuring (it was moved from the Police to the Motor Transport Inspectorate) leading to an increase in fatalities by 350 within a year. Analyses showed that Poland's road safety standards are far from the standards applied in the European Union. These imperfections became challenges when the next national road safety program was being formulated.

2013–2020 In the first 5 years of IV NRSP fatalities fell by 20% reaching 2831 (i.e., 709 fatalities less compared to 2012). Since 2016 fatalities and serious injuries have leveled off (Fig. 15). There are some real downsides to the Program: the automatic speed camera system has a more limited coverage (2015) following the shutdown of speed cameras on local authority roads, which led to an increase in fatalities by 150 in the first year of the new smaller system and selected sectoral actions (mainly soft actions) are delivered by central bodies (Secretariat of the National Road Safety Council, Police, Road Transport Inspectorate, Fire Service). The Program's main targets are at risk with a 15–20% fall in fatalities in 2020 rather than the expected 50% and serious injuries may only fall by 3–5% in 2020 instead of the expected 40% (Fig. 15).

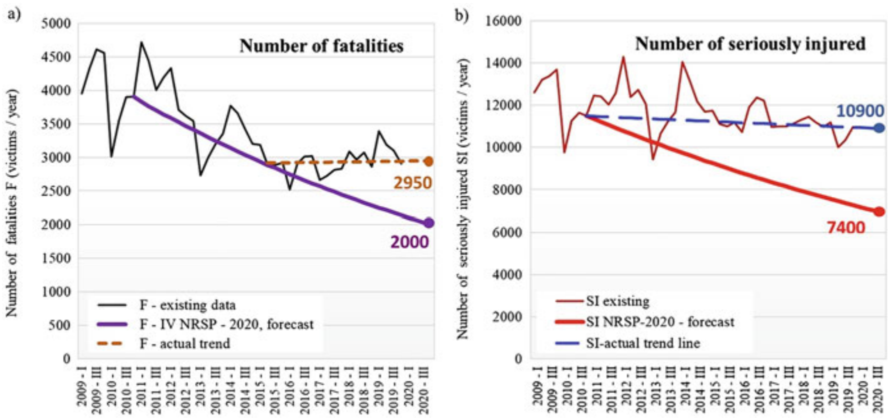


Fig. 15 Barometer of casualty change: (**a**) deaths F, (**b**) serious injuries SI in road accidents during the IV NRSP 2020

Prospects for Poland's Vision Zero

Possible Scenarios

Following a series of research projects, studies, analyses, and assessments of the previous four National Road Safety Programs in Poland, steps were taken to analyze and assess the potential for delivering the Polish Vision Zero. Some recommendations were also developed regarding new road safety programs in Poland until 2050. The analysis was made using the scenario method (Stipdonk and Wesemann 2007; Koornstra 2007; EC-DGTM 2011; Zmud et al. 2013; Jamroz et al. 2019). Four scenarios were developed (shown in Table 4) setting out key strategic actions and two groups of factors: level of socioeconomic development measured with an increase in the GDPPC and level of transport policy effectiveness regarding road safety.

Using the authors' own method for long-term forecasts of fatalities described in the works of Jamroz et al. (Jamroz 2011, 2012; Jamroz and Smolarek 2013b; Jamroz et al. 2014b, 2016), a fatality forecast was made for four road safety scenarios until 2050 listed in Table 5. The baseline year is 2017 with fatalities on Polish roads at F = 2831 people and the road fatality rate at RFR = 75 fatalities/one million population.

In addition, the particular scenarios assume that parameters may change until 2030 and that a similar pace of change may continue until 2050 (GAMBIT 2018).

Optimistic scenario S1 is characterized by a very high rate of socioeconomic development and a very strong effect of transport policy on road safety action.

Very high level of socioeconomic development includes a quick rate of the country's economic growth (increase in GDP more than 5% annually) and GDPPC at nearly 74,000 ID per capita in 2050. This will help to increase expenditures on the development of a network of modern and safe roads and a wide-ranging modernization of existing local roads, expenditure on health and rescue services on roads,

Table 4 Potential road safety scenarios of Vision Zero in Poland

The impact of transport policy on road safety improvements	Level of socioeconomic development (GDP growth rate)			
	Very high	High	Low	Very low
Very strong	S.1 Optimistic scenario			
Strong		S.2 Moderate scenario		
Weak			S.3 Stagnation scenario	
Very weak				S.4 Pessimistic scenario

Table 5 Expected number of fatalities F, by scenario and period

Scenario	Expected number of fatalities F (fatalities/year)				Expected RFR (victims/1 m inhab./year)				Summary number of people until 2050 PF (thous. Inhab./ 34 years)	
	2020	2030	2040	2050	2020	2030	2040	2050	killed	saved
S1	1850	630	180	40	49	19	6	2	24.1	39.5
S2	2240	1120	480	180	59	30	14	6	36.1	27.5
S3	2860	1650	750	300	75	45	22	9	49.6	14.0
S4	3020	2120	1300	750	108	57	38	21	63.6	–

transport education in schools, a safety management system, etc. The scenario assumes that population numbers will fall fairly quickly (29,600,000 in 2050 as a result of low birth rate) and that trips by car will fall (to 346 billion vkm/year in 2050).

A strong transport policy in relation to road safety action will primarily be designed to: strengthen the role of leader and that of road safety bodies, maintain a high degree of construction of motorways and expressways (up to 8000 km) and other roads of a high road safety standard, implement a wide range of activities in the area of road infrastructure safety management, reduce the role of the car and change how cities are planned, develop an automatic road traffic enforcement system (more speed cameras and sections with automatic speed enforcement, $FV_1 > 1300$), implement new systems for road traffic management (ITS, speed management), implement new technologies (autonomous and automatic vehicles), develop a system of road rescue, gain strong political support from the central level, and develop a strong safety culture of road authorities and among road users.

Moderate scenario S2 is characterized by a high pace of socioeconomic development and a strong effect of transport policy on road safety action.

High level of socioeconomic development includes a fairly quick rate of the country's economic growth (increase in GDP more than 4% annually) and GDPPC at 63,000 ID per capita in 2050. This will help to allocate substantial funds to the development of a network of modern and safe roads and a wide-ranging modernization of existing local authority roads, expenditure on health and rescue services on roads, transport education in schools, a safety management system, etc. The scenario assumes that population numbers will fall moderately to 33 million in 2050 (modern birth rate) and that trips by car will fall (to 389 billion vkm/year in 2050).

A strong and responsible transport policy in relation to road safety action will be designed to strengthen the role of leader and that of road safety bodies, maintain a high degree of construction of expressways (to 7200 km) and other roads of a high road safety standard, implement activities in the area of road infrastructure safety management, develop an automatic road traffic enforcement system (slightly more speed cameras and sections with automatic speed enforcement, $FV_2 < 1000$). The scenario is a continuation of effective and efficient actions already started under III NRSP. It shows what fatality reductions can be achieved and the consequences if the trend is abandoned.

Stagnation scenario S3 is characterized by a low pace of socioeconomic development and a weak effect of transport policy on road safety action.

Low level of socioeconomic development includes a slower pace of the country's socioeconomic development (increase in GDP below 3% annually) and GDPPC at 51,000 ID per capita in 2050. With a limited pool of funding less money will be spent on building a network of safe roads and modernizing the network of existing local authority roads, there will be less spending on health care and road rescue, transport education in schools, a safety management system, etc. The scenario assumes an average pace of population decrease to 33 million people in 2050 (moderate birth rate) and that trips by car will fall (to 389 billion vkm/year in 2050).

A weak transport policy in relation to road safety means lack of a leader and a limited role of road safety bodies, slower pace of building expressways (to 6500 km) and other roads of high road safety standards, slow or limited implementation of safe road infrastructure management, a limited road traffic enforcement system (including a limited number of speed cameras and sections with automatic speed enforcement, $FV_3 < 750$).

Pessimistic scenario S4 is characterized by a very low rate of socioeconomic development and a very weak effect of transport policy on road safety action.

Very low level of socioeconomic development means a slow pace of the country's economic growth (increase in GDP below 2% annually) and GDPPC at 51,000 ID per capita in 2050. With a limited pool of funding, less money will be spent on building a network of safe roads, there will be less spending on health care and road rescue, etc. The scenario assumes an average pace of population decrease to 36.6 million people in 2050 and that trips by car will not fall (436 billion vkm/year in 2050).

A very weak transport policy in relation to road safety means lack of a leader and a limited role of road safety bodies, slower pace of building expressways (to 6500 km) and other roads of high road safety standards, no implementation of safe road infrastructure management, a limited road traffic enforcement system (including a limited number of speed cameras and sections with automatic speed enforcement, $FV_4 < 500$).

Estimating the Expected Effects of the Scenarios, if Delivered

The assumptions and scenarios of the country's socioeconomic development and road safety-related transport policies were estimated for the reductions in road accident fatalities they can achieve. The results are shown in Table 5 and Fig. 16.

If road safety efforts were to follow **optimistic scenario S1** which represents the effect of a broader set of road safety actions, the pace of change would be likely to stay strong, i.e., about 170 fatalities annually in the next decade. The reduction in fatalities could amount to 66% over the 10 years of the Program V NRSP (between 2021 and 2030). This would make RFR = 17 fatalities per one million population in 2030, close to the rate forecasted in that period in Sweden, the Netherlands, and the United Kingdom. The scenario shows that it was highly likely that Poland's fatalities could be close to zero in 2050 with about 40,000 more lives saved from road death

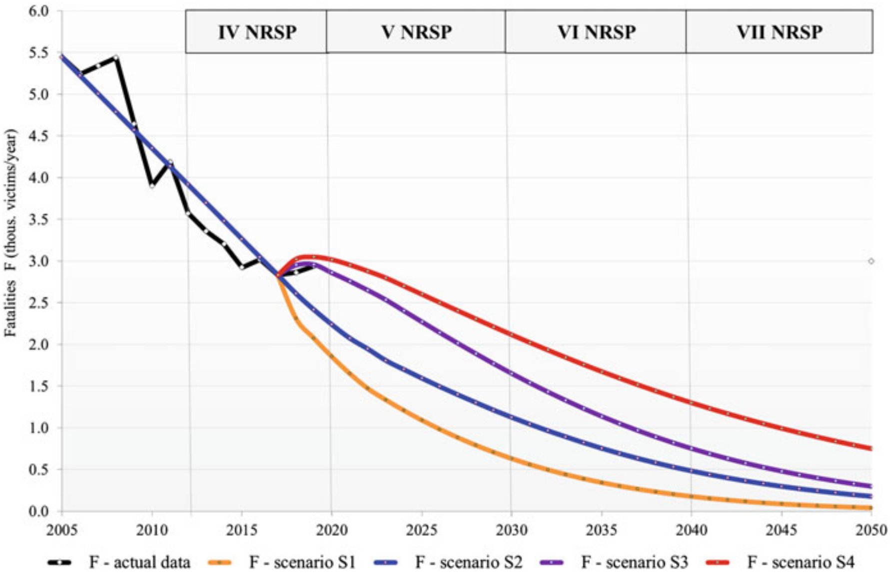


Fig. 16 Forecast of road accident fatalities until 2050 in Poland for different road safety scenarios

than in the worst-case scenario (S4). Given the setbacks Poland's road safety system has suffered in the last few years, the fact that low-cost road safety treatments have been almost used up and that other conditions have put the brakes on positive road safety developments, the scenario is not very likely to happen.

If road safety efforts could follow **moderate scenario S2** which represents the effect of a fairly broad set of road safety actions, the pace of change would be likely to stay fairly strong, i.e., about 130 fatalities annually in the next decade. The reduction in fatalities could amount to 50% over the 10 years of the Program V NRSP (between 2021 and 2030). This would make the rate RFR = 30 fatalities per one million population in 2030 close to the rate as it is today in Sweden, the Netherlands and the United Kingdom. The scenario shows that it was fairly likely that Poland's fatalities could be close to zero in 2050 with about 27,500 more lives saved from road death than in the worst-case scenario (S4). Given the setbacks Poland's road safety system has suffered in the last few years, the scenario is not very likely to happen.

The setbacks in delivering road safety efforts and the resulting stagnation in fatalities at the level of 2016–2017 and seriously injured at the level of 2010 suggest that the number of fatalities is likely to change according to **stagnation scenario S3.** The scenario is a warning against doing less for road safety.With a limited scope of actions, the rate of decline in fatalities will slow down. It can be expected that over the 10 years of the Program V NRSP (between 2021 and 2030), the reduction in victims could be by 42%. This would make the rate RFR = 45 fatalities per one million population in 2030 higher than expected. This, however, is not enough to achieve V NRSP targets and deliver Vision Zero in 2050.

Pessimistic scenario S4 provides a stark warning against stopping or reducing road safety efforts because the average rate of fatality reduction will be about 45 fatalities annually until 2030 and the reduction in fatalities expected over the 10 years of the Program (2020–2030) could be a mere 29%. This is definitely not enough to achieve Program targets and deliver Vision Zero in 2050.

Given the history of previous road safety efforts, stagnation scenario S3 seems most likely. Unfortunately, this scenario will not ensure the achievement of the EU's strategic goal by 2030 (reduction in the number of fatalities), so additional measures will be necessary such as moderate scenario S2.

Guidelines and Recommendations for New Road Safety Programs

Three programming periods are envisaged on the way to achieving Vision Zero in 2050 (Fig. 16).

1. V NRSP – to be delivered in the years 2021–2030 – requires a new approach, a lot of organizational and financial effort, a change in road user behavior, road user control reinforcement, implementation of a fleet of modern vehicles equipped with new technologies, development of safe infrastructure (completion of a planned motorway and expressway network, implementation of new traffic control technologies), and changes in mobility management. Depending on the scenario, in 2030 fatality reduction F could be in the range of 3020–1850 and the RFR in the range of 110–50 fatalities per one million population.
2. VI NRSP – to be delivered in the years 2031–2040 – requires a continuation of the approach from the previous period, a further development of road safety management system, broader changes in road user behavior, development of a fleet of modern vehicles, increasing the share of public transport and alternative means of transport in modal split, development of safe road infrastructure by adapting existing roads to new standards, common use of new traffic control technologies, and development of sustainable urban mobility management. Depending on the scenario, in 2040 fatality reduction F could be in the range of 2120–630 and the RFR in the range of 60–20 fatalities per one million population.
3. VII NRSP – to be delivered in the years 2041–2050 – requires a continuation of the approach from the previous periods, improving the development of road safety management system, significant changes in road user behavior and its control, development of a fleet of modern vehicles, a significant share of public transport and alternative means of transport in modal split, development of safe road infrastructure by adapting existing roads to the newest standards (increasing requirements), common use of new traffic control technologies, and development of sustainable urban mobility management (e.g., eco-city, techno-city). Depending on the scenario, in 2050 fatality reduction F could be in the range of 750–40 and the RFR in the range of 20–2 fatalities per one million population.

Analyses have shown that an intensified effort in the initial period of V NRSP could be followed by scenario **S2** actions. This, however, requires a wide spectrum of strategic, management, and operational activities designed to develop a system of road safety, change road user behavior, develop modern vehicles, build a modern and safe road infrastructure, and strengthen the road rescue system (Wadhwa 2001; NR2C 2018).

Actions to develop a road safety system are mainly to: adapt legal regulations to new challenges, develop and implement a new national road safety program and new urban and regional road safety programs, involve nongovernmental organizations and voluntary movements.

Actions to change road user behavior are mainly to: use an automatic lock to prevent drunk drivers from starting the engine (alcolock), develop automatic enforcement and speed management (speed cameras, systems of adaptive speed management (Intelligent Speed Adaptation ISA)), pedestrian and cyclist safety devices and new systems of driver training.

Actions to develop modern vehicles are mainly to: ensure a common use of winter tires, develop devices to aid drivers (maintaining a set speed and distance, detecting conflicts), develop and implement autonomous vehicles, electric and hybrid vehicles, car co-sharing, vehicles communicating with external devices (with another vehicle (V2V), with road infrastructure (V2X), with a traffic control system (V2C)).

Actions to develop a modern and safe road infrastructure are mainly to: eliminate head-on collisions by separating carriageways (a more common use of 2 + 1, 2x2 cross-sections), eliminate side crashes by using safe junctions (roundabouts, signalized junctions), use new and safer types of interchanges, use safety devices (barriers, terminals, fencing) and devices for vulnerable road users (pavements, cycle roads, pedestrian crossings), develop autonomous and electric vehicle friendly infrastructure, take advantage of Intelligent Transport Systems. To achieve this, it is necessary to:

(a) Improve the regulations and guidelines for safe road design
(b) Develop new technologies and use adequate and durable construction materials and long life and low maintenance structural elements which guarantee a high level of safety and efficiency (object life cycle)
(c) Develop new materials, technologies, and structural parts to ensure a higher level safety for road users

Actions to develop mobility management are mainly to: implement traffic zoning, promote shared space, eliminate cars from central parts of cities (charges, public transport, cycling, ring roads), use new forms of urbanization (techno city, eco city).

Moreover, in addition to infrastructure measures and the development of road safety management tools, efforts should be undertaken and strengthened to develop the road safety culture. Actions should be aimed at changing the safety culture of individual road users by changing behavior, choosing less risky routes or means of transport, requiring and supporting actions to improve road safety. It is also important to change the approach of politicians, managers, road management employees, project offices, and media, so that road safety issues are included in everyday activities.

Summary

The moment of adopting Vision Zero can be perceived as the beginning of systemic work for road safety in Poland. Since the III NRSP was developed and approved by the then government, Vision Zero has become not only a political slogan, but also a practical tool for the functioning of the road safety system. The vision has been included in national strategies and adopted by many cities and regions in their road safety strategies. Poland's approach to road safety has become holistic; it has started to be perceived as an important social problem and given a higher priority. In combination with the requirements of the European Union and its technical and financial support, the road safety activities undertaken in Poland brought significant effects. The problem of road safety has also gained more attention of researchers – the results of road safety analyses, Polish case studies, and evaluation of road safety measures were presented at numerous conferences and published in research journals. Local government officials, educators, journalists, policemen, paramedics, road designers, engineers, and administrators are interested and more aware of the issue of road safety. With more experience and interest in road safety, Polish institutions (i.e., national road administration), universities, and technical associations have started international cooperation, learning from better performing countries and passing on the experience of applying a systemic approach to road safety to countries with lower level of road safety (Egypt, Jordan, Lebanon, Uzbekistan, Albania, etc.).

However, the results of road safety policies are still below the expectations and many problems have not been solved. Road accidents are still not considered a major problem. As a consequence, they are low on political agendas and the institutions remain ineffective due to a sense of collective responsibility for road safety problems. Achieving Vision Zero will require many changes, learning from past mistakes, taking advantage of the experience of the best performing countries, and, above all, taking effective and efficient actions with their systematic monitoring.

Studies and analyses designed to evaluate Poland's road safety programs between 1996 and 2019 show that:

1. Ethical road user behavior, facts, research, and shared responsibility are the main pillars of Vision Zero and achieving it requires new ideas, technologies, and management systems to take account of human behavior as road users, modern vehicles, safe road infrastructure, mobility management, and development of the road safety management system.
2. A country's socioeconomic development is clearly a factor contributing to its road safety level and the main contributing factors are gross domestic product,

population mobility, level of the organizational system (level of education, level of the health care system, level of corruption), level of the development of safe road infrastructure (network of safe roads), and change in road user behavior (speed, seatbelts, alcohol).

3. The goals, priorities, strategic actions, and objectives of new programs in Poland and in other countries should be based on a model for changing a country's road safety depending on its socioeconomic development and a method for estimating fatalities.
4. The effectiveness of road safety action depends on a number of factors. The current state of science and experience of countries that have a high level of safety show that it is possible to reach a maximum effect by adopting an ambitious vision and a systemic approach to achieving goals and strategies. Key to this is having a clearly defined and science-based philosophy of action rather than myths and popular opinion.
5. Analyses show that support and advanced efforts can help to reduce fatalities in the subsequent programming periods and achieve Vision Zero in a few decades.
6. Poland's experience shows that political and systemic change can have a significant effect on positive change in socioeconomic development, which is also beneficial for road safety. In the case of Poland, it was accession to the European Community that contributed to the significant drop in road accident fatalities.

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Vision Zero in Lithuania

13

Vidas Žuraulis and Vidmantas Pumputis

Contents

Abstract

This chapter covers statistical data and initiatives related to the challenges and achievements of road safety in Lithuania. After providing an overview and an evaluation of previous programs to improve road safety in Lithuania, we discuss a selection of various improvements and assessment of safe traffic measures and their efficiency through relevant information from research and statistical data analysis. Priorities to achieve safer behavior of road users, safer streets and roads, safer vehicles, safer rail transport, and higher survival rates after accidents are discussed in more detail. The country-specific issues of pedestrian fatalities in

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dark hours, intensive land transportation due to geographical location, and accidents related to railway level crossings are also presented.

Keywords

Lithuanian roads · Vision zero · Safe roads · Safe behavior · Safe railways · Road accidents

Introduction

Lithuania, as a member of the European Union, aims for sustainable road transport and sets high goals in order to significantly reduce the road crash rate. Life experience in historical period of oppression left a mark on the mentality and social norms of society without excluding the road safety issues. Moreover, while high penetration of land transport in society provides undeniable benefits in everyday life, the fast evolution of machines also reveals the physical and psychological fragility of human beings. People naturally make mistakes, which comes out as injuries or fatalities; therefore, exceptional attention must be focused on this area.

The Vision Zero Declaration in transport in 2018–2030 is the Lithuanian road safety strategy aimed at preventing fatalities and severe injuries in the road transport sector. The guiding principle of this vision is the shared responsibility of transport sector managers and users, bearing in mind that the traffic environment and vehicles must be tailored to maximize the protection of the road user from potential errors and, if they occur, to ensuring effective technical and medical assistance to road users affected by the crash.

This declaration will be implemented through inter-institutional action plans that are coordinated by the Ministry of Transport and Communications. The authorities that are implementing the plans set out in the declaration must submit data on the results achieved to the Ministry of Transport and Communications within 60 days of the end of the year. This will reach the Commission on Traffic Safety for further consideration.

The Vision Zero Declaration in Transport 2018–2030 continues the efforts of previous traffic safety programs and is aligned with:

- United Nations 2030 Agenda for Sustainable Development (Target 3.6)
- Decade of Action for Road Safety 2011–2020
- for the purposes of the White Paper on Transport
- European Union Road Safety Program (2011–2020)
- National Progress Program for Lithuania for the period 2014–2020
- Verona Declaration
- Valletta Declaration

The programs and declarations emphasize common issues that are important for Europe, that is, social cohesion, greener economy, education, and innovation. These objectives are taken into account ensuring safe and sustainable mobility of all citizens and exploiting the full potential of technological progress. The program of Decade of Action for Road Safety 2011–2020 is focused on national and local level actions highlighted as safer roads and its management, safer vehicles and road users, and post-crash response. The White Paper on Transport adopted by the European Commission on 28 March 2011 states that a high priority must be given to road traffic safety, as it is essential to minimize the number of road accidents and deaths in order to improve the overall efficiency of the transport system and meet the needs and expectations of the citizens and businesses. European Union Road Safety Program (2011–2020), in addition to the actions already mentioned, declares boost of smart technologies, strengthening education and training, better enforcement, focus on motorcyclists. Verona Declaration adds attention to importance of funding, enforcement, and the use of best practices.

Overview of Previous Programs to Improve Road Safety in Lithuania

There were three road safety programs-strategies in Lithuania from 1990 to 2017.

The first program was in force from 2002 to 2004. The main purpose of this program was "to ensure that fewer people comparing with 2011 are killed and affected in road crashes":

- To reduce the number of fatalities by 4% in 2002
- by 5% in 2003
- by 6% in 2004

The program target set for 2004 was not achieved as the number of fatalities on the roads started to increase rapidly between 2004 and 2006. This has been attributed to the high rate of cases of speeding, the consequences of intoxicated drivers, the low level of safety culture and discipline of all road users, etc. Equally important systemic issues include the inadequate national approach to road safety issues, including the legal framework, education and awareness, and the lack of an integrated road transport policy covering road transport development, road and street infrastructure, and road safety issues (Pikūnas and Pečeliūnas 2005). As the situation was changing, since 2007, the number of road fatalities has started to decline indicating the positive tendencies and better positioning in the context of the European Union (Tolón-Becerra et al. 2014). One of the reasons for the positive implementation of road safety was the adoption of road infrastructure management to safe design principle based engineering. Small roundabouts, speed cameras, and other engineering devices were integrated into urban and rural roads, but it is assigned to the second road safety program.

The second program was in force from 2005 to 2010. The main objective of this program has already been linked to that of the European Union – "to reduce the number of road fatalities in half by 2010 compared to 2004":

- to reduce road fatalities by 25% by 2008 (reached 33%)
- by 2008, reduce the number of road crash victims by 10% (reached 26%)
- by 2010, to reduce the number of road crash victims by 20% (achieved 45%)

The purpose of this program was to create conditions for the targeted and long-term improvement of safe traffic and to design and implement measures to reduce the number of road crashes. The program provided for raising the responsibility of road users, changing their behavior, improving road infrastructure, vehicle safety, and improving the legislative framework.

As part of the traffic safety program, funds were allocated for the reconstruction of high crash rate road sections, intersections, lighting, construction of pedestrian and bicycle lanes, automatic speed measuring equipment, road weather information system (KOSIS), and road safety audits for all road objects under construction and reconstruction. The program promoters were: the ministries of Transport and Communications, Health, Education and Science, Interior and Finance, Police Department, and other institutions. For example, in 2006 measures to improve road safety included the installation of 57.35 km of hiking and cycling trails and 46.6 km of protective metal barriers, elimination of 11.8 km of separate road sections, and reconstruction of 17 intersections.

The following provisions were legalized in the country in 2006:

- It is mandatory to drive with the dipped-beam headlamps on during daylight hours.
- Passenger cars are allowed to drive at 110 km/h on motorways, on the speeds up to 90 km/h on asphalt or concrete roads, and speeds up to 70 km/h on other roads (previously was 90 km/h).
- The Road Traffic Regulations (RTR) provide that if a vehicle decelerates before a pedestrian crossing, the driver of another vehicle travelling in the same direction must slow down or stop and restart only after verifying that there is no pedestrian at the crossing.
- Compulsory use of safety belts in all vehicles weighing less than 3.5 t and in buses.

To sum up the results (the number of road fatalities decreased by 33%, road injuries decreased by 45%), the program objectives for 2005–2010 were achieved with success.

The third program valid from 2011 to 2017. For the first time, this program mentions a long-term vision on road safety "*No deaths and no serious injuries of road users in Lithuania*" (Government of the Republic of Lithuania 2011).

The strategic objective of the program is ambitious, inspired by the success of the program of 2005–2010: "In improvement of the condition of road safety, to achieve Lithuania to be among the top 10 best performing countries in the European Union by the number of fatalities per 1 million road users (or no more than 60 per million population killed)."

Significant progress has been made in the area of road safety over the program implementation period, but the objectives set have not yet been met, and it is, therefore, necessary to find new effective solutions to reduce the number of fatalities and injuries.

High collision rates at level crossings were observed in the analysis of statistical data; therefore, in 2007, the railway safety strategy of the State Railway Inspectorate under the Ministry of Transport was approved. Based on Sweden's good example, a zero vision has been formulated: "A safe society and safe rail transport without fatalities and injuries." Based on this zero vision, measures to reduce fatalities, injuries, and the prevention of road crashes were included in safety strategy.

Our achievements: Lithuania in the local and in the European context. The number of road traffic fatalities and injuries in Lithuania has changed significantly over the last decade. From 2007 to 2011, the number of registered road crashes and injured persons decreased rapidly (Fig. 1). The rapid decrease in 2006–2008 is linked to the intensive implementation of engineering traffic safety measures on the roads and streets of the country, intensified traffic law enforcement of driver violations, tightening of sanctions for violations, and the changed focus on traffic safety education. Another indirect cause is the impact of the economic crisis, which has significantly slowed down the road freight transport in the country. In 2008 about 25% fewer incidents of road crashes were registered in Lithuania, and their volume was almost twice as low in 2011 compared to 2007.

Overall, the number of road crashes and injuries in Lithuania was reduced by more than half in 10 years, but worse periods with temporary increase of accident rate have not been avoided since 2011. The number of road fatalities has also been decreasing over the last decade. In 2008, compared to 2007, road fatalities had fallen

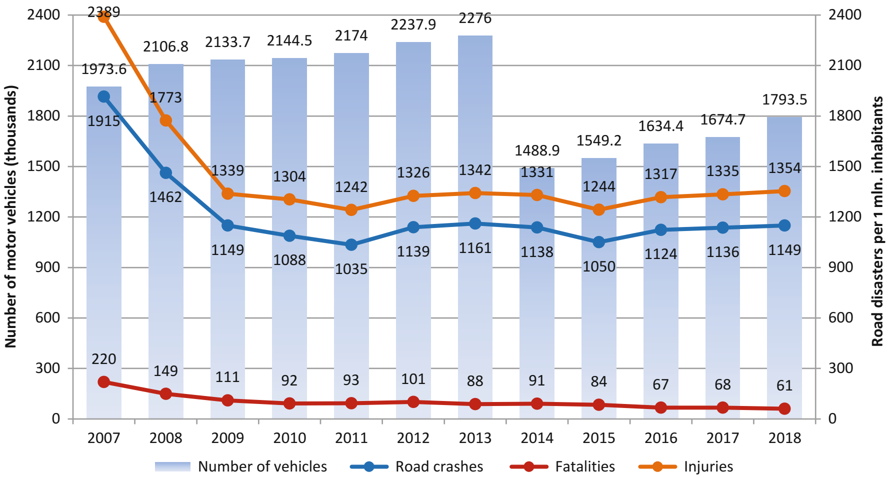

Fig. 1 Number of registered vehicles, road crashes, injuries, and fatalities in 2007–2018. (Source: Lithuanian Road Administration (LRA) 2019)

by 33%, and they have already been reduced by half in 2009. In 2011, compared to 2007, 60% fewer fatalities were recorded. Since 2011 the number of road fatalities in Lithuania changed insignificantly and unevenly. The number of road fatalities in Lithuania decreased more than three times in 10 years period (Fig. 1). Nonetheless, these results are not encouraging, as they were achieved in the background of the extremely alarming previous period when the number of road fatalities used to exceed 600 per year (Pikūnas and Pečeliūnas 2005). Despite the results achieved, the started works must be continued and extended by new means.

At the beginning of July 2014, the country introduced changes to vehicle registration procedures, which are also reflected in the analysis of national statistics (Fig. 1). Under the new regime, vehicles without compulsory civil liability insurance and (or) roadworthiness tests have been de-registered, resulting in a reduction of the vehicle fleet by more than one-third. Now, these data are more in line with the actual number of vehicles on the country's roads, but the upward trend remains evident, reflecting the intensive road transport in Lithuania.

In 2010–2018 Lithuania's progress in reducing road crashes had been assessed in the context of the European Union. The second best crash reduction rate achieved (−43%) and the Road Safety Performance Index (PIN) rating are shown in Fig. 2. This PIN indicator is established by the European Transport Safety Council (ETSC), a Brussels-based, independent nonprofit organization dedicated to reducing the numbers of deaths and injuries in transport in Europe (ETSC 2019). Lithuania has

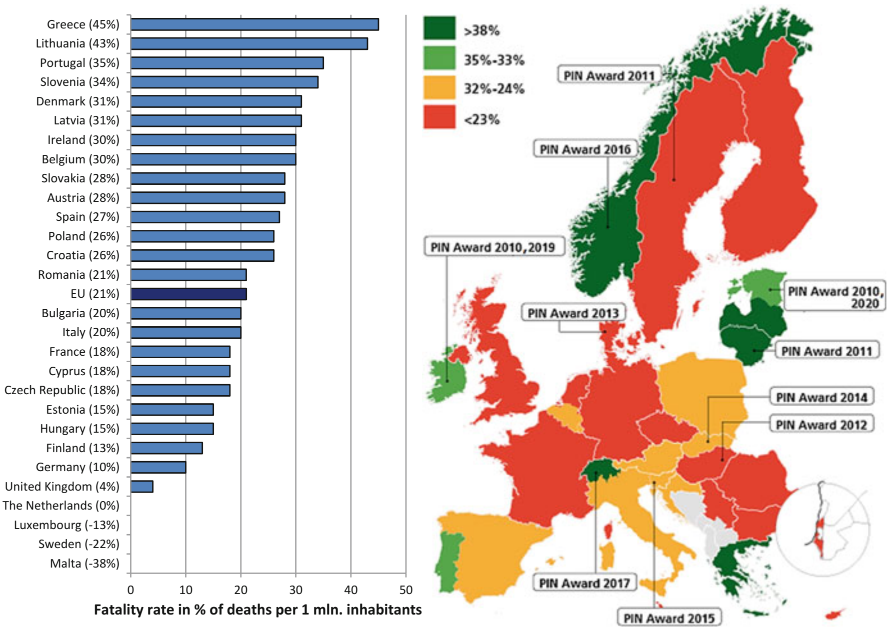

Fig. 2 Relative change in road deaths between the period 2010–2018 (left) and map of Road Safety Performance Index (right)

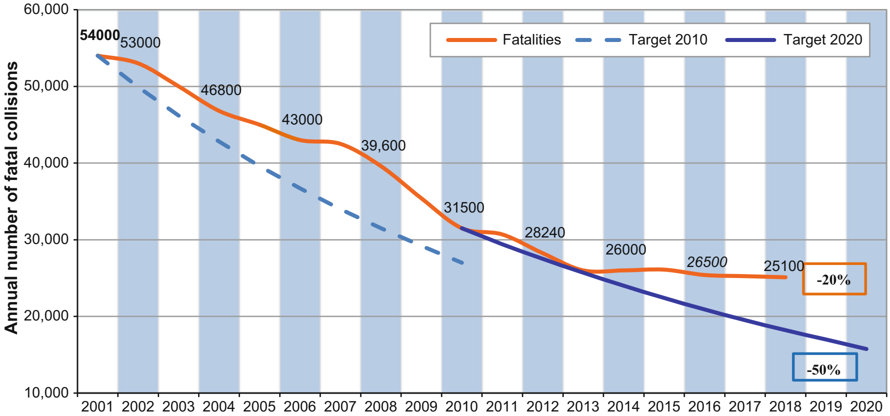

Fig. 3 EU fatalities in road accidents and targets 2010–2020. (Source: CARE – EU road accidents database)

taken a significant step toward the safer road transport but remains below the EU average (Fig. 2).

In 2016 there were 25,500 road fatalities in the European Union, 1.5 million of road users were injured. In 2016, a total of 67 people died in road crashes in Lithuania per 1 million of population, whereas the European Union has an average of 50 fatalities per 1 million of population. The trend of this period reflects a consistent move toward the European Union's goal of halving the number of road fatalities over the last decade. Nevertheless, the EU road accident statistics of recent years is not improving in accordance with the set scenario (Fig. 3). In 2018, the EU average was 49 fatalities per 1 million of population.

Despite the results already achieved, Lithuania remains a high road traffic risk country compared to other EU member states. In 2018, 60.5 people died in road crashes per 1 million of population. Even taking into account the shrinking population and investment in road infrastructure and public education and awareness, the number of road crashes in the country is significantly higher. Such statistic is characteristic to most East-Central European countries (Fig. 4).

Needs for Building Strategic Directions

For the second consecutive decade, international organizations such as the United Nations and the European Commission are formulating objectives on the road safety for the decades to come (UNECE 2019; European Commission 2019). Meanwhile, the main goal is to reduce the number of fatalities to zero by 2050. The current road safety objectives of these organizations are linked to the year 2020 and the prospects for 2030 are already planned. As Lithuania usually sets its goals in the field of road safety in accordance with the objectives of the European Commission, a new strategy (as a vision) is envisaged.

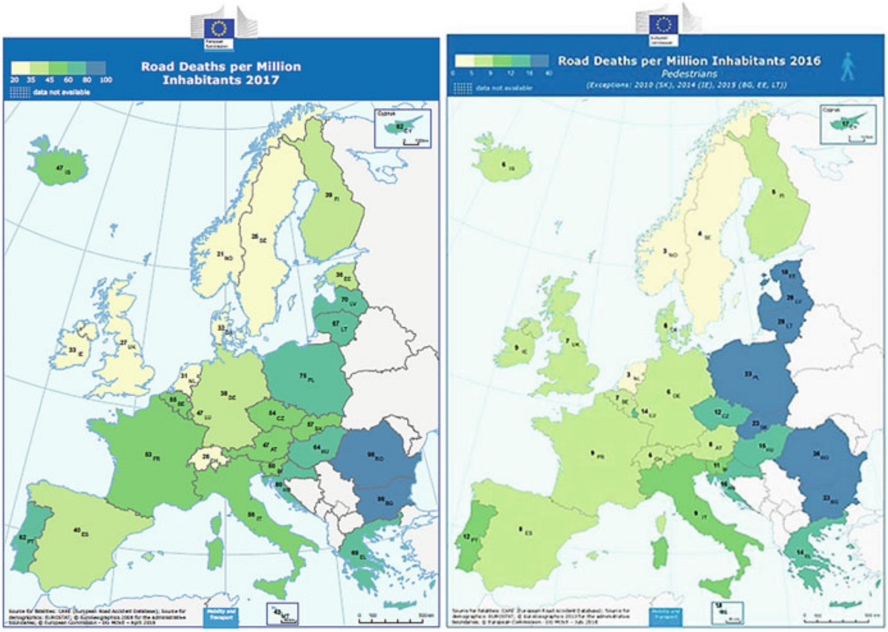

Fig. 4 Europe’s map for road deaths per million inhabitants, 2016–2017. (Source: CARE)

VISION – ZERO IN TRANSPORT IN 2018-2050

The third Lithuanian Road Safety Program, valid for 2011–2017, formulated a long-term vision on road safety “No road user is killed or seriously injured in Lithuania.” The importance of such a vision has not diminished; on the contrary, it is largely followed by the international community. As the current situation in the field of traffic safety remains intolerable, this vision is further pursued in Lithuania.

Essential measures to improve road safety:

- Improvement of infrastructure on state roads.
- Stricter sanctions for offenders.
- Zero promille of blood alcohol level (BAC) for certain driver group + the legitimation of Alcolock idea.
- The average speed enforcement has started.
- Close cooperation between institutions in organizing educational activities.

Unlike the previous one, the new program in addition to objectives defined and tasks formulated for each of them has measures already provided for and the specific institutions assigned to their implementation. Evaluation criteria, expressed in quantitative values, are provided for the implementation of the goals and objectives of the program. For example, (i) the task to reconstruct dangerous intersections on main and national roads is intended for the Lithuanian Road Administration. It provides for the responsibility to reduce the number of accidents in 2025 by 90%, and in 2030 by 100% compared to 2018. (ii) The Lithuanian Transport Safety Administration and the Police Department have the task and responsibility to perform roadside inspections of the technical condition of vehicles in 2025 – 7% and in 2030 – 8% from the fleet. It is expected that more specific tasks and responsibilities will better achieve the stated objectives of the new program.

Selection of Specific Measures for Traffic Safety Improvement and Evaluation of Its Efficiency

The guiding principle of the program "Vision Zero" is based on shared responsibility of the road traffic managers, vehicle manufacturers, and companies representing the interests of the manufacturers for road safety, that is, the traffic environment and vehicles must be designed and maintained to help road users avoid errors, and in the event errors, to have the least possible consequences, and the road users must act the way that does not pose a risk to themselves or others (National Road Traffic Safety Programme "Vision Zero" 2020).

TARGET – zero fatalities and serious injuries in road transport

Significant attention is directed toward the prevention of deliberate violations of road traffic regulations, development of the safer road infrastructure, management of safer vehicle fleet, and mitigation of the consequences of road crashes. The following subsections are the description of the identified issues and selected measures addressed for safer behavior of road users, safer roads, safer vehicles, and more efficient rescue assistance.

First Priority: Safer Behavior of Road Users

Compliance with Permitted and Safe Speed

In accordance with the analysis of accident data of the country, it has been found that the most common factors of fatal crashes are related to noncompliance with safe driving, as defined in the traffic rules. It includes the human risk factors, among them, the unsafe speed of a vehicle in a bend of the road – 9%. In Lithuania, as many as two out of three drivers in the territories of settlements exceed the permitted speed. Observations show that 17.6% of motorists exceed the speed limit on motorways of more than 10 km/h, and same can be said about 31.6% of drivers on state roads and 19.2% of drivers on regional roads. This encourages the pursuit of compliance with **the speed limits as a habit for drivers**.

Exceeding the speed is the most common violation of traffic rules and safe driving principles both in Lithuania and in many other countries. Unfortunately, there is a prevailing perception among drivers that exceeding the speed up to 10 km/h is not a violation and does not interfere with road safety. However, even a slight over speeding will result in longer reaction time of the driver, more complex car handling in unexpected circumstances and adverse conditions. Unfortunately, drivers do not see the problem speeding above 10 km/h. This is due to a lack of awareness of how increases the risk of driving and the possible consequences of colliding with another vehicle or hitting a pedestrian even at low speeding. Long-term tolerance of low speeding, including the relatively high tolerance of speed cameras, has also contributed to this attitude and behavior of most drivers. Unfortunately, when individual drivers do not exceed the speed limit at all (often buses or trucks with speed limiters), they become objects of continuous overtaking. This further increases the risk of driving, so the control of unsafe and right-hand overtaking, as well as speeding without tolerance, must remain an active means of implementing safe driving.

The National Police Department has started controlling the speed of cars on state roads using sectorial speed meters and the number of sections that record cases of average speed violations are expanding. In the coming years, a total of 130 average speed measuring sections will be installed in the country (Fig. 5). The network of

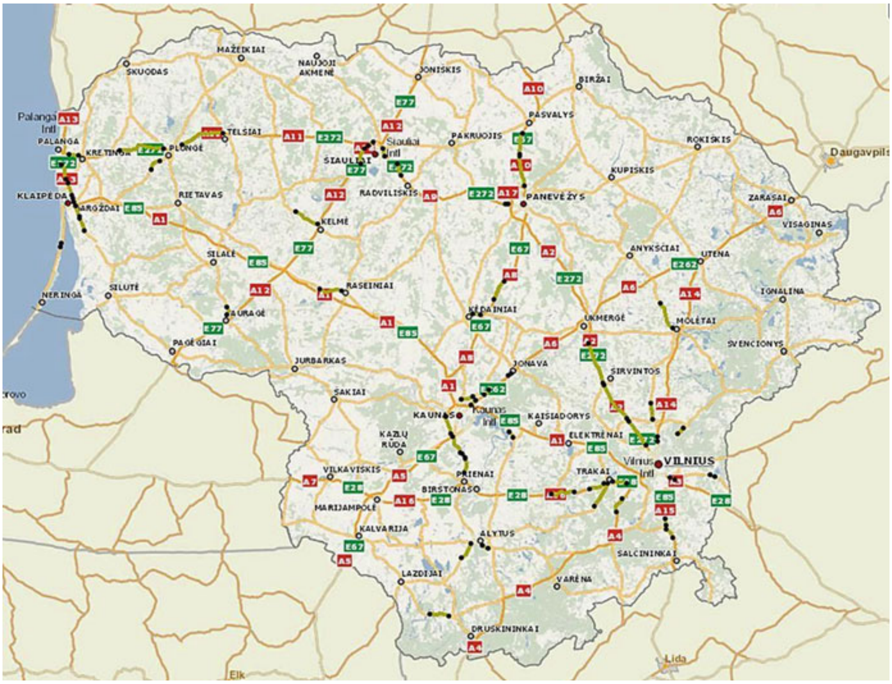

Fig. 5 Estimated average speed measurement sections on Lithuanian roads. (Source: LRA 2019)

Table 1 Implementation of permissible and safe speed compliance. (Adapted from National Road... 2020)

Measure	Expected effect	Assessment indicator
Change of the legal base		
Change the legal base by introducing a zero tolerance for speeding	The introduction of lower tolerance for speeding is intended to reduce the cases of speeding	30% reduction in the number of drivers exceeding the speed limit in settlements up to 10 km/h
Road users education		
Emphasizing the risks of speeding in a social advertising campaign	Modern and attractive forms of education will be used to explain the risks of speeding	At least 50% of respondents in the public poll report that social advertising has had a positive impact on their behavior in traffic, particularly in respect of speed limits
More efficient supervision		
Development of an automatic speed control system (including insurance, roadworthiness tests, etc.) on country roads	On the sections where an automatic speed control system will monitor the speed, the number of speeding and registered crashes will be reduced	A number of registered crashes on the road sections with automatic speed control reduction after the implementation of the control system on the section by at least 80%
The inevitability of penalties for severe violations of RTR (especially for speeding)	In case of detection of a severe RTR infringement by automatic means on a vehicle registered in another EU country, a report is sent to the owner of the vehicle	Contract on data exchange in accordance with Directive (EU) 2015/413 of the European Parliament and the Council has been signed with at least 20 member states

instant speed cameras is also expanding by installing 70 cameras (15min.lt 2019). These tools are directly focused on law enforcement on the permitted speed limit.

Table 1 shows the measures, the expected effects, and evaluation indicators to address the issue of compliance with admissible and safe speed. In the context of the various measures to implement road safety, it is important not only to define those instruments clearly but also to anticipate their effects. When applying measures at the level of national regulation, it is very important to provide an indicator of evaluation for each measure – the best-achieved result in terms of quantity. This format will continue to apply to other measures described.

After implementing measures to improve traffic safety in the long-term, the proportion of motor vehicles exceeding the speed limit in Lithuania in settlements is expected to reduce from 68% in 2014 to 60% in 2025 and up to 45% in 2030.

Public Intolerance of Drunk Driving

In 2019 alone, drunken road users (drivers, motorcyclists, cyclists, pedestrians) caused 265 road crashes, resulting in 351 injuries and 25 fatalities. The statistics for the last four years have not changed significantly, and that warns of the

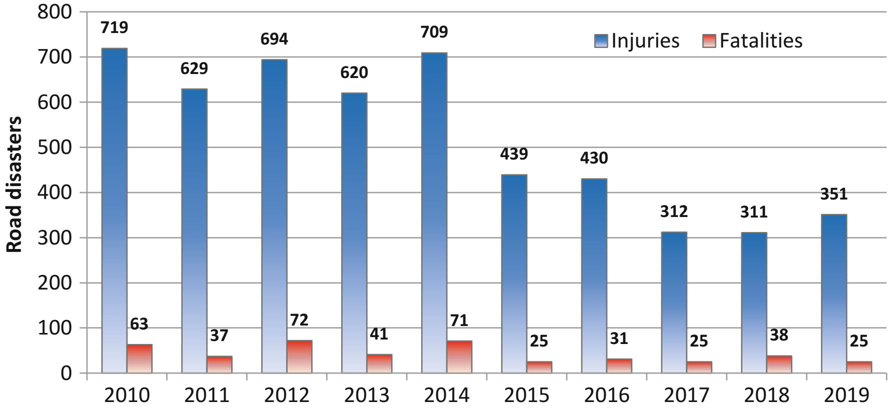

Fig. 6 Alcohol-impaired road traffic fatalities 2010–2019. (Source: Lithuanian Police)

ineffectiveness of the measures currently taken. The statistics for the period 2010–2019 due to road disasters caused by drunk road users is presented in Fig. 6.

Between 2013 and 2016, the highest numbers of fatal crashes (23% of all fatal crashes caused by road users) were due to the impact of alcohol: 14% for drunk drivers, 8% for drunk pedestrians, and 1% for drunk cyclists. **It is therefore planned to achieve that the public does not tolerate driving under the influence of alcohol or psychoactive substances**. The following are the main reasons identified as to why drivers are drunk while driving in the country:

- Drivers hope a police officer will not catch him on the road
- It is naively believed they succeed in making a "consensus" with a police officer on the road.
- They do not know the exact details of imminent sanctions and all the hassle in recovering a driving license.
- High availability of alcoholic beverages (ban on their trade-in petrol stations and limited time after trading in shops).
- Public indifference toward drunk drivers.

Successful measures to reduce the number of drunk drivers in foreign countries:

- The consequences of alcohol use for each individual and society as a whole are publicly and clearly identified (health, early mortality, increased injuries at home and work, long-term decline in the quality of life and satisfaction).
- Significant strengthening and publicizing the sanctions for unauthorized alcohol use.
- Thorough traffic law enforcement by officials (the inevitability of criminality).
- Ongoing intensive educational campaigns to explain the harm of alcohol and the improvement of people's lives without alcohol.

- Promotion of more sports, active recreation and leisure without the excessive alcohol or food consumption (development of cycle path infrastructure, public urban spaces, parks, restriction of access to alcohol and fast food).

In 2016 the country set a legal limit of zero promille of BAC for the following groups of drivers: novice drivers, drivers of a taxi, motor vehicles, mopeds, motorcycles, tricycles, light quadricycles, quadricycles, power quads, vehicles with a maximum permissible mass exceeding 3.5 tons or with more than nine seats or carrying dangerous goods. It has been agreed during the revision of the legal liability of road users that the installation of alcolocks in vehicles should be done on a voluntary basis. Choices are offered: disqualification from driving or a reduced term for driving disqualification, but compulsory participation in a rehabilitation program and the use of alcolock system in the vehicles. Drivers who install alcolocks on their vehicles and undergo the drunk driving rehabilitation programs could reduce their disqualification term by a factor of two. As of 2016, alcolocks are installed on all new school buses reaching the country's roads.

Educating road users through the involvement of alcoholic beverage manufacturers, more effective supervision through intensive police checks are also effective tools. A variety of road safety education activities are carried out by most public authorities or nongovernmental organizations in the EU (such as the European Transport Safety Council (ETSC), the International Traffic Safety Data and Analysis Group (IRTAD)), both in a combination of actions by police officers or stricter controls on certain groups of road users (e.g. educational activities against a drunk driver, at the same time the enhanced control of driver intoxication enforcement). See Table 2 for additional measures, expected effects, and assessment indicators for the problem of intoxicated driving.

After the implementation of measures to improve traffic safety in the long term, it is estimated that in Lithuania the number of road crashes caused by intoxicated road users would decrease from 307 in 2017 to 100 in 2025 and to 50 in 2030.

No Use of Mobile Devices

In Lithuania, about 45% of drivers talk on the phone without a headset while driving a vehicle and about 30% of drivers write messages. About 16% of drivers also browse their smart devices while driving, and this behavior is playing an increasingly important role in life and is rapidly growing. Using a phone negatively affects driving safety in two ways: it physically complicates the operation of the vehicle, especially in unexpected or sudden changes in driving conditions, and distracts the driver's attention and thoughts from monitoring and interpreting the traffic environment, thereby increasing his response time (Žuraulis et al. 2018).

It is intended **to prevent drivers from using a mobile device while driving a motor vehicle**. Measures, expected effects and evaluation indicators to address this problem are presented in Table 3.

After implementing measures to improve traffic safety in the long term, it is estimated that in Lithuania, the number of drivers using mobile communication

Table 2 Implementation of public intolerance to drink driving. (Adapted from National Road… 2020)

Measure	Expected effect	Assessment indicator
Change of the legal base		
To prepare a rehabilitation program for drivers who violated the RTR while driving when their blood alcohol levels exceeded the legal limits	Drivers opting for a rehabilitation program will be allowed to drive motor vehicles with integrated engine blocking equipment that responds to alcohol concentration in the driver's exhaled air	The program includes at least 50% of the drivers disqualified from driving under the influence of alcohol
To carry out an in-depth analysis and improvement of procedures and methods to determine whether or not road users are /were intoxicated with narcotics, psychotropic and other psychoactive substances	This measure aims to improve procedures and methods for determining whether road users are/were under the influence of narcotic substances	Police are using new procedures and methods to determine whether or not road users are intoxicated with narcotic substances
Road users education		
Social advertising emphasizes the dangers and risks of driving under the influence of alcohol or psychoactive substances	Modern and attractive forms of education are used to explain the risks of driving under the influence of alcohol or psychoactive substances	At least 50% of respondents of the public poll report that social advertising has had a positive impact on their behavior in traffic, in particular by discouraging them from driving under the influence of alcohol or psychoactive substances
More efficient supervision		
On a large scale, to perform the law enforcement of driving under the influence of alcohol or psychoactive substances	Frequent and continuous law enforcement campaigns of driving under the influence of alcohol or psychoactive substances in the whole of Lithuania for non-compliant drivers will mean the inevitability of sanctions.	A 5% annual reduction in offenders in road crash who ignore the prohibition of driving while under the influence of alcohol or psychoactive substances.

devices, in the way prohibited by the RTR, will reduce from 45% in 2016 to 10% in 2025 and to 5% in 2030.

It is important to note that using a mobile device for calls or surfing is dangerous not only from the drivers' part but also from other road users. Pedestrians pose a danger to themselves and others by focusing their attention on the phone screens at intersections, pedestrian crossings or their accesses. In order to draw the attention of such pedestrians, pedestrian footpaths are equipped with loudspeakers that signal the danger of entering the street under a red traffic light (Fig. 7). Also, warning signs are painted on the pavement just in front of a pedestrian crossing in the hope that it will draw the attention of pedestrians who are with their heads in the phone (browsing).

Table 3 Implementation of non-use of the mobile device while driving. (Adapted from National Road. . . 2020)

Measure	Expected effect	Assessment indicator
Change of the legal base		
Changing the legal framework by introducing a zero speed tolerance for unauthorized use of mobile devices while driving	The legislative changes are intended to reduce the number of unauthorized use of mobile devices while driving	A reduction of at least 20% in the number of unauthorized use of mobile devices while driving
Road users education		
The emphasis during social advertising of the risks arising from driving and using mobile devices in an unauthorized manner	Modern and attractive educational forms will be used to explain the risks of unauthorized use of mobile devices while driving	At least 50% of respondents in the public poll report that social advertising has had a positive impact on their traffic behavior, namely, avoidance of the unauthorized use of mobile devices while driving
More efficient supervision		
To carry out the law enforcement campaigns and their publicity on the avoidance of the use of mobile devices by hands while driving	Talking on a cell phone without using a headset, texting or surfing the Internet while driving is one of the causes of serious road crashes and therefore this tool is intended to alert drivers to the risks and consequences and to raise driver awareness	More than 70% of drivers are not using the phone without a handset while driving More than 80% do not write short messages while driving More than 90% of them do not surf the Internet while driving

Fig. 7 Audible and visual means to draw the attention of pedestrians using phones at pedestrian crossings

The LED strips on pavement crossings in front of the pedestrian crossings in the sidewalk in several cities of the country have drawn the particular attention of the public (Fig. 8). Along with the traffic lights, these strips are illuminated red or green and are very noticeable and ensure a good warning at dusk or when it is completely dark. Such a means is also focused on the attention of pedestrians who constantly divert their gaze to the phone screen.

Fig. 8 Pavement LED stoplight strips are mounted to duplicate traffic lights and draw the attention of pedestrians using phones

Listening to music through headphones in heavy traffic areas, which limits the perception of pedestrians and cyclists, is also dangerous. In some cases, this may prevent the traffic participant from hearing special vehicles with acoustic signals. Understandably, it is not possible and reasonable to apply the tightening of liability for all cases. Therefore the long-term public education and awareness-raising of the public must remain a priority strategy in the improvement of road safety. In the case of use of mobile phones education of road users by involving mobile operators, insurance companies or nongovernmental organizations popular in the public domain is also considered a useful tool.

Use of Reflective Elements

In 2018 the most significant number of pedestrians were killed on Lithuanian roads and streets – as much as 40% of all road users (Fig. 9). There were 1021 hits of pedestrians by cars, with 1024 pedestrians injured and 69 killed. Of these, 327 persons were injured, and as many as 52 were killed at night. The distribution of road fatalities and injuries in Lithuania in 2018 is shown in Fig. 9.

Autumn and winter are characterized by long dark hours and unfavorable traffic conditions, which worsen road safety for the most vulnerable road users – pedestrians. Autumn and winter account for about 70% of all pedestrian hits. The majority of pedestrian fatalities are older citizens (>64 years), which is related with their lax approach to safety measures (reflective vests, reflectors) and their proper use or human recklessness. Meanwhile, young people (aged 15–34) make up the majority

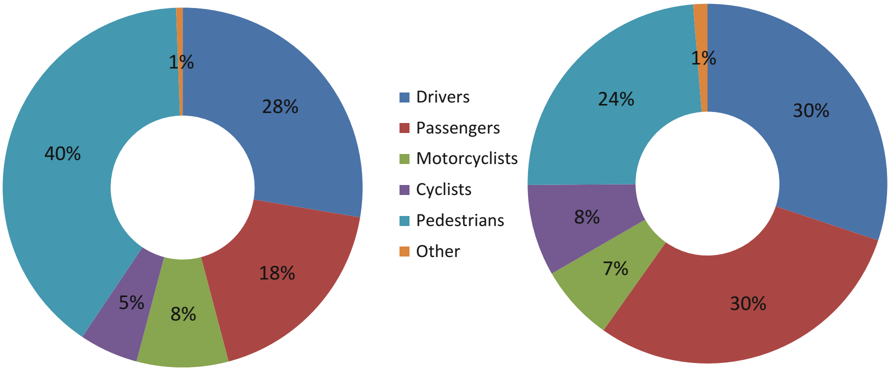

Fig. 9 Deaths (on the left) and injuries (on the right) by road user category in 2018. (Source: LRA 2019)

of injured pedestrians. Risk in this age group is explained by a lack of focus and a characteristic hasty behavior. Nevertheless, due to the high number of pedestrian fatalities, the state authorities responsible for the design, renewal, and periodic maintenance of road infrastructure also have a significant role to play. A significant number of pedestrian-hazardous road sections can be predetermined and adapted to safe pedestrian traffic – paved paths with barriers from the carriageway, maintained roadsides, controlled speeding, necessary road signs built, and other engineering measures to improve traffic safety equipped.

The Road Transport Research Institute, which is currently expanding its activities to include air transport and licensing, is now operating as an Agency for Transport Competencies, contributing significantly to the monitoring and prevention of road crashes in the country. In 2014 and 2016, the Institute conducted a study on the use of reflectors during the dark hours (KTTI 2016a), monitoring pedestrians and cyclists on 30 state roads at public transport stops, shops, and other places near resident attraction points. The study showed that about 22% of all pedestrians and cyclists do not use reflectors, and about 21% are misusing them in the dark hours. The use of reflectors by different groups of vulnerable road users is presented in Fig. 10. The same study was conducted by the Institute in 2014. Comparing the results, in 2016, the number of road users using reflectors during the daytime increased by 14%, the number of them misusing them increased by 16%, and the number of road users not using them during the dark hours declined by 30%. This demonstrates the need to continue educational campaigns on reflector distribution and awareness of their use.

The importance of reflectors is evident, as a pedestrian wearing a reflector, a vest or other clothing with reflective elements is visible from a distance of 300 m, and without reflectors only from a distance of 100 m from a vehicle with high beam headlamps on. When the vehicle is passing with the dipped-beam headlamps on, a pedestrian with reflective elements is noticeable from a distance of 150 m and only from 50 m without them. In these circumstances, even at a speed limit of 50 km/h,

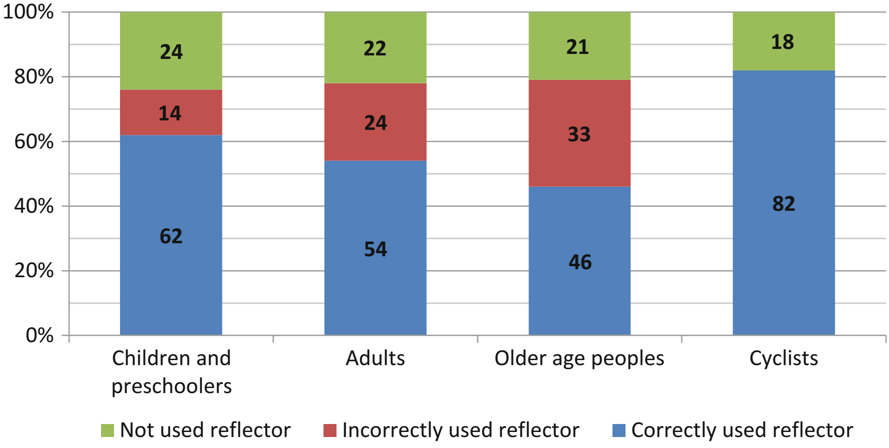

Fig. 10 Use of reflectors in accordance with the monitoring carried out in 2016 on the roads of national importance. (Source: KTTI 2016a)

the driver will be able to stop the vehicle from a distance of at least 35–40 m on wet surfaces, taking into account his reaction time in the dark (1.2–1.5 s). It is therefore important to seek that **vulnerable road users (pedestrians, cyclists) make appropriate use of reflective elements during the dark hours**. This involves the education of road users through the active involvement of municipalities and supervisory enforcement activities (Table 4).

In the long term, after implementing measures to improve traffic safety, the proportion of road users who do not use reflectors or similar devices at all and misuse in Lithuania is expected to decrease from 43% in 2016 to 30% in 2025 and 15% in 2030.

Use of Seat Belts in Rear Seats and Child Seats

The consequences of road crashes are heavily influenced by whether the occupants of the vehicle are wearing seat belts or not. Over the period of 2013–2016, it has been recorded that almost one-fifth of road users were not wearing seat belts. Seat belts in the front of the vehicle in Lithuania are used by 97% of vehicle occupants, while only 30% wear them when sitting in the back (including child seats) (KTTI 2016b); therefore, **correct use of seat belts in child car seats and the rear seats of the vehicle must be encouraged**. Measures, expected effects, and evaluation indicators to address this problem are presented in Table 5.

Following the implementation of measures to improve traffic safety in the long term, it is estimated that in Lithuania, the proportion of vehicle occupants in the rear seat wearing seat belts (including child seats) will grow from 30% in 2016 to 60% in 2025 and to 95% in 2030.

Table 4 Implementation for use of reflective elements by road users. (Adapted from National Road. . . 2020)

Measure	Expected effect	Assessment indicator
Road users education		
Emphasize the risks of not using or misusing reflectors or other visibility enhancers during the dark hours should be made in social advertising	Modern and attractive forms of education will explain the risks of not using or misusing reflectors or other visibility enhancers at night	At least 50% of respondents in the public poll report that social advertising positively influenced their behavior in traffic, namely, in promoting the use of reflectors or similar visibility enhancers at night and explaining the risks of their misuse
More efficient supervision		
To conduct the traffic law enforcement campaigns and publicize the use of reflectors	One-fifth of all pedestrians, cyclists, and riders misuse the reflectors. Significant reductions in pedestrian fatalities are expected. Autumn and winter are characterized by long dark hours and unfavorable traffic conditions, which reduce road safety for unprotected road users, pedestrians. About 70% of all pedestrian hits occur in winter and autumn	More than 90% of all pedestrians, cyclists, and riders of state roads use reflectors in the dark. The reflectors are used by more than 90% of pre-school age youth, more than 85% of middle-aged people and more than 80% of elderly people Reflectors in the dark I used by more than 90% cyclists Among all reflector users, more than 90% pedestrians, cyclists, and riders use reflectors correctly.

Higher Driving Culture and More Responsible Pedestrian Behavior

Road users cause about 90% of road accidents, and this is a common issue in Lithuania and other countries on average. Most road crashes are the result of deliberate violations of road traffic regulations or safe driving principles (e.g. safe speed selection) by road users. The behavior of road users on the road is heavily influenced by the monitoring of compliance with traffic regulations and the application of impact measures on road traffic offences. Involving more intensive traffic law enforcement as automated speed control, frequent and fast intoxication tests, seat belts and child seats (especially sitting in the back), as well as unauthorized use of mobile devices control will lead to more responsible drivers' behavior and less violation of RTR. Public intolerance occurring as announcements about obvious violations of RTR, and of course, education of the public about RTR violations is also crucial. The basic principles of road safety must be built during special activities at school. They should familiarize the young road users with the basic rules of the road and why they must be obeyed. It is also important, in the initial phase of driver training, not only to train young drivers of the rules of the road traffic and to provide

Table 5 Implementation of seat belt fastening. (Adapted from National Road... 2020)

Measure	Expected effect	Assessment indicator
Road users education		
Emphasizing the dangers of driving with seat belts off, emphasizing the use of seat belts in rear vehicle seats and city buses and the safe transport of children in social advertising	Modern and attractive forms of education will be used to explain the dangers of driving with seat belts off	At least 50% of respondents in the public poll report that social advertising has had a positive impact on their behavior in traffic, namely, through the promotion of using seatbelts in rear seats and coaches and the safe transport of children
More efficient supervision		
Carry out and publicize the campaigns of wearing seat belts for front and rear-seat passengers and seat belt fastening for passengers in buses and country buses	Due to the failure to use seat belts, many people are still injured or killed in road crashes. The measure would encourage the use of seat belts, including seat belts in rear vehicle seats and country buses	98% of front passengers wear seat belts 50% of passengers in the rear wear seat belts (including child seats) In coaches equipped with seat belts, they are used by 50% of passengers
Carrying out and publicize the traffic law enforcement of children's transport in seats (seats, seating systems) adapted to their height and weight	Carriage of children in places not adapted for this purpose may result in injuries or loss of life during road crashes. The measure would encourage the transport of children in seating positions (seats, seating systems) adapted to height and weight	The proportion of children carried in seating positions (seats, seating systems) adapted to their height and weight, to be at least 80% of all children carried

them with the necessary skills but also to ensure their responsibility and mutual respect. Drivers training and examination system and the interrelations between the institutions involved in this process play an important role here (Valiūnas et al. 2011). To reduce the road crash rate, Lithuania should pay greater attention to development of a road safety based training system, including practical and safe traffic skills in drivers, special training of professional drivers, and improvement of their qualification. The system should ensure improving the qualification of drivers, continuous training of drivers, and examination of their knowledge as well as the development of traffic safety knowledge and skills in road users of all age groups.

In order to achieve **a higher driving culture and more cautious and responsible pedestrian behavior**, the challenge is to reduce the number of abusive driving situations dangerous to others, as well as to reduce the behavior of non-cautious pedestrians (especially children and seniors). Here the role of system designer is envisaged for special attention to the development of safe pedestrian and cycling infrastructure. For this reason, it is necessary to separate the pedestrian and bicycle traffic from the motor vehicle traffic, expand quiet traffic areas with speed limited to 30 km/h – near schools, children's playgrounds, healthcare institutions, shopping centers, parks. Other

Table 6 Implementing a higher driving culture. (Adapted from National Road. . . 2020)

Measure	Expected effect	Assessment indicator
Change of the legal base		
Encourage candidate drivers to acquire as many driving skills as possible before passing the practical driving test	The aim is to encourage to acquire as many practical driving experience as possible before taking the practical driving test. Studies have shown that the learning of practical driving skills for about 120 h (including training with a family driving instructor), after getting a license, the chances for a beginner driver of being involved in a road crash are reduced by 40%	50% of applicants seeking to acquire the right to drive category B motor vehicles, before passing the practical driving test, acquire practical driving skills while driving for at least 50 h
Road users education		
Examining road crashes, their causes and selected measures, sharing them with driving schools and publicizing	The aim is to provide road users with information that will help them avoid errors in their behavior on the road	Thematic plans for driver training have been supplemented with new, relevant topics that would contribute to increasing traffic safety
More efficient supervision		
Encourage road users to report cases of reckless driving or other violations	The aim is to raise public intolerance for the abusive driving that endangers the lives and health of other road users	Surveys show that driving culture is improving

measures, expected effects, and evaluation indicators to address to a higher driving culture and more responsible pedestrian behavior are presented in Table 6.

Government of the country back in 2016 has endorsed the Code of Administrative Offenses, which provides for stricter liability for violations of the rules on vehicle overtaking, dangerous and reckless driving, therefore currently the sanction for violation of overtaking rules includes a fine and the withdrawal of the right to drive from 3 to 6 months. In the event of loss of a driving license, additional medical examinations have to be passed (if the right of driving has been Substandard because of being intoxicated with alcohol or other substances), to receive a certificate of health knowledge certification and to attend additional driver training courses. The content of the latter courses includes a lecture on the accident levels and prevention of road crashes, a conversation with the psychologist of at least 55 min about the offense committed, the driving culture and responsibility on the road, and practical driving session with a driving instructor. If the right to drive has been withdrawn for a year or more, the driver has to retake both the theoretical and the practical driving test. Additional driver training may also be provided to novice drivers (not having two years of experience) who violate the RTR rules, as young drivers are more prone to errors or unsafe behavior on the road (Šeibokaitė et al. 2020). If these courses are not attended, a 10-year valid driving license is not issued to them.

A number of studies have been carried out in the country to monitor the behavior of road users, as road users specifically are the main perpetrators of road crashes. The irresponsible behavior of drivers, pedestrians, and cyclists, apart from carelessness and negligence, leads to disasters where they are most often affected, but it is too late for many citizens to become aware of the principles of good road behavior. The behavior of 1896 drivers was observed while they were waiting for the green light at signal-controlled intersections in various cities of Lithuania (Bogačionok and Rimkus, 2020). The most commonly encountered extraneous non-driving related activities are talking on and surfing on the phone (16.2% of observed drivers), communication with passengers (11.3%), and smoking (4.9%). In addition, other kinds of extraneous activities have been observed, that is, eating/drinking, checking one's appearance in the mirror, searching for fallen objects, cleaning the cabin, dozing off, throwing of rubbish through the window, using a computer, etc.

Another study observed pedestrian behavior and found that 18.6% of them crossings behave irresponsibly or violate rules at pedestrian (KTTI 2014). The study included a total of 23 h of surveillance of pedestrian crossings in the two largest cities in the country. In unregulated pedestrian crossings, pedestrians usually do not look around properly, are distracted from the traffic or simply cross the street, not at the crossing. The regulated pedestrian crossings are dominated by non-observance of traffic lights as well as inattentiveness and off-crossing.

Special attention needs to be paid to professional drivers as they spend their day on the road while carrying freight or large groups of passengers. Understandably, their responsibilities, in this case, are higher, so the requirements for the selection of such drivers are also stricter. A study of psycho-physiological characteristics of drivers (reaction time, attention concentration) and the influence of fatigue of these drivers on road crashes was carried out in a public transport company of the capital city of Lithuania, engaged in passenger transport within the city and suburbs (Zaranka et al. 2012). The study found that drivers are most likely to be involved in a road crash on the first day after a day off and that the likelihood of crash increases during the first hour of work and in the middle of the shift when the first signs of fatigue occur. Taking into account the results of the study, the company has applied a special method of selection of drivers based on driving experience, skills and attention keeping ability in accordance with the age group of the driver.

Second Priority: Safer Roads

The total network of Lithuanian roads reaches 84.5 thousand km. Roads are divided into national (21.2 thousand km) and local roads (63.1 thousand km), depending on the traffic permeability of vehicles and their socioeconomic importance. The network of roads assigned to the streets is 7.2 thousand km (LRA 2019).

Lithuania is a transit country in terms of its geographical location and share of gross domestic product. Back in 1994, the European transport ministers at a

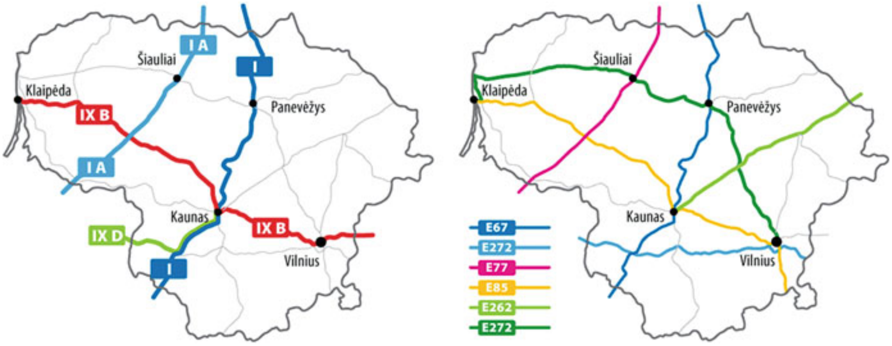

Fig. 11 Interstate road network crossing Lithuania: branches of the *Trans European Network* corridor (left); highways of European significance (right)

conference in Crete identified two Trans European Network corridors crossing Lithuania's territory (Fig. 11a). In addition, there are six highways of European significance in the country (Fig. 11b). Such interstate road infrastructure, the geographical location of the country, and the state policy implemented make land transport a significant contribution to the national economy. In accordance with the Lithuanian Department of Statistics, the state receives about 13–17% of the gross domestic product of the country due to cargo transportation. Therefore, Lithuania can rightly be called a transit state. In Lithuania, in the area of export services, road transport accounts for the largest proportion, 28.7% of services, compared to other modes of transport (railways, air and sea). The majority of cargo, 62.3%, is also carried by Lithuanian motorways (LRA 2015).

Despite the apparent benefits of the transport business, heavy traffic of vehicles carrying goods is causing a significant part of total crashes, which requires more attention and additional investment in ensuring the safety of the road infrastructure. Heavy vehicle drivers are responsible for about 25 road fatalities of road users each year in the country, which corresponds to about 14% all fatalities in the country's roads.

From the point of view of road safety, it is important that professional drivers working in the field of transport comply with the requirements in terms of road safety that apply to them. For this purpose, the country provides for automatic preliminary law enforcement of driving and rest regime and heavy and large-sized vehicles. The integration of vehicle number plates and data validation system in the road infrastructure requires automatic traffic law enforcement of the driving and resting mode. Thus, drivers will try not to violate the prescribed driving and resting regime, and it has a direct connection with driving and traffic safety. An automated traffic law enforcement system would also allow heavy and large-sized vehicles to be controlled, so drivers and logistics companies will try to stay within the maximum weight and size limits.

In its strategy, Lithuania has set a target that the share of driving and rest violations classified as very serious and severe of the number of drivers checked should be reduced from 10% in 2016 to 5% in 2025 and up to 1% in 2030. The reduction of the share of noncompliant vehicles in terms of securing goods and carriage of dangerous goods by 2030 is expected to be 10 and 5 times, respectively.

The ratio of serious and very serious violations detected and rectified, to road vehicles when the allowed dimensions, gross mass and axle loads are exceeded without authorization, should increase from 10% to all recorded violations of this type (2016) to 50% (2025) and up to 80% in 2030. The objective of this indicator is to limit and eventually fully stop the participation in general traffic of vehicles which, when exceeding the maximum permissible parameters, pose a severe traffic safety hazard and have a significant negative impact on the environment or serious property damage.

Once the state road crash trends are identified, apart from the measures aimed at the education, traffic law enforcement and responsibility of road users, separate measures should be applied in parallel to other priority areas: streets and roads, vehicles, efficient post-crash assistance, sustainable interaction with other modes of transport.

The streets and roads we travel on every day also make a significant contribution to our security. Every year, over 250 high crash risk sections are reconstructed on state roads with various measures to improve the traffic safety (roundabouts, barriers, city gates, safety islands, directional lighting, speed controls, etc.). Due to consistent activities, the number of high risks sites on state roads has been reduced from 280 to 37 in 7 years (Fig. 12).

One of the causes of road fatalities is the poor condition of some roads as well as the lack of modern road safety and traffic control measures (Government of the Republic of Lithuania 2013). Thirty-two percent of Lithuanian roads are in poor or very poor condition, and the existing road pavement reconstruction volume (1.6% of the total road length in 2009) is five times lower than optimal. EU Directive 2008/96/EC provides that measures to improve road safety shall be implemented throughout the road infrastructure network.

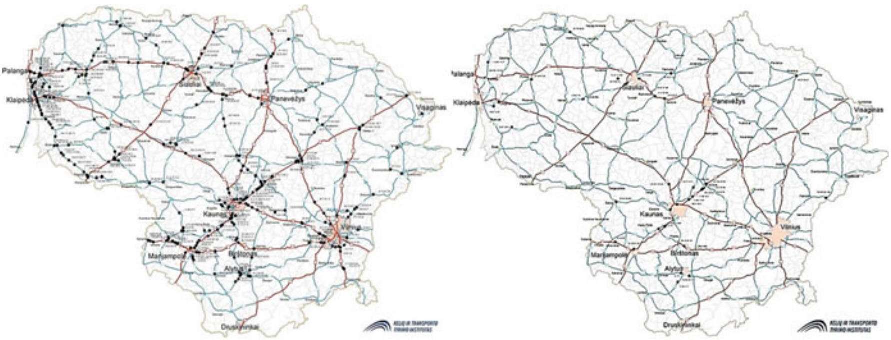

Fig. 12 Maps of high risks sites on national trunk roads and state roads 2007 (left) and 2015 (right). (Source: Transport Competence Agency)

Despite the decreasing number of high crash risk sections on the country's roads, it is imperative that **the road infrastructure is managed using advanced technology and interstate road safety standards and provides the reliable information needed to improve road safety**. The main tasks applied for this are:

- Continuous road maintenance and implementation of engineering safety improvement measures and evaluation of their effectiveness
- Advanced traffic safety management
- Collection and analysis of advanced crash information using advanced techniques

Lack of information about the circumstances is noticed during the analysis of road crashes in Lithuania. The specific information covers incorrectly specified exact location of an accident, insufficient information about specifics of local infrastructure, insufficient information about seat belts, child seats or helmets usage and airbags deployment, poor information on human injuries, inaccurate information on the type of the crash. Thorough data about road crash collection will help to identify the root causes and select, as well as implement specific measures for avoidance of fatal crashes.

The detailed measures, anticipated effects, and evaluation indicators to address the problems related to the management of road infrastructure are presented in Table 7.

The Valletta Declaration (No 9994/17 TRANS 252), approved by the Council of the European Union on 8 June 2017, states that Member States undertake, in their efforts to achieve the objective of reducing the number of fatalities up to 2020, to continue work together toward: (i) reduction of the number of serious injuries in road crashes; and (ii) by 2018 at the latest start providing reliable and comparable data using a common definition based on the MAIS 3+ injury classification (Maximum Abbreviated Injury Scale of three or more (MAIS3 +)).

In order to reduce the number of fatalities among pedestrians and cyclists and to reduce the number of crashes caused by overtaking, it is necessary **to develop the road infrastructure that improves road safety and mobility by**:

- Reconstruction of unsafe crossings so that they meet their requirements, extension of pedestrian and cycle paths (including cycle lanes), an adaptation of road infrastructure to persons with disabilities, development of road infrastructure ensuring the safer movement of animals when crossing the road network, reconstruction of dangerous intersections, removal of unprotected left turns on the highways
- Installing and developing intelligent transport systems (ITS) on the roads of national importance for ensuring traffic safety (prevention of unauthorized overtaking, etc.)

Table 8 shows the exhaustive measures, expected effects, and evaluation indicators to address the problems related to the development of road infrastructure to improve road safety and mobility.

Table 7 Implementation of advanced technology in road infrastructure management. (Adapted from National Road... 2020)

Measure	Expected effect	Assessment indicator
Advanced road safety management		
Implementing a road infrastructure management system	The created road infrastructure system will allow more efficient planning of investments, need and use of funds for improving road safety, prioritization of repairs and other work	The road infrastructure of national importance is managed using a unified information system
To carry out the road safety impact assessments and road safety audits for street construction, reconstruction, and major repair projects	All new street construction, reconstruction, and major repair projects will be evaluated in accordance with a set methodology for safe traffic. The objective is to make them safer for all road users when constructing or redesigning objects	Road safety impact assessment and traffic safety audits are carried out for street construction, reconstruction, and major repair projects, 100% in 10 largest cities in Lithuania
Establish the procedures for training and certification of road safety auditors	More specialists able to carry out road infrastructure safety audits will be trained to ensure that road and street construction, reconstruction, and major repair projects meet the road safety requirements	Traffic safety auditors shall be trained and certified in accordance with the procedure established by the competent authority of Lithuania
To set requirements for adaptation of roads and their elements to people with special needs	The newly constructed or reconstructed road and street infrastructure will be adapted to people with special needs and will ensure their safe participation in traffic	Road reconstruction or significant repair projects are carried out in accordance with the requirements for the adaptation of motorways and their elements to people with special needs
Perform street safety inspections	Regular inspections are a necessary tool to prevent intrinsic hazards, and therefore safety inspections would be carried out on the operating streets to identify aspects related to street safety and to prevent crashes.	A safety inspection of the streets of the ten largest cities of the country was carried out for 100%
Prepare maps of high risks road sites in the cities	The safety of existing streets must be increased by directing investments to the most crash-prone sections and those with the highest crash reduction potential. Drivers must be made aware of high-traffic road sections in	Maps of high risks road sites have been prepared for the ten largest cities of the country, and plans for elimination of high risks sites have been approved

(continued)

Table 7 (continued)

Measure	Expected effect	Assessment indicator
	order to change their behavior and to enforce road traffic rules, in particular as regards speed limits	
Collecting and investigating detailed information of road crashes		
As research is an essential tool for improving road safety, it is provided to carry out an in-depth analysis of serious collisions involving road users	The development and demonstration of components, tools, and methods and the dissemination of research results play an essential role in improving the safety of road infrastructure. The specific crash causes involving road users will be investigated, and remedies identified to remove these causes	A new classification of crash causes affecting road users has been prepared
To update the methodology of crash data collection using advanced solutions	The update of the methodology will allow collecting more information on the number of road users who have been injured, allowing for more accurate modeling of the management of the risks involved	A new methodology has been adopted
To establish an information system for the analysis of data on road crashes and for monitoring the implementation of road safety measures, which can be accessed by all interested authorities	More accurate crash information will be collected, which will enable for more precise identification of the circumstances of the crash and will allow this data to be used in selecting measures to prevent other potential accidents Responsible authorities would have access to primary crash data and could analyze their causes. The use of IS would result in the preparation of maps of high risks sites and monitoring the results of implemented traffic safety measures	A computer-based traffic data filling application is used to collect crash data, 80% of all crashes affecting road users Competent authorities have access to the updated database of accidents affecting road users
Categorize injuries sustained in road crashes as minor and severe in accordance with the MAIS3+ method	Uniform monitoring of statistics on traffic-injured persons to allow for a more efficient selection of traffic safety measures, is in place	A new methodology for classifying injuries sustained in road crashes as mild and severe in accordance with MAIS3+

Table 8 Development of road infrastructure to improve road safety and mobility. (Adapted from National Road... 2020)

Measure	Expected effect	Assessment indicator
Increasing road and street safety		
Increase the length of fences against wildlife, the number of wildlife crossings and other roadside protection measures	The aim is to reduce the number of encounters with large and small species of wildlife	Road sections with the introduction of these changes shall 80% less of road crashes involving injuries or fatalities due to collision with wild animals
To reconstruct trunk roads with the most intensive (transit) traffic	Significant reduction in the number of road crashes is expected due to the reconstruction of highways with the highest traffic density	After the reconstruction of trunk roads, the number of road crashes in which injured or killed road users are reduced by 50%
To increase the overall length of roads with dividing strip, pedestrian and bicycle trails, illuminated roads, reconstruct unsafe intersections, increase the length of safe sidewalks	These measures are aimed at improving road safety and providing the right conditions for safe cycling	50% less of road crashes involving injuries or fatalities occur on the road sections where these changes are implemented
To develop the installation of the bike and ride stops and bike-sharing systems in the cities	These measures are intended to encourage and facilitate cycling	Equipped system of bike and ride stops and bike-sharing in six cities
To remove or modify any existing pedestrian crossings that do not comply with the rules for the organization of pedestrian crossing through roads and streets	Potentially dangerous pedestrian crossings will be eliminated or converted into safe areas	80% of crossings comply with the requirements of the rules for the organization of pedestrian crossing through roads and streets. In such crossings, 50% less of pedestrians are killed or injured compared to the situation before the conversion of crossings
To carry out the maintenance of roads of national importance at a higher level	Road safety conditions will be insured, and roads will meet the security requirements in response to the changing climatic conditions or obstacles on the road	To decrease the number of crashes involving road users on slippery roads on state roads by 20%
To develop a road and weather information system	Road users will be provided with more accurate information on road traffic conditions. Getting more information about metrological conditions will make road maintenance more efficient	Development of a network of metrological stops by 15% annually

(continued)

Table 8 (continued)

Measure	Expected effect	Assessment indicator
To increase the efficiency of lighting on roads of national importance	Road sections will be better lit	Reduction of accidents affecting road users in the road sections where road lighting has been replaced by more efficient lighting, by 10%
Deployment and development of road safety improving the its		
Implementing a multifunctional violation control system on state roads	This system will allow controlling the weight, dimensions, speed of passing vehicles or their combinations, checking whether the vehicles have valid roadworthiness tests, compulsory motor third-party liability insurance, and registration data. In addition, the information obtained is required for traffic management on motorways	For road sections with a multifunctional violation control system implemented, no violations of RTR are detected in the passing 90% of vehicles
To implement an average speed control system on state roads	The introduction of an average speed control system aims to keep vehicles within the set speed limits Sanctions will be applied to drivers who exceed the established speed limit on the road section	On-road sections fitted with an average speed control system, the percentage of motor vehicles exceeding the speed limit above 20 km/h does not exceed 2% of the total number of passing motor vehicles
To develop a network of stationary speed meters on state roads by expanding their functionality	By increasing the number of fixed speed meters on the roads by more than three times and supplementing their functions, to record the leaving vehicles exceeding the set permitted speed, it is expected to significantly reduce the number of speeding vehicles on dangerous road sections	On-road sections with fixed speedometers, the percentage of motor vehicles exceeding the speed limit above 20 km/h shall not exceed 2% of the total number of passing motor vehicles
To deploy a dynamic safety speed management system on state roads (road signs with variable information)	The introduction of a dynamic safe speed management system will allow for rapid response to metrological conditions or obstacles on the road	50% fewer accidents due to failures to select safe speed occur on the road sections with a dynamic safe speed management system installed

After implementing measures to improve the management of road infrastructure in the long term it is expected that in Lithuania from 2018 to 2030:

- The number of pedestrian fatalities should drop to 34 (−50%)
- The number of cyclists killed will decrease to 8 (−50%).
- The number of road crashes involving animals on state roads will drop to 5 (−83%).
- The number of collisions when driving to the opposite lane should reduce to 80 (−66%).
- The number of road crashes affecting road users when the motor vehicle is driven off the road will fall to 394 (−30%).
- The length of the pedestrian and (or) bicycle trail network on state roads will increase to 1418 km (+ 18%).

The majority of measures to improve street and road infrastructure need to be adapted to the specific safety concerns and needs and habits of different groups of road users. A holistic assessment of the situation leads to a long-term and sustainable positive outcome. One example of this was the permission for cyclists to drive on pedestrian sidewalks, given the needs and specific habits of road users, where there is no bicycle lane or bike lane nearby and without endangering pedestrians, introduced in 2014. Nonetheless, often, if the interests of some road users are considered, then the interests of other users are undermined. Improving pedestrian safety by the reduction of the speed of movement of motorists, flow capacity or driving comfort, is a typical example. A change to the RTR has been introduced in the country, obliging drivers to park a vehicle at least 5 m behind a pedestrian crossing if there is one lane in each direction on the street, this way, not obstructing the visibility of pedestrian crossing to other drivers.

Given that the number of road crashes involving pedestrians in their crossings has increased over several years (2014–2016), the rules for the organization of pedestrian crossings on roads and streets were adopted in 2017. These rules prescribe the conditions, requirements, and restrictions for the installation of pedestrian crossings in the territory of the Republic of Lithuania. It is intended that the provisions of these rules should apply to the construction or reconstruction of roads and streets and major or ordinary repairs to roads and streets. The rules will also encourage municipalities to improve the safety of existing pedestrian crossings in the coming years. The approved rules set requirements for pedestrian crossings equipped on state roads can also be applied to local roads and streets maintained by municipalities. The rules establish the general conditions for the installation of pedestrian crossings and the requirements for engineering measures to ensure safe traffic. They are obligatory for newly constructed or reconstructed pedestrian crossings on state roads, recommended for previously installed pedestrian crossings on all roads (streets) of local importance. Municipalities reconstruct dangerous pedestrian crossings in accordance with the terms and conditions of the rules in order to improve the level of safe traffic for hazardous pedestrian crossings and to ensure pedestrian safety (Fig. 13). The rules for the installation of pedestrian crossings have been developed,

Fig. 13 Examples of reconstructed pedestrian crossings in Lithuanian cities

taking into account the acceptable practices of foreign countries. The rules are characterized by the fact that, depending on the traffic intensity of pedestrians and cars, they clearly indicate when:

- Engineered traffic safety measures are installed for the safe crossing of the road (street)
- pedestrian crossings are installed
- Traffic light-controlled pedestrian crossings are installed
- Underground pedestrian crossings or pedestrian crossings above the road (street) are installed

The rules are designed to maximize pedestrian safety on the roads (streets). As an example, no pedestrian crossings can be on the roads (streets) where driving speed is above 50 km/h. Road design in those sections should be changed or pedestrian crossing removed. The rules also set visibility requirements for pedestrian crossings to be installed so that both pedestrians and drivers can notice each other in due time. The indicated engineering traffic safety measures are applied together with pedestrian crossings.

In 2018, the Lithuanian Road Administration (LRA) under the Ministry of Transport and Communications conducted a study that found that as many as 1,721 pedestrian crossings from 1,949 on national state roads were unsafe (LRA 2018). It is estimated that almost 95% of pedestrian crossings are not illuminated by directional lighting, 29% crossings have no raised islands or dividing sections, thereby requiring pedestrians to cross a driveway wider than 8.5 m. Almost 20% crossings have no sidewalks, pedestrian and (or) bicycle paths, 18% of the crossings have no lighting at all, and adequate visibility is not ensured in them. More than 10% of crossings have no raised islands or dividing sections, although pedestrians have to cross more than two traffic lanes. The majority of such pedestrian crossings are being reconstructed, while the remaining part, where the speed limit is higher than 50 km/h and in other urban areas, will be eliminated.

Several priorities are set to attain ambitious road crashes reduction tasks in Lithuania, and one of them is modern information technologies. The objective of the priorities is to improve the process of collecting and presenting traffic data and implementing and developing Intelligent Transport Systems (ITS) in road infrastructure and vehicles (Jarašūnienė and Batarlienė 2020). After the deployment of the intelligent transport systems, Lithuania moved closer to the Western European countries in terms of the level of information traffic systems. Now road users, when planning their trips (and on the road), can quickly obtain traffic information or information on weather conditions and road surface conditions (Fig. 14), road repairs, their duration and detours, natural traffic restrictions, dangerous obstacles, and traffic disruptions (LRA 2015).

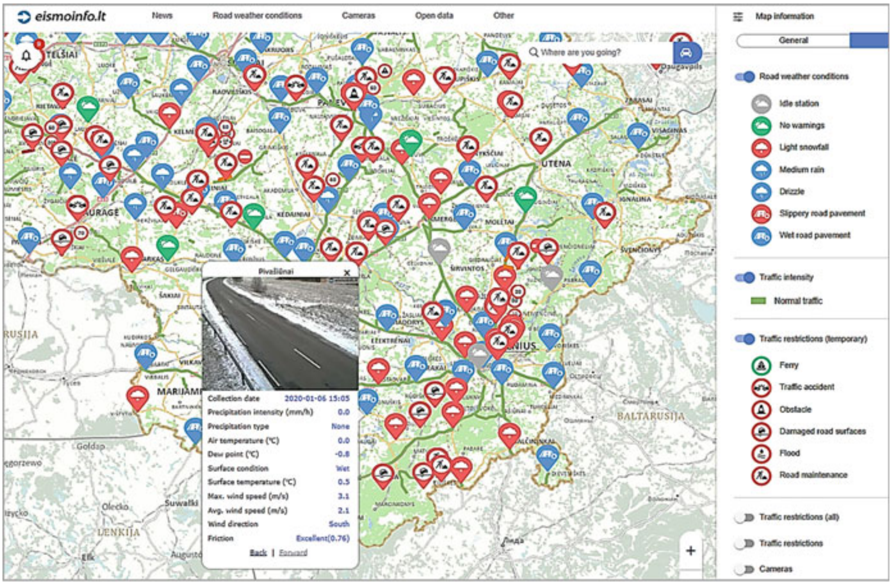

Fig. 14 Image from the website, providing drivers with instant information on the state of the country's roads, meteorological conditions, repairs, etc. (http://eismoinfo.lt)

Despite the country's progress, there are also difficulties or delays in the work. The existing trans-European transport network infrastructure in Lithuania does not meet some of the requirements: lack of efficient interconnections, unresolved some of the bottlenecks, incomplete adaptation of intelligent transport systems ITS, the current state of infrastructure is unable to meet the increasing road safety, and environmental requirements (Government of the Republic of Lithuania 2013). These shortcomings hinder the smooth and safe mobility of passengers and freight. Inefficient interconnection between different modes of transport and between the main and general transport network elements does not ensure sufficient interoperability between different transport modes. This reduces the cost of passenger and freight transport and increases the flexibility of transport services, but also contributes to reducing the negative environmental impact of the transport system.

Third Priority: Safer Vehicles

The average age of the country's passenger vehicle fleet in 2018 was as high as 14.4 years, while new cars registered for the first time made up only 16%, although this rate started to increase in 2019 (Source: VĮ Regitra). The big age of the vehicle fleet means that only every second passenger vehicle passes the mandatory roadworthiness test from the first attempt (Source: Lithuanian Association of Technical Inspection Companies Transeksta). Most of the deficiencies include unadjusted dipped-beam headlamps (13.3%) and malfunctioning suspension elements (11.9%). It is found that vehicle defects relating to lighting and signaling equipment have a weaker correlation with accident rates (coefficient of correlation 0.23) than brake failure (0.49) or tire failure (0.38) (Bureika et al. 2012). However, taking into account the natural conditions of Lithuania when the dark time predominates in October to March, the importance of vehicle lighting equipment for road safety is much higher. The target is that the assurance of good technical condition of the vehicle must be the responsibility of each driver.

Given the age of the country's fleet of vehicles and the prevailing technical shortcomings, it is crucial **to ensure that only safe means of transport are used on the roads of the country and to reduce the number of crashes caused by technically unsound vehicles**.

The detailed measures for achieving these objectives, the expected effects and evaluation indicators are presented in Table 9.

After the implementation of safe vehicles for road traffic in the long term it is expected that in Lithuania by 2030:

- The proportion of noncompliant vehicles banned from operating will be reduced to 1% (from 5% in 2016)
- The average age of passenger cars registered in Lithuania will decrease to 10 years (from 15 in 2016)

Table 9 Implementation of safe vehicles on the roads. (Adapted from National Road... 2020)

Measure	Expected effect	Assessment indicator
More efficient law enforcement of the conformity of road vehicles with the specified technical requirements		
A more thorough inspection of requirements of vehicles should be applied during roadworthiness tests where the deficiencies of vehicles pose an immediate and imminent danger to road safety or which have a negative impact on the environment during a roadworthiness test	As vehicle requirements change, deficiencies that pose a direct threat to road safety are more clearly identified; therefore, targeted inspections can more accurately identify deficiencies, and the equipment used will allow for a more reliable system performance checks	Vehicle requirements are tested using equipment and the latest technology
Aim to Reduce the average age of the passenger car fleet		
To prepare a study on cost-effective ways to promote the purchase of safer and greener cars	Measures will be selected to encourage the purchase of safer and greener vehicles	An implementation plan for the measures has been approved
State support for residents to purchase a newer vehicle and disposal of the old vehicle	Newer vehicles will be purchased and old unsafe and polluting vehicles will be discarded	Reduction of the age of the fleet of passenger cars to 10 years
Renewal of local (urban and suburban) public transport fleet with green vehicles	Local public transport will be safer and greener	Increase in the share of public transport travel compared to 2016, by 5%
Ensure that only safe vehicles are returned to traffic after road crashes		
Establishing precise requirements for safe vehicle operation and the restriction of the use of unsafe vehicles	The participation of unsafe vehicles in public traffic will be severely restricted	Reduced number of unsafe vehicles in public traffic

Newer cars on the country's roads mean not only their better technical condition, which correlates with the rates of accidents caused by vehicles state, but they also have more active safety systems (wheel-antilock braking, stability, automatic emergency braking, lane-keeping, blind zone monitoring, driver attention tracking) (Jarašūnienė and Batarlienė 2020). Newer vehicles also have advanced passive safety, reducing the impact of a road crash on the driver, passengers, and vulnerable road users. Although under normal driving conditions, active safety systems often do not give drivers too much confidence or the expected effect, their increasing use in the long term contributes to the overall improvement of safety and the positive assessment by drivers (Broughton and Baughan 2002; Reagan et al. 2018). From the current advanced driver assistance systems (ADAS), automotive manufacturers distinguish the automatic emergency braking system as most contributing to the reduction of accident rates. However, the reliability of these systems still depends to a large extent on the technology used (obstacle detection by radars or cameras), environmental conditions (road surface adhesion, foreign objects), and driving circumstances (driving speed and nature of the obstacle movement). Taking this into account, in Lithuania in 2018–2019, the research team of Vilnius Gediminas Technical University (VTGU) conducted research of new cars with the emergency braking system. Of the 51 vehicles tested (23 vehicles from different manufacturers), 24 vehicles driving at 30 km/h stopped on time before the stationary obstacle, 8 cars stopped incompletely, and the remaining 19 did not significantly reduce their speed. This result indicates that electronic braking assistants are still merely auxiliary steering systems and that drivers need to rely entirely on their driving skills and leave the operation of ADAS systems only for emergencies. A similar performance of the system, not exceeding 59% for the front-to-rear crash, was shown in a study carried out by the Insurance Institute for Highway Safety (Cicchino 2017).

Fourth Priority: More Efficient Rescue Assistance After a Road Crash

One has to admit that human errors cannot be avoided both by the road users or by specialists who are responsible for ensuring their safety. Therefore, even in the event of a road crash, it is imperative **to seek effective assistance from rescue teams**. Depending on the event, post-crash rescue teams in Lithuania consist of police, fire and rescue services, medical, and road maintenance personnel. Thanks to the Emergency Response Centre, which already operates in the country, the responsible call reaches rescue teams smoothly, and they can respond quickly and promptly to the call. Nonetheless, there are cases where emergency services have to perform extra tasks that are outside their scope of operation. For example, at night or in remote areas, police officers or rescuers have to clean the scene of the crash, and police officers are delayed by the owner of the vehicle or cargo that is not arriving or arriving late to the scene (KTTI 2017). Rescue services also require improved financial provision for rescue measures and materials. The detailed measures, expected effects, and evaluation indicators for achieving this objective are presented in Table 10.

Rail Transport and Road Traffic Safety

The European Union Railway Safety Report, published by the European Railway Agency in 2014 and presented to the European Commission, provides a significant threat to society posed by the railway system of the Republic of Lithuania as the highest among 28 Member States of the European Union. In the period 2010–2016, there were 180 major rail traffic crashes, with 129 persons killed and 61 seriously injured. The highest number of victims of rail crashes is bystanders (persons not entitled to be in a dangerous railway area), level crossing users (persons crossing the railway line by any means of transport or by foot on the railway crossing), and crossing users (persons crossing the railway line by foot at the level crossing). A minority of the victims are employees of railway companies (Fig. 15).

Table 10 Implementation of efficient rescue assistance. (Adapted from National Road. . . 2020)

Measure	Expected effect	Assessment indicator
Enhanced collaboration between rescue teams		
Number of joint exercises for rescue services	Following the implementation of the measure, the actions of the rescue services involved in the removal of crashes will be better coordinated	Different scenarios for the joint exercises of the fire brigade, ambulance, emergency response center, police every year
Improving the qualifications of rescue team specialists		
Additional practical driving training for rescue team drivers	After implementing this measure, rescue team drivers will continually improve the practical driving skills needed to perform their functions safely	Mandatory training of rescue crew drivers on reduced adhesion surfaces has been introduced
Interoperability of information systems used by emergency services, general assistance centre, police, and traffic management centre		
Accept e-call system calls	In the event of an accident, a signal will be sent immediately to the General Assistance Centre	The crash is reported to the medical personnel within 2 min after receiving a call through the e-call system
Improving the issue of driver health certificates, the authority issuing the driving licenses shall receive data electronically on the fitness to drive	There will be no possibility of acquiring a driving license without complying with the health requirements for drivers (health condition and psycho-physiological abilities must be appropriate for driving in the relevant category (s) of vehicles)	Information on the fitness of a person in terms of health and psycho-physiological abilities to drive a vehicle of the appropriate category (s) shall be transmitted electronically to the licensing authority, 100%
Transmission of electronic data to the licensing authority in the event of a change in the health condition and the person is unable to drive a motor vehicle	Failure of the driver to meet the prescribed medical requirements (i.e., health condition and psycho-physiological abilities to drive the relevant category (-ies) of vehicles) shall result in immediate restriction of the ability to drive, etc.	When a medical institution determines that a person's health condition and psycho-physiological abilities are unfit to drive a vehicle of the relevant category (s), the information shall be transferred to the the authority managing the driving license register electronically, 100%

The main types of violations which result in fatalities or injuries in road crashes are:

- Users of level crossings enter the level crossing under the prohibiting traffic lights when the barrier is lowered or starts to fall
- Bypass other vehicles that have stopped before the level crossing to pass the train
- Arbitrarily raise or circumvent a barrier

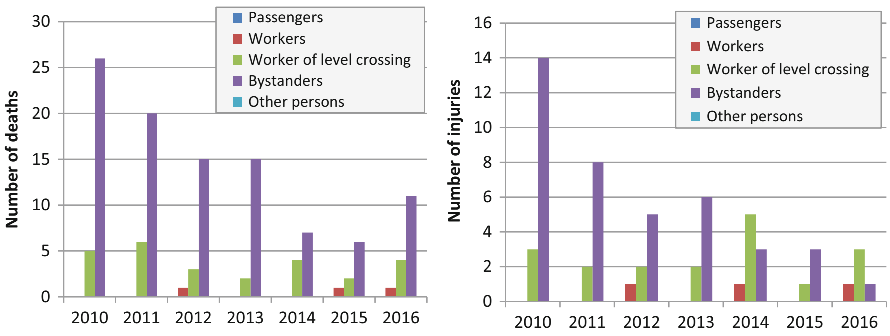

Fig. 15 Railway crashes in 2010–2016. (Source: Lithuanian Ministry of Transport and Communications)

- Enter the crossing area if there is an obstacle behind it
- Deliberately transports unprepared agricultural, road, construction, and other machinery through the crossing

These violations are due to the following reasons:

- Vehicle breakdowns
- Poor visibility due to poor weather conditions and (or) poorly designed road infrastructure
- No sense of responsibility for one's actions (no perception of the level of danger, a habit of breaking traffic rules at level crossings, not being expected to be punished)
- Lack of education and effective information campaign on safe behavior at a level crossing
- Drivers rush/late
- Users of level crossings can physically violate the road traffic regulations (lack of proper railway infrastructure or inconvenience to use it)
- Drivers are tired of waiting at the crossing
- Persons crossing the railway are intoxicated with alcohol or other psychoactive substances
- Because of convenience and time-saving, and due to poor road infrastructure, pedestrians cross the railway at unsuitable locations

The crossing of motorways with the infrastructure of other land vehicles raises **an important need for safer level crossings and safer rail infrastructure**. In some cases, a level crossing is not possible without direct interaction with road vehicles or pedestrians (one level) and a huge difference in mass and speed often lead to the tragic consequences of accidents. As some part of rail accidents is related to roads, the causes and suggested measures are analyzed in the context of road traffic safety. Therefore the main measures to increase safety are: automatic level crossing violation control, reconstruction of level crossings and railway stations, an update of rules for installation and use of level crossings with basic safety standards, implementation of means of information, education on safe behavior in the dangerous railway area for different social groups, in-depth analysis of rail crashes involving road users. After the implementation of railway transport safety measures in the long term, Lithuania is expected to have zero fatalities in the collisions at level crossings in Lithuania by 2030.

Some pedestrians (especially children) are not sufficiently familiar with the basic rules and regulations applicable to road and rail traffic – do not recognize road signs, ignore traffic lights, believing that they are intended for cars. Others are aware of wrongdoing but are not aware of the potential consequences of their behavior that endanger the health and well-being of themselves and others. Other persons (railway employees or suicides) injured or killed in rail crashes are not related to a road safety system.

Conclusions

Three road safety programs before current Vision Zero have been carried out in Lithuania since the country's independence in 1990. While all road safety programs were aimed at reducing road crashes, only the period of 2007–2011 registered significant achievements in the reduction (more than twice) of fatalities and injuries. Nevertheless, long-term problems of violation of traffic rules and safe driving principles, faulty road safety systems design and ignorant road user behavior remained. A new road safety strategy with the vision to achieve zero fatalities was introduced emphasizing the improvement of road infrastructure, stricter sanctions for offenders of traffic rules, responsibilities and cooperation between institutions and organizations in activities, law enforcement, and education. Specific measures are detailed and targeted at speeding, intoxicated road users, unauthorized use of mobile devices while driving, inappropriate use of reflective elements, seat belt and child seat use, as well as the development of road infrastructure including advanced technologies and its management, implementation of safe vehicles, more efficient rescue assistance after a road crash, and safer level crossings and rail infrastructure. It is expected that purposeful and consistent work will lead to a reduction of 50% in road transport fatalities by 2030 compared to 2018.

The Lithuanian government, civil society and other public, private, academic, and social institutions are committed toward Vision Zero by doing as much as possible in the effort of improving the safety situation in our roads as soon as possible.

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Vision Zero in EU Policy: An NGO Perspective

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Contents

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Abstract

This chapter documents the roots of Vision Zero in EU road safety policymaking and is written from the perspective of the European Transport Safety Council, an NGO that has been deeply engaged in the topic for more than 25 years, from the very beginning of EU road safety policy in the mid-1980s to its first adoption in 2011 and on to the present day. The chapter shows that the Vision Zero approach is now integrated into the new EU road safety strategy. The presence of elements of Vision Zero during the different timeframes is presented. These include ethics, shared responsibility, the philosophy of building a system which allows for error and, finally, creating a mechanism for change. The current EU road safety strategy, which adopts these elements, is reviewed in more detail. More recent implementation is illustrated by references to Vision Zero within two recent, important pieces of road safety legislation, on infrastructure and vehicle safety.

This chapter is written by ETSC and based on the organization's interest and key role in the discussions. It refers to EU official documents going back to 1984, ETSC's own reports and the institutional experience of ETSC and of the two authors. Despite every effort being made to be as objective as possible, the chapter is written from the perspectives of two active participants in the discussions and is therefore not a truly independent account. However, it is hoped that the material presented is useful nonetheless.

Keywords

European Union · Road Safety · Vision Zero · European Parliament · European Transport Safety Council · Target · Strategy

Introduction

This chapter documents the roots of Vision Zero in EU road safety policymaking, from the very beginning of EU road safety policy in the mid-1980s to its first adoption in 2011 and on to the present day. The chapter shows that the Vision Zero approach is now integrated into the new EU road safety strategy. The presence of elements of Vision Zero during the different timeframes is presented. These include ethics, shared responsibility, the philosophy of building a system which allows for error and, finally, creating a mechanism for change. The current EU road safety strategy, which adopts these elements, is reviewed in more detail. More recent implementation is illustrated by references to Vision Zero within two recent, important pieces of road safety legislation, on infrastructure and vehicle safety.

Written by ETSC, thus, the perspective is based on EU official documents and ETSC's own published documents from 1984 which predate the personal experiences of the two ETSC authors, to present day. As this is written by authors who were in part influencing the process of adopting and implementing Vision Zero in Europe, this impacts on the views expressed in the chapter.

This chapter will start with a definition of Vision Zero; this section of this chapter is a summarized extract of a text entitled *Vision Zero*: *from Concept to Action* published by the Swedish Road Administration in 1999 and cited in the important report by the OECD/ITF entitled "Towards Zero: Ambitious Road Safety Targets and the Safe System Approach" (Swedish Road Administration in OECD/ITF (2008)). The aim is to frame the entire chapter on EU policy with a clear definition.

Sweden's Vision Zero: Not Just Zero Fatalities and Zero Serious Injuries

Recognizing that the road transport system is one of the most dangerous technical systems humanity has created, the elected members of the Swedish Parliament in autumn 1997 adopted a new traffic safety policy, known as "Vision Zero." This new policy expresses a new long-term goal and is based on four elements: *ethics*, *responsibility*, *a philosophy of safety* and *creating mechanisms for change* (Swedish Road Administration in OECD/ITF (2008)).

Human life and health are paramount ethical considerations. According to Vision Zero, life and health should not be allowed to be traded off against the benefits of the road transport system, such as mobility. Rather than placing responsibility for crashes and injuries on the individual road user, the responsibility under Vision Zero is shared between the providers of the system and the road users. The road user remains responsible for following basic rules, such as obeying speed limits and not driving while under the influence of alcohol. The system designers and enforcers – such as those providing the road infrastructure, the car-making industry and the police – are responsible for the functioning of the system. In the event that road users make errors or even fail to follow the rules, the responsibility reverts to the system designers to ensure that these failings do not result in death or serious injuries.

Vision Zero Philosophy

The Vision Zero philosophy is based on two premises: human beings make errors, and there is a critical human body limit beyond which survival and recovery from an injury are not possible. The safety philosophy recognizes that a system that combines human beings with fast-moving, heavy machines will be very unstable, and a human tragedy can occur if a driver loses control for just a fraction of a second.

The road transport system should therefore be able to take account of human failings and absorb errors in such a way as to avoid deaths and serious injuries. Collisions and minor injuries, on the other hand, need to be accepted. The chain of events that leads to a death or disability must be broken, and in a way, that is sustainable, so that over the longer time period loss of health is eliminated. The limiting factor of this system is the human body's tolerance to mechanical force. The components of the road transport system – including road infrastructure, vehicles and systems of restraint – must therefore be designed in such a way that they are linked to each other. The amount of energy in the system must be kept below critical physical limits, by ensuring that speed is restricted.

Driving Mechanisms for Change

While society as a whole benefits from a safe road transport system in economic terms, Vision Zero relates to the citizen as an individual and his or her right to survive in a complex system. It is therefore the demand from the citizen for survival and health that is the main driving force. In Vision Zero, the providers and enforcers of the road transport system are responsible to citizens and must guarantee their safety in the long term. In so doing, they are necessarily required to cooperate with each other, because simply looking after their own individual components will not produce a safe system.

While Vision Zero does not say that the ambitions on road safety historically have been wrong, the actions that would have to be taken are partly different. The main differences probably can be found within how safety is being promoted; there are also some innovations that will come out as a result of the vision, especially in infrastructure and speed management.

This chapter of the handbook will identify when the different elements of Vision Zero, as defined by Sweden and listed below, started to appear in EU road safety policy and give some examples of Vision Zero philosophy and its practical application.

The Four Key Elements of Vision Zero

1. Ethics: no trade-off of safety for mobility.
2. Responsibility: shared between road users, authorities and industry.
3. Philosophy of safety: system absorbs errors.
4. Creating mechanisms for change: targets, strategy, governance and adopting measures. (Swedish Road Administration in OECD/ITF (2008))

EU Decision-Making in Road Safety

This first section of this chapter provides a brief overview of the European Union's policymaking, legislative and regulatory procedures. Right from the start in the mid-1980s, the EU's decision-makers have had a variety of measures at their disposal to improve road safety and start to realize Vision Zero. This short explanation of the procedure is most relevant in understanding how the EU can use the "mechanism for change" element of Vision Zero. EU procedures have evolved since the 1980s. This brief general overview gives an outline of present-day EU decision-making, which builds upon structures and procedures, mostly already in place in the 1980s, when EU road safety policy started to be formulated.

Policymaking: A Cyclical Process

The EU's policymaking process can best be visualized as a cycle of stages. Legislation finds its origins in commitments made in political declarations or strategies, such as the ones documented in this chapter, or in requirements in existing legislation or lastly in the evaluation of existing measures. After the preparation stage, decision-making stage and implementation stage of the measure, it is evaluated, following which the results may feed into a revision that marks the start of a new cycle.

While the concept of the policymaking process as a cycle will help visualize and understand the sections below, it is important to keep in mind that this concept is a simplification of reality. For example, the cycle's stages might overlap. Another example would be a change of political leadership with the beginning of a new mandate, with a change of political leadership in the European Commission and in the European Parliament following elections which may result in changes to the policy direction.

The Treaty on the Functioning of the European Union (TFEU)

The Treaty on the Functioning of the European Union (TFEU) updated last in 2009, originally in place as of 1958, together with the 1992 Treaty on the European Union (TEU), is the constitutional basis of the European Union (European Union 2012). It lays down the structure and powers of the EU institutions and sets out the law-making processes, such as the ordinary legislative procedure.

Moreover, it sets out the EU's competences for different policy areas. There are three main types of competences: exclusive competences, shared competences and supporting competences. For policy areas in the exclusive competences, the EU has the sole right to legislate – for example, in the case of the customs union.

For policy areas in the shared competences, the EU has the right to legislate; however, Member States may do so as well on issues where the EU has not legislated. Transport and the internal market are policy areas where the EU shares its competencies with Member States.

Every legislative measure taken by the EU needs to have a legal basis in the TFEU. Most road safety measures have their legal basis in Article 91 TFEU, which allows the EU to adopt measures on the implementation of the common transport policy and which explicitly mentions the improvement of transport safety.

However, this is not always the case. For example, the legal basis for the General Safety Regulation (GSR) is Article 114 TFEU, which allows the EU to adopt measures aimed at the functioning of the internal market. Therefore, although the GSR improves the safety of vehicles, road safety itself is not the legal basis. Instead, the first recital of the GSR explains that it lays down the administrative provisions and technical requirements for the type approval of motor vehicles "with a view to ensuring the proper functioning of the internal market" (European Union 2012). Only as a second point is the level of safety and environmental performance mentioned in the legal text.

The European Union's Legal Acts

The TFEU also sets out the EU's legal acts. Regulations and directives are the two main legal acts used by the EU. A regulation is a binding EU law that applies directly all across the EU as of its date of entry into force. A directive, on the other hand, is a binding EU law that sets out goals, which every Member State subsequently has to transpose into their own national legislation. The Member States have the freedom to decide how they transpose the directive's goals into their own laws in order to achieve these goals.

Strategies, Work Programs, Conclusions and Own-Initiative Reports

Nowadays, the European Commission usually sets out its envisaged actions in strategies and work programs, usually per work area or theme including, for example, the most recent EU road safety strategy setting out its own commitment to Vision Zero, as presented in the previous section. Although non-binding and non-legal, these documents provide an outline of the measures and actions the European Commission intends to take in the upcoming few years in order to address certain problems and issues. The documents therefore reflect and give an insight into the policies the European Commission pursues.

Similarly, the Council may adopt "conclusions" on topics to express its vision for an area of EU policy, whereas the European Parliament may adopt own-initiative reports for the same purpose. Both conclusions and own-initiative reports may call on the European Commission to come forward with legislation or regulation on certain topics. They have frequently done so since the mid-1980s in the area of road safety in general and specifically have called, for example, for the adoption of Vision Zero since the late 1990s as illustrated in this chapter.

The Ordinary Legislative Procedure

The main legislative procedure used in the European Union's decision-making process is the ordinary legislative procedure (OLP), previously also known as the co-decision procedure, and is used for the adoption of regulations and directives (European Union 2012).

The European Commission has the exclusive right to initiate legislation, meaning that only the European Commission is allowed to present a legislative proposal. It can therefore already decide on which policy options are included in the legislative proposal. Once the European Commission presents the proposal, the European Parliament and the Council will separately establish their informal positions on the proposal. They will then together discuss the final text of the legislative act during informal negotiations known as "trilogue negotiations." If an agreement is reached between the two co-legislators, the act will then be formally adopted by both institutions and subsequently published as a new law.

Implementing Measures

While a new regulation or directive sets out the main requirements, the technical and administrative details of those requirements are subsequently set out in delegated and implementing acts prepared by the European Commission. The importance of delegated and implementing acts should not be underestimated, as their technical requirements will dictate the required minimum (e.g., safety) performance that is expected. In some policy areas, the European Union wishes to harmonize technical standards at a global level, usually to facilitate trade. It may therefore be the case that the legislation or implementing acts refer directly to these international standards or contain the same requirements.

Roots of Vision Zero in Europe 1984–2000

With this EU policymaking overview in mind, this chapter will now track the development of EU road safety policy with a focus on the roots of Vision Zero.

In 2018, 26,000 people died on European roads. But in the 1980s and early 1990s, when there were fewer vehicles, road transport was much more lethal than today. Sixty thousand died on European roads in 1980; by 1990, the figure was still more than 50,000 (ETSC 2019d).

Road collisions clearly represented a major challenge to European public health and the economy. The Council of Transport Ministers of Member States gave the first real political commitment to road safety in 1984. In 1986, there were some activities within the first ever framework of the European Road Safety Year. The late 1980s saw the first attempts by the European Commission to develop EU legislation on road safety. The European Commission tested the waters for support for a directive to introduce a common low-level drink-driving limit across the EU. In a similar vein, they also considered adopting a directive on "appropriate speed limits" in January 1987 for road safety, pollution and fuel efficiency reasons. Both attempts were not supported by enough Member States. A first package of legislative measures was put forward in 1989 by the European Commission. This was followed by the publication of the "Gerondeau" Report on road safety, prepared by a group of high-level experts (European Commission 1991). One of the first and important pieces of EU road safety legislation to be adopted was the introduction of the legal obligation to wear a seat belt in 1991 (European Council 1991).

The first formal recognition of the need to take more holistic action on road safety at European level came with the Treaty of Maastricht, signed on 7 February 1992 by the then twelve members of the European communities. The treaty, for the first time, made improving transport safety a formal competence of the European institutions (European Union 1997). The White Paper on the Future Development of the Common Transport Policy (European Commission 1992) contained a commitment to adopt a Community Road Safety Action Program proposing an integrated approach based on qualitative targets and the identification of priorities.

The first EU road safety action plan was adopted in 1993, which effectively marks the beginning of an EU policy on road safety, thus indicating the increased political importance attached to the topic. The Transport Council also adopted council conclusions on the new action plan. In the same year, the European Transport Safety Council (ETSC) was founded. It was to be an independent, member-based organization established as a Belgian international non-profit organization. The stage was set for EU action on road safety. Thus, the development of a succession of road safety plans prepared by the European Commission with input from the European Parliament and Council followed, all under the watchful and critical eye of civil society organizations including ETSC. This also paved the way for the eventual adoption of Vision Zero in 2011 nearly 20 years after the first EU Road Safety Action Program.

Following the adoption by the EC of the new road safety plan in 1993, the European Parliament welcomed the plan with a resolution in 1994. In the area of target setting, note that an increasing number of Member States are setting “percentages by which they aim to reduce the number of deaths and injuries on the roads” adding that the European Parliament wanted “to see a 20% reduction in the number of road deaths by the year 2000” (European Parliament 1994).

Early on, ETSC also recognized the need for strategic road safety targets and strategies. An ETSC report, “A Strategic Road Safety Plan for the European Union,” was crucial in laying out proposals for the second official road safety program which also came later in 1997 (ETSC 1997b). In the report, ETSC floated the idea of the EU adopting Vision Zero the same year as Sweden: “It has been suggested that it is unethical to accept anything other than a zero casualty target. While the long-term objective can only be the reduction of all fatalities known as the ‘zero vision,’ the setting of numerical targets acknowledges that this will not happen overnight and that good progress can be achieved by a step-by-step approach.” The 1997 EU Action Program developed by the European Commission, with input from the European Parliament and the Council, paved the way for European road safety targets and eventual adoption of Vision Zero, first adopted by the EU in 2001 and renewed in 2011 and 2018.

As mentioned previously, elected members of the Swedish Parliament adopted a new traffic safety policy, known as “Vision Zero” in 1997. Shortly after, Sweden reduced speed limits in densely populated areas, changed the education system for drivers and introduced new standards for work-related road safety and public procurement. ETSC was monitoring the developments in Sweden and in its 1997 annual overview entitled "Visions, Targets and Strategies" reported that "While no time goal is set to achieve the long-term objective of Vision Zero, ETSC believes that the principles laid down in this exciting new strategy indicate that Sweden clearly continues to mean business in its road safety work" (ETSC 1997b).

The same 1997 ETSC annual overview also reported on a debate of the EU ministers at the Council on the Second Road Safety Action Program stating that "It is clear that Vision Zero for EU road safety work as a whole is a long way off. With the EU transport Council of Ministers failing to countenance even a short-term casualty reduction target to demonstrate that political will for effective actions exists, despite the encouragement given by the Dutch EU Presidency" (ETSC 1997b).

In February 1998, the European Parliament adopted a report on the communication from the Commission, "Promoting Road Safety in the EU: The Program for 1997–2001." There was no mention of Vision Zero. However, the MEPs gave their strong support for a target: "The EU should establish a numerical target to reduce the annual deaths from the current level of 45 000 to a maximum of 25,000 by the year 2010." Furthermore, "considers that such a target would provide a stimulus to all parties involved in the promotion and improvement of road safety and would contribute to mobilizing their efforts further."

Setting numerical targets to reduce road deaths and serious injuries is an interim step in realizing the long-term Vision Zero (Swedish Road Administration in OECD/ITF (2008)).

In sum, the described key elements of Vision Zero were to be found in the early days of EU road safety policy development. ETSC and others were following the adoption of Vision Zero in Sweden with interest. So point 1 on "ethics" was starting to attract interest. The first steps of "creating mechanisms for change" were taking root. The European Parliament and ETSC were calling for the setting of a numerical target and political will by decision-makers. There were the first efforts at adopting EU legislation on road safety.

2001–2010: The First Numerical Target to Reduce Road Deaths – Still No Vision Zero

Toward the end of the Second Road Safety Action Program in the year 2000, the Commission published a communication in the form of a progress report on fulfilling the actions of the last program (European Commission 2000). The Council adopted a resolution in 2000 also supporting the "wisdom of setting a target figure for a reduction in the total number of victims on the roads of the Community" (European Council Resolution 2000). This was significant, as the European Commission had the support of the Council to proceed and adopt a target. ETSC continued to call for "a proposal for an EU numerical target to reduce deaths to a maximum of 25,000 annually by the year 2010" (ETSC 2000). Finally, after years of work, the first EU target to reduce road deaths was adopted by the European Commission in 2001 in its White Paper. "In the battle for road safety, the European Union needs to set itself an ambitious goal to reduce the number of people killed between 2000 and 2010. The Commission plans to marshal efforts around the target of halving the number of road deaths over that period" (European Commission 2001). Thus by 2001, one of the key framework elements of Vision Zero, "creating mechanisms for change," was put in place: Europe's first target to reduce road deaths.

ETSC welcomed the new road safety target but with a note of caution: "ETSC welcomes the fact that the White Paper sets, for the first time, a numerical aspirational target to cut road deaths" (ETSC 2001). ETSC strongly supported "the Commission's intention to set an ambitious goal, but notes that the targeted level of safety performance is more challenging than has ever been achieved by even the best performing Member States or proposed by the European Parliament and safety organisations" (ETSC 2001).

The Third Action Program in 2003 and ETSC's Response

The EU's Third Road Safety Action Programme was adopted in 2003 and was a much more comprehensive document than previous ones, encompassing a total of 62 measures. It reiterated the target set out in the Transport White Paper, namely, to cut EU road deaths by 50% between 2000 and 2010. The program explained that targets can mobilize action and that "It is broadly accepted that targeted road safety programs are more beneficial in terms of effectiveness of action, the rational use of public resources and reductions in the number of people killed and injured than non-targeted programmes" (European Commission 2003). The European Commission also stressed that the target needed to be monitored closely and reviewed especially with the upcoming enlargement of the EU. Performance indicators could also be used in a next stage, although their adoption finally came in 2019 for use in the new 2021–2030 program.

With the adoption of the Third Action Programme in 2003, one of the key framework elements of Vision Zero, "creating mechanisms for change," was put in place including a strategy, a target and some elements of European road safety governance as well as lots of measures.

The European Commission's 2003 program mentioned the Swedish Vision Zero in passing when elaborating possible action in the area of public procurement: "In 1997 Sweden adopted a road safety program to combine the efforts of the State, the regions, the towns, the private sector and individuals to aim to achieve zero death and serious injuries on the road" (European Commission 2003). But the adoption of Vision Zero as a guiding road safety philosophy for Europe was still a way off.

The 2003 EU Action Program was entitled "Halving the Number of Road Accident Victims in the European Union by 2010: A Shared Responsibility," thus clearly including the second key element of Vision Zero on sharing responsibility amongst road users and the authorities (European Commission 2003). The strategy also called for "a shift in thinking among both those with responsibility for the traffic system and users about how people use the roads and how they can be used safely" (European Commission 2003).

The third element of Vision Zero – "philosophy of safety: a system absorbs errors" – was also included: "Since human beings frequently and inevitably make mistakes, the system of infrastructure, vehicles and drivers should be gradually adapted to protect users more effectively against their own shortcomings" (European Commission 2003), citing influence from "the approach in other modes of transport and safety at work" (European Commission 2003).

ETSC's response papers to the new European Commission program included a subtitle of "A Strategy without a Bite?," repeating the concern about the ambitious target (ETSC 2003). ETSC called for the need for more action at EU level and also for the new EU member states set to join the EU in order to reach the new target (ETSC 2003). ETSC also raised a concern that there was no vision included in the action programme. ETSC said that a targeted road safety programme should be accompanied by a vision, such as the Vision Zero in Sweden (ETSC 2003). Specifically, it said that motivating change needs a common vision. "To achieve the necessary shift in the mind-set of decision-makers and stakeholders, the vision needs to be further-reaching and medium to long-term, looking beyond what is immediately achievable" (ETSC 2003).

2004: The European Parliament Proposes to Endorse Vision Zero for the First Time

The European Parliament adopted its resolution on road safety in 2004 as a response to the new EC Action Program, welcoming the new EU target to reduce road deaths (European Parliament 2004). The report also called "on the Commission to develop a long-term road safety concept, going beyond 2010 and describing the required steps leading to the avoidance of all fatalities and serious injuries caused by road accidents ('zero vision')" (European Parliament 2004). In the explanatory statement, it added that "the very long-term objective is the Nordic Vision Zero" (European Parliament 2004).

The Verona Process: Commitment of the Transport Council on Road Safety 2003–2006

It was during this time also that transport ministers met more regularly to discuss road safety. The first occasion was on the initiative of the Italian EU Presidency and hosted by the mayor of Verona, who was very keen to see more action on road safety. EU transport ministers confirmed the urgent need for action on road safety and proposed a number of measures. In the first ministerial declaration from 2003, ministers stated that "the huge amount of human victims on the roads is too high a price and that, the situation being such, the eradication of this scourge is a top priority on their political agenda" (European Council 2003).

Within this context, ETSC was aiming to capitalize on the political leadership shown by the Italian Presidency and others by suggesting the launch of the so-called

Verona Process (ETSC 2003a). ETSC's recommendation was to use the EU policymaking method of open coordination, which would lead to regular ministerial meetings on road safety.

This process had already been successfully applied in other sectors, for instance, in the "Lisbon Process" on economic development. ETSC argued that "this new process would serve primarily to create the political leadership needed for action on road safety through an annual review based on performance indicators" (ETSC 2003a). This didn't really catch on, but successive EU Presidency holders have continued to demonstrate their commitment to road safety to the present day, thus fulfilling some of the other elements of Vision Zero such as taking shared responsibility for road safety and supporting a 'mechanism for change.'

At the second meeting in December 2004, again hosted by Verona, European transport ministers formally adopted the conclusions from their second Verona meeting on road safety. In these conclusions, ministers again outlined priorities for enhancing road safety by improving road design, compliance with rules and vehicle safety (European Council 2004). As regards the funding of road safety work, ministers proposed the creation of a European road safety fund, drawing on a percentage of vehicle taxes, motorway tolls, insurance premiums or traffic fines.

Yet, "the Commission distanced itself from the Ministers' conclusions, stating it would act only in accordance with the right of initiative given to it by the treaties" according to ETSC's "Safety Monitor" (ETSC 2004b). In a declaration attached to the document, the Commission warned against "anticipatory effects" for measures which are difficult to implement, such as the "establishment of specific funds to finance measures to improve road safety" (as cited in ETSC 2004b). At this moment in the EU's road safety history, the European Commission was not in step with the level of political ambition demonstrated by the Council.

A third Verona meeting was held in November 2005. Transport ministers adopted conclusions in which they committed to promoting road safety policies in their respective countries, based notably on improving driver training, provisional driving licenses for young drivers and additional training for repeat offenders (as cited in ETSC 2005b). The conclusions also placed an emphasis on tougher sanctions. This was just ahead of an informal council on road safety hosted by the Austrian government under their EU Presidency in Bregenz in March 2006.

The focus of the meeting in Bregenz was on E-Safety with a practical demonstration on a track allowing ministers to try out vehicles fitted with new safety technologies. During the meeting, the European Commission presented the mid-term review of the Third Road Safety Action Program and as ETSC reported "took the Council's pulse" before preparing to present new legislation on topics such as cross-border enforcement and infrastructure in 2006 (ETSC 2005a). After this, the more regular council meetings dedicated to road safety had a hiatus. But elements of Vision Zero here were also starting to take root, shown by the political ambition of EU transport ministers to hold regular meetings with road safety as a focus.

ETSC PIN Program

It was within this context that ETSC launched its Road Safety Performance Index program (PIN). Since 2006, the Road Safety Performance Index program (PIN) has presented an annual award to the European country making the best progress in reducing road deaths. The annual PIN ranking of progress has inspired many poor performing countries to up their game. The PIN is a policy tool to help EU Member States improve road safety. By comparing Member States' performance, it serves to identify and promote best practice in Europe and bring about the kind of political leadership that is needed to create a road transport system that maximizes safety.

The PIN program covers all relevant areas of road safety including road user behavior, infrastructure and vehicles, as well as road safety policymaking more generally. National research organizations and independent researchers from 32 countries participate in the programme and ensure that any assessment carried out within the program is based on scientific evidence and is effectively communicated to European road safety policymakers.

Since the beginning of the program, cross-national comparisons have addressed a wide range of road safety themes and indicators. The PIN program includes a number of Vision Zero's key elements. The ethics of not having a trade-off of safety for mobility, supporting the creation of a system which absorbs errors and sharing responsibility between road users, authorities and industry are integrated into their annual reports and data-led reports, as is element four on "creating mechanisms for change" tracking country's developments and adoptions of targets, strategy and governance.

One of the later reports looking at this aspect was the "Road Safety Management" flash report published in 2012 (ETSC 2012). It presented a snapshot of the Road Safety Management frameworks in terms of key elements inspired by best practice and innovative experience in Member States. The PIN report stressed that "systematic and strategic thinking, complemented by actions on the lines recommended are vital for the sustained medium- and longer-term reductions in death and injury on the roads" (ETSC 2012). The overview was based on questions linked to the ETSC publication from 2006: "A methodological approach to national road safety policies" (ETSC 2006a).

2006: Mid-term Review of the Transport White Paper and the Fourth Road Safety Action Program

The next significant milestones were the mid-term reviews of the Transport White Paper and the Third Road Safety Action Program in 2006. ETSC repeated its previous call for the adoption of a road safety vision: "A prerequisite for effective action to reduce death and injury in traffic collisions radically is a strongly felt and lasting motivation for change which is sufficient to root out and overcome deep-seated tolerance of disproportionate numbers of people being killed or injured on the roads" (ETSC 2006b). Adding that, "one way of generating and communicating such a motivation for change is by promoting an inspiring vision of safer road use" (ETSC 2006b). The mid-term review of the Transport White Paper just reaffirmed the new target and created an annual road safety day (European Commission 2006a).

The European Commission's mid-term review of the Road Safety Action Programme listed the actions taken and traced the reduction trends. Some elements of the "Vision Zero" approach such as that of the 'system absorbing the errors' found their ways into the thinking. For example, under the vehicle section, "all road users are liable to make mistakes. Given the potential seriousness of these mistakes, we must limit their consequences (passive safety) or prevent them from occurring in the first place (active safety)" (European Commission 2006b), concluding that "faster progress is being made than in the past, but it is patchy and there is still a lot of room for further improvement" (European Commission 2006b). Emphasis was put on the newly adopted concept of "shared responsibility." another important element of Vision Zero.

ETSC's 2000 response urged for renewed action in delivering stalled legislative priorities and demanding a tighter interpretation of "sharing responsibility" (ETSC 2006b). ETSC also stressed that "More than sharing responsibility, Member States, the European Commission and the automotive industry should 'take' their responsibilities. The development of guidelines on implementing best practice by Member States should not replace the need for an EU directive on any given matter, but should instead represent a step toward concise legislation at EU level" (ETSC 2006b).

In 2006, the European Parliament repeated their calls for the adoption of Vision Zero that had first been mentioned in 2004. In their contribution to the mid-term review of the Road Safety Action Program in 2007, MEPs called for "the Commission to develop a long-term road safety strategy beyond 2010 and setting out the steps required for the avoidance of all fatalities and serious injuries caused by road accidents ('Vision Zero')" (European Parliament 2007), thus continuing to mention Vision Zero by name as well as including many of the key elements such as the "mechanism for change" calling for a strategy with targets.

Ahead of the Adoption of Vision Zero in 2011

Following the mid-term reviews of both the Transport White Paper of 2001 and the Road Safety Action Program of 2003, ETSC then set about preparing the main input to the next Road Safety Action Program (ETSC 2008). ETSC's 2008 blueprint document recalled that every far-reaching road safety program needs a vision. Taking inspiration from Sweden but not Vision Zero, ETSC proposed that "every citizen has a fundamental right to, and responsibility for, road traffic safety. This right and responsibility serves to protect citizens from the loss of life and health caused by road traffic." This citizen's right was adopted in the Tylősand Declaration at the annual Swedish conference on traffic safety in 2007 (Tylősand Declaration 2007) and then adapted by ETSC, strengthening the responsibility component.

Ahead of the adoption of Vision Zero in the EU Transport White Paper, the European Parliament report provided input but did not repeat its call for a Vision Zero from 2006. However, MEPs did stress that road safety and the new target for 2020 should be an important part. Calling for “a 40 % reduction in the number of deaths of and serious injuries to active and passive road transport users, with this target being laid down in both the forthcoming White Paper on Transport and the new Road Safety Action Programme” (European Parliament 2010).

Adoption of the Third Road Safety Action Program in 2010

ETSC was very critical of the adoption of the Third Road Safety Action Program which came in 2010, just ahead of the landmark Transport White Paper which finally adopted Vision Zero (ETSC 2010), mainly because of the dilution of the European Commission’s previously expressed ambition and what it viewed as a downgrading of road safety as a priority for EU transport policy.

Moreover, ETSC did not yet know what was just around the corner, i.e., the EU’s adoption of Vision Zero. ETSC wrote that the “‘Towards a European Road Safety Area: policy orientations on road safety 2011-2020’ include some elements of an Action Programme, yet its scope, structure and name are very different from the three previous European Road Safety Action Programm” (ETSC 2010), although a new target to halve road deaths was set for 2020.

ETSC said that the decision of the European Commission to adopt “policy orientations” with a weak set of objectives and actions instead of a new far-reaching European Road Safety Action Program called seriously into question the chances of reaching the target (ETSC 2010). Moreover, the road safety community had hoped for a new EU 10-year action program providing a vision, priorities and a detailed road map against which performance could be measured and delivery made accountable. ETSC concluded that “the adopted Communication falls short of these expectations” (ETSC 2010). In terms of a vision, there was no clearly defined vision in the document, only “principles” (ETSC 2010).

The 2010 EC Action Plan stated that “Road Safety policy has to put citizens at the heart of its action: it has to encourage them to take primary responsibility for their safety and the safety of others. The Road Safety Policy aims at raising the level of road safety, ensuring safe and clean mobility for citizens everywhere in Europe” (European Commission 2010).

These are principles, which ETSC also viewed with a critical eye. ETSC recognized “the important responsibilities of road users but believes that it is just as important for the traffic system to be adapted to their needs, errors and vulnerability. Putting the citizen at the heart of the action should not mean moving responsibilities from authorities to citizens, but emphasising the human role as a measure of EU policy actions.” Here, the European Commission’s new road safety program did not encompass one of the key elements of Vision Zero regarding sharing responsibility nor building a system which can absorb errors.

ETSC was also skeptical of the bold statement in the Road Safety Policy Orientations communication and what it said regarding new legislation that “with over a dozen legislative instruments on road safety, the EU acquis are essentially in place” (ETSC 2010). ETSC said that this revealed a disturbing complacency about the legislative foundation for action for the next decade (ETSC 2010). The European Commission stated that it “intends to give priority to monitoring the full and correct implementation of the EU road safety acquis by Member States” (European Commission 2010). ETSC argued that there was still a great deal that should still be done in the next decade in the field of EU legislation to improve road safety (ETSC 2010).

Another area of disappointment was that, although the European Commission included a new emphasis on serious injuries, it did not yet set a target (ETSC 2010). ETSC called for the swift adoption of a detailed road map, saying that its absence may result in the situation in which slower Member States hold back those already prepared to work with a standardized definition (ETSC 2010). ETSC was stressing that this process was bound to take time and that an interim target should be set in terms of countries’ existing definitions of serious injury (ETSC 2010).

Although the new program had some of the elements of Vision Zero, it was weak under the part on “creating mechanisms for change: targets, strategy, governance and adopting measures.” A strategy was there in parts including a target to reduce deaths, but not yet serious injuries, and the measures were much reduced, especially in light of the challenges to reach the new road death reduction target by 2020.

There was more EU action to come in 2011 with the adoption of the new Transport White Paper. In 2010, ETSC had said that the Commission “should consider the need to include a strong section in the white paper on road safety, reiterating there the new 2020 target to reduce road deaths by 50%” (ETSC 2010).

The Groundbreaking Adoption of Vision Zero in the 2011 Transport White Paper

With the background of the 2010 Road Safety Policy Orientations and ETSC’s critical input, the adoption of “Vision Zero” in the Transport White Paper the following year came as a surprise to the road safety community (European Commission 2011).

One of the ten goals for achieving a competitive and resource-efficient transport system was set as “By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020” (European Commission 2011).

Including a “Vision Zero” for road safety was recognized as a new and potentially groundbreaking visionary goal for 2050 by ETSC, complementing the “Road Safety Policy Orientations 2011–2020” target of halving road deaths by 2020 (ETSC 2011a).

ETSC congratulated the European Commission on this new long-term vision and welcomed the White Paper’s renewed commitment for an EU target to reduce road deaths by 50% by 2020 (ETSC 2011a). The transport safety section of the Transport White Paper was entitled “Acting on Transport Safety: Saving Thousands of Lives” and subtitled “Towards a ‘zero-vision’ on road safety” and contained a summary of the actions from the previously adopted Road Safety Policy Orientations (European Commission 2011).

However, what was missing at the time was a root and branch reorganization of the EU's road safety management structure and governance in line with all of the elements of "Vision Zero." The White Paper did not elaborate the idea of sharing responsibility between the different actors nor the principle of building a system which absorbs errors. The "chapeau" heading of "Vision Zero" included some intended measures but was not supported by the necessary actions.

Vision Zero Supported by the European Parliament

Just after the adoption of Vision Zero in the 2011 Transport White Paper, the European Parliament also adopted a new report in 2011, entitled European Road Safety 2011–2020 (European Parliament 2011). MEPs shared some of ETSC's criticisms of the EC's 2011 "policy orientations" stating that "The EU must make a start on the work of turning this vision into reality and developing a strategy which looks beyond the 10-year time frame" (European Parliament 2011).

In an opening section in the report on "ethical aspects," MEPs warned that "a complementary, long-term strategy is needed which goes beyond the period covered by the communication under consideration here and has the objective of preventing all road deaths ('Vision Zero')" (European Parliament 2011). This view had been supported by ETSC in a briefing for MEPs (ETSC 2011b). A whole section of the report was dedicated to "Vision Zero" explaining that 15,000 deaths in 2020, though an improvement, were still not acceptable:

> Your rapporteur wholeheartedly supports the objective of halving the number of road deaths by 2020. This means, however, that in 2020 some 15,000 people would still lose their lives in road accidents. The price EU citizens pay for their mobility would thus still be shockingly high. If even one person is killed or injured in a road accident it is one too many. Although absolute safety is an impossibility, the objective of only halving the number of road deaths – however ambitious it may be given the period – is ethically questionable. The Commission should therefore finally acknowledge Parliament's call and set as the long-term aim the prevention of all road deaths ("Vision Zero"), as a number of Member States have already done (European Parliament 2011).

The appeal of the EP to consider the ethical implications of setting short-term targets and appealing for longer-term planning embodies one of the elements of Vision Zero.

Corporate Sustainability Reporting

The EU is an influential leader in setting global sustainability reporting standards. A little later in 2014, the EU also adopted a directive requiring large companies to disclose certain information on the way they operate and manage social and environmental challenges (European Union 2014). The thinking was that this can help investors, consumers, policymakers and other stakeholders to evaluate the non-financial performance of large companies and encourages these companies to develop a responsible approach to business. The so-called Non-financial Reporting Directive 2014/95 (NFRD) lays down the rules on disclosure of non-financial and diversity information and amends the accounting Directive 2013/34/EU. Although there is no specific reference to road safety, health and safety at work are included. This links into the idea of Vision Zero that responsibility is shared beyond the public sector in delivering on social and environmental goals, which could also include road safety.

According to the legislation, companies with more than 500 employees are required to include non-financial statements in their annual reports from 2018 onward. Under Directive 2014/95/EU, large companies have to publish reports on the policies they implement in relation to environmental protection, social responsibility and treatment of employees (including health and safety at work), respect for human rights, anti-corruption and bribery as well as diversity on company boards. The EC adopted guidelines to elaborate reporting under the directive in 2017 (European Commission 2017), further updated in 2019 (European Commission 2019a). The directive is also due for revision under the European Green Deal with a consultation for the revision underway in February 2020 to strengthen sustainable investment even further (European Commission 2020e).

The Stockholm Declaration of 2020 on road safety includes a recommendation which calls upon "businesses and industries of all sizes and sectors to contribute to the attainment of the road -safety-related SDGs by applying Safe System principles to their entire value chain including internal practices throughout their procurement, production and distribution process, and to include reporting of safety performance in their sustainability reports" (Stockholm Declaration on Road Safety 2020). This is explained further in the report of the Academic Expert Group for the Stockholm Declaration (Stockholm Declaration on Road Safety Academic Expert Group 2020). Global supply chains associated with multinational corporations account for over 80% of global trade and employ one in five workers (Thorlaksen et al. 2018).

Mid-term Review of the Transport White Paper and Road Safety Policy Orientations

At the halfway point of the target period for 2020, in early 2015, the European Commission undertook a review of the Road Safety Policy Orientations and the Transport White Paper, with the European Parliament undertaking an Own Initiative Report on the White Paper. The European Commission opened a public consultation on progress on the Road Safety Policy Orientations at the end of 2014 and on the Transport White Paper shortly afterward. In its contribution to both of these reviews, ETSC called upon EU policymakers to redouble European efforts in the field of road safety and to strengthen and expand the scope of action needed to reach the 2020 target (ETSC 2015a).

The European Parliament in its contribution to the mid-term review of the Transport White Paper had a strong section on road safety under “Placing people at the heart of transport policy.” The Resolution stressed that “although significant improvements have been achieved in road safety over the past years, differences between Members States still persist and further measures are needed to attain the long-term Vision Zero objective” (European Parliament 2015).

MEPs called for a raft of different actions, very much in line with ETSC’s recommendations at the time, including for the European Commission to come forward with a revision of vehicle safety legislation (the GSR 2009/661), to improve HGV safety and to mandate the “greater application in new passenger cars and commercial vehicles of driver assistance safety systems such as overridable intelligent speed adaptation (ISA)” (European Parliament 2015). Already then, they were calling for a revision of Directive 2008/96/EC on road infrastructure safety management, calling for an extension of its four main measures to other parts of the road network, including all parts of motorways and rural and urban roads. They were also calling for the European Commission to review driving license legislation to, for example, introduce a second phase to obtain the full license and a harmonized EU blood alcohol concentration limit of 0.0 for professional drivers and for new drivers in the first 2 years. These latter measures have still not happened to date.

The Adoption of an EU Serious Injury Target and Its Importance for Vision Zero in Europe

In its 2015 resolution, the European Parliament called for “the swift adoption of a 2020 target for a 40% reduction in the number of people seriously injured, accompanied by a fully-fledged EU strategy” (European Parliament 2015). Furthermore, MEPs called on “the Member States to provide without delay all relevant statistical data so as to enable the Commission to set that target and strategy” (European Parliament 2015). But the EU had to wait until 2019 for the final adoption of such a target. This is significant for Vision Zero in Europe as it illustrates the difficulties in adopting targets beyond reducing deaths, an important part of the Vision Zero philosophy.

The mid-term review of both the Road Safety Policy Orientations and the Transport White Paper came just after the start of the mandate of the new European Commissioner for Transport Violeta Bulc. The road safety community had high hopes for new action, and the new commissioner made a promising start. ETSC was especially looking forward to the adoption of an EU target for reducing serious injuries, which had been long promised. Although a common EU definition of seriously injured casualties was adopted in 2013 (European Commission 2013), the EU had previously missed the opportunity to adopt a target and measures to achieve it.

ETSC had long argued for the need for a separate pan-European target to reduce serious road injuries, to complement the targets that have been in place since 2001 to reduce deaths. Since 2010, the European Commission committed to introducing such a target. In 2013, the crucial common definition of the types of injuries to be recorded and tracked was approved (European Commission 2013). A target was finally expected to be set in the first half of 2015, having been promised "shortly" in a Commission press release in 24 March 2015. But the European Commission backtracked, and the target was placed in limbo. ETSC convened an expert meeting in March 2015 to discuss a priority list of measures for EU action to reduce serious injury (ETSC 2016a).

A step was taken when the European Commission published, for the first time, a figure in April 2015 for the estimated number of people seriously injured on Europe's roads: 135,000 in 2014 (European Commission 2015).

ETSC then launched an official campaign entitled "Let's Go for a European Serious Injury Target to Reduce Road Injuries" calling on the Commission to publish a target by the end of 2015 (ETSC 2015b).

More than 70 experts and representatives of road safety organizations and victims groups from across Europe together with 12 members of the European Parliament wrote to the European Commission President Jean-Claude Juncker urging him to reverse the decision to drop the target. Public health groups and medical experts from across Europe joined the call along with transport ministers from across the EU. Also in 2015, ETSC worked with the Luxembourg Presidency who arranged a debate on the Transport White Paper at the October Council and a lunch debate on road safety at the December Council. Both debates included the serious injury topic. In February 2016, ETSC met with both President Juncker and Transport Commissioner Bulc to hand over the banner from the campaign and press the case for setting a target (ETSC 2016b).

A group of MEPs launched the initiative to sign a "written declaration" on the importance of the serious injury target. The declaration was signed by 275 MEPs.

The Valletta Declaration and the Adoption of an EU Serious Injury Target

One of the key milestones in the run-up to the adoption of the serious injury target was the adoption of the Valletta Declaration on road safety (EU Council Valetta Declaration 2017). Malta held the EU Presidency in the first half of 2017 and wanted to contribute to improving road safety. The Maltese Presidency organized a high-level conference and an Informal Ministerial Transport Council on the 28th and 29th of March 2017 where the Valletta Declaration on road safety was officially adopted.

ETSC participated in a preparatory meeting organized by the European Commission and sent initial written input to both the European Commission and the Maltese Presidency on the draft declaration. Ahead of the meeting in January, ETSC contacted all EU 28 Member States to present their priorities for inclusion. The main request from ETSC was for EU Member States to endorse an EU target for serious injuries.

The Valletta Declaration was adopted on 28 March, including a call for the adoption of an EU serious injury target. In June 2017, European Union transport ministers formally agreed to set a target of halving the number of serious injuries on roads in the EU by 2030 from their 2020 level (EU Council 2017). In their council conclusions, ministers formally endorsed the Valletta Declaration on improving road safety, issued at the informal meeting organized by the Maltese Presidency on 29 March 2017. Ministers called on the European Commission to come forward with a new road safety strategy for the decade 2020–2030 including targets for reducing deaths and serious injuries (ETSC 2017a). The road safety community still had to wait until 2018 until the targets were finally adopted within the new strategy.

EU Road Safety Action Policy Framework: Next Steps Towards Vision Zero

In June 2019, the European Commission published the EU Road Safety Policy Framework 2021–2030: Next Steps Towards "Vision Zero" (European Commission 2019). The publication was a follow-up to a shorter action plan published in May 2018 (European Commission 2018a), as part of the Mobility Package III, which included two new road safety regulations on vehicle and infrastructure safety standards. In its launch press release, the European Commission stated that "These two measures [on vehicle and infrastructure safety] could save up to 10,500 lives and avoid close to 60,000 serious injuries over 2020-2030, thereby contributing to the EU's long-term goal of moving close to zero fatalities and serious injuries by 2050 ('Vision Zero')" (European Commission 2018b). A strong link to Vision Zero was repeated by Commissioner Bulc: "Today the Commission has completed its agenda for safe, clean and connected mobility. New decisive steps towards #"VisionZero: 0 fatalities on EU roads, 0 pollution, 0 paper by 2050" (European Commission 2018c). Throughout her tenure, Commissioner Bulc was a strong advocate of Vision Zero and was sure to include it in her many speeches and updates on road safety.

ETSC was broadly positive of the new strategy and welcomed that the long-term Vision Zero would guide the announced EU Road Safety Policy Framework for 2021–2030 and embody the "Safe System Approach" (ETSC 2019e) and also that it included a new target to halve road deaths between 2020 and 2030 as well as, for the first time, a target to reduce serious injuries by the same amount. Thus, it enshrined the targets adopted in the Valletta Declaration.

Ethics

Looking at the inclusion of the Vision Zero elements of ethics, philosophy, shared responsibility and mechanism for change, in the new document, all could be interpreted as being present in some form.

In terms of ethics and vision, the introduction says "the EU has reaffirmed its ambitious long-term goal, to move close to zero deaths by 2050 ('Vision Zero')" (European Commission 2019c). They speak of "the mind-set of 'Vision Zero'" which "needs to take hold more than it has so far, both among policy makers and in society at large." The European Commission makes an oft-cited parallel with air traffic. "Road crashes are 'silent killers,' in that they often go virtually unnoticed in the public sphere, even though, taken together, they kill as many people – around 500 – as fit into a jumbo jet every week, in Europe alone" (European Commission 2019c). Then also in line with the original Vision Zero, "We do not accept deaths in the air, and we should no longer accept them on the road – the premise that no loss of life is acceptable needs to inform all decision making on road safety" (European Commission 2019c). This is supported by the adoption of the Safe System Approach: "The core elements are ensuring safe vehicles, safe infrastructure, safe road use (speed, sober driving, wearing safety belts and helmets) and better post-crash care, all long established and important factors in the Safe System approach" (European Commission 2019c).

Shared Responsibility

A whole section of the new strategy is dedicated to "shared responsibility" which states that for "the Safe System approach to work, experience shows that all actors need to play their part in a coordinated manner" (European Commission 2019c) and also that the overarching theme of the Safe System Approach "involves multi-sectoral and multi-disciplinary action and management by objectives, including timed targets and performance tracking" (European Commission 2019c).

ETSC stresses that "Road safety policy needs to be supported by effective institutional management in order to achieve long-term effects on road safety" (ETSC 2019e). Moreover, "clear institutional roles and responsibilities should be set up with strong political leadership from the Commissioner for Transport" (ETSC 2019e). The European Commission has since worked to enhance the mandate of the High-Level Group on Road Safety, which is made up of representatives of EU member states, and will now organize "results conferences" every 2 years. The European Commission has also appointed a European Coordinator for Road Safety and expressed the intention to coordinate at senior level involving all DGs with policies relevant to road safety. ETSC however is still calling for more, for example, "the development of a more complete framework which should include clear priority measures for action and a detailed road map against which performance is measured and delivery made accountable to specific bodies. As an example of such an approach ETSC referred to the Irish Road Safety Strategy" (Ireland Road Safety Strategy 2013).

Moreover, ETSC is critical of the efforts to "share responsibility" with industry. A part of the proposed actions in the Commission's road safety action plan comes in the shape of "voluntary commitments" from stakeholders, for example, the Vision Zero pledge from ACEA (ACEA 2018). ETSC says that "although such commitments can be welcome, especially in new areas as a precursor to legislation, it is less favourable as the action may not end up being completed without the legislative obligation" (ETSC 2019e).

Philosophy of Safety

The part of the Vision Zero and Safe System philosophy about building a system which absorbs errors is also included in the new EU strategy. For example, in the introduction:

> According to the Safe System approach, death and serious injury in road collisions are not an inevitable price to be paid for mobility. While collisions will continue to occur, death and serious injury are largely preventable. (European Commission 2019b)

The strategy goes on:

> The Safe System approach aims for a more forgiving road system. It accepts that people will make mistakes, and argues for a layered combination of measures to prevent people from dying from these mistakes by taking the physics of human vulnerability into account. (European Commission 2019b)

In terms of the different elements of the system:

> Better vehicle construction, improved road infrastructure, lower speeds for example all have the capacity to reduce the impact of crashes. Taken together, they should form layers of protection that ensure that, if one element fails, another one will compensate to prevent the worst outcome. (European Commission 2019b)

Under, for example, the section on infrastructure:

> Well-designed and properly maintained roads can reduce the probability of road traffic accidents, while “forgiving” roads (roads laid out on Safe System principles e.g. with median safety barriers to ensure that driving errors do not need to have serious consequences) can reduce the severity of accidents that do happen. (European Commission 2019b)

Mechanisms for Change

Under the section in the strategy entitled “Safe System approach at EU level,” the European Commission presents a framework including targets and key performance indicators and also examines how to change the structures to deliver and improve road safety policy at EU level.

An example of a very new “mechanism for change” is the plan to develop new key performance indicators (KPIs) for road safety, linked to outcome targets already announced by the European Commission in May 2018 (European Commission 2018a).

According to a 1993 directive, EU Member States are legally obliged to report to the European Commission on the number of road collisions that result in injury or death. These new KPIs should give a more detailed sense of how Member States are performing in terms of reducing some of the most important risks. However, the reporting on KPIs will be voluntary, thus putting in place some new parts of the Vision Zero structure: "creating a mechanism for change."

ETSC in its response to the new strategy stated that "strong measures and a wider coverage of existing and emerging road safety issues will be essential to addressing the recent stagnation in progress on reducing road deaths in the EU" (ETSC 2019e).

ETSC said that although the Commission's analysis of the current state of road safety in Europe was correct, the planned policy approach would need renewed effort if it will result in the needed rapid and far-reaching improvement (ETSC 2019e).

In particular, rapidly evolving technologies such as micromobility and automated driving need substantial regulatory efforts now to avoid creating new and unforeseen risks. Long-term research into these, and other areas, is welcome – but robust legislation following the precautionary principle and the Safe System Approach will be needed sooner rather than later (ETSC 2019e).

The new EU strategy was adopted in the midst of a road safety crisis in Europe, a drastic slowdown in the positive trend of reducing road deaths and the realization that the 2020 EU road death reduction target would not be reached.

Since 2010, the average annual progress in reducing the number of road deaths in the EU is 2.8%, a 21% reduction between 2010 and 2018. Most of that progress was made in 2011, 2012 and 2013. A 6.7% year-to-year reduction was needed over the 2010–2020 period to reach the 2020 target (to halve road deaths in a decade) through consistent annual progress. Since 2013, the EU as a whole has been struggling to reach a breakthrough. The number of road deaths declined by only 4% in the 5 years since 2013. For the EU to reach the 2020 target, road deaths now need to be reduced by around 20.6% annually in 2019 and 2020 – an unprecedented and highly unlikely possibility.

Renewal of Vision Zero plus the Safe System Approach: Is This Enough to Deliver Vision Zero in Europe?

Since the adoption of Vision Zero in 2011, the new EU strategy for 2021–2030 has had more elements of the Vision Zero integrated than in the original 2011 road safety strategy and White Paper, especially in the areas of "ethics" and "governance," although more could still be done to strengthen, for example, the governance structure.

ETSC has repeatedly called for the setting up of an EU agency for road safety, as exist for other transport modes. Such an agency could be "responsible for the collection and analysis of data, helping speed up developments in road safety and providing a catalyst for road safety information and data collection" (ETSC 2019e). The agency could also come up with new safety standards for vehicles as well as overseeing and coordinating EU input to the UNECE process (ETSC 2019e).

In themselves, the implementation of all of the planned actions in the EU strategy will not be enough to deliver the long-term Vision Zero nor possibly the new 2030 targets. ETSC has commented on the possible causes of the recent stagnation in the EU. “The economic recovery, and consequent increase in road transport usage, partly explains the lack of progress. As do cuts to transport police numbers and infrastructure maintenance budgets by Member States as road safety fell down the political priority list in some countries” (ETSC 2019e).

Other explanations could be about the possible consequences of EU and Member State inaction and delay of adopting new life-saving policies in its PIN Annual Report (ETSC 2019d). “But the EU must also shoulder some of the responsibility for waiting almost until the end of its five-year political cycle to deliver its biggest and boldest road safety initiatives: an update to minimum vehicle safety standards and a significant increase in the scope of infrastructure safety management rules” (ETSC 2019). These eventually came in May 2018, with final political agreements reached in the last few months of 2019. ETSC recognizes that this was a massive achievement, which will save thousands of lives. But it will be several years before we see the full impact (ETSC 2019e).

The EU will have to show strong political will from the start of the new mandate, including from the newly appointed EU Transport Commissioner Ms. Vălean, if it wants to reach the new 2030 targets.

In her opening statement at her hearing in the European Parliament, Ms. Vălean said, “25 000 [deaths] per year is simply unacceptable. We should share the objective of halving the number of road deaths and serious injuries by 2030 compared to 2020.” Later at the same hearing, she affirmed that “for road safety we are committed to zero vision, zero deaths in 2050. We put a strategy in place and I plan to promote it strongly. With strategy comes actions” (ETSC 2019f).

This is mirrored at a higher level in the “mission letter” to the new transport commissioner, from the European Commission President Mrs. von der Leyen: “Cutting across all of your priorities is the need for the highest safety standards. This is becoming all the more important as traffic increases and security threats become ever more complex” (European Commission 2019d). Together, this implies the intended willingness to act of the new commissioner with competence for road safety and the president of the European Commission.

The EU will need to fulfil, as a minimum, all of the planned actions in the EU realm of implementation.

ETSC in its response says that the planned actions are not sufficient and in its response document puts forward more possible actions under the different priority actions saying that there is “room for improvement and increased ambition” (ETSC 2019e). Yet, it needs also to go above and beyond and work to encourage EU Member States to place road safety high on the political agenda. ETSC wrote in its response to the new EU strategy that “as well as putting forward legislation, in the next decade the European Commission must continue to fulfil its crucial role in supporting and motivating EU Member States to act” (ETSC 2019e). Moreover, it must now also rise to the challenge of dealing with the Covid-19 pandemic and probable economic downturn.

Examples of Vision Zero in Action at EU Level

New legislation on infrastructure and vehicle safety was finally adopted in 2019; both are due to have a substantial impact on reducing deaths and serious injuries and the implementation of Vision Zero. This next section will show how these examples of legislation have been adopted since the inclusion of Vision Zero in the Transport White Paper of the EU in 2011 and the EU road safety strategy.

Adoption of the General Safety Regulation on Minimum Vehicle Safety Standards in the EU

Already in 2010, the European Commission indicated in its communication on "Policy Orientations on Road Safety 2011–2020" that it would make proposals to encourage progress on the active and passive safety of vehicles (European Commission 2010). ETSC much welcomed the priorities set by the European Commission at the time to focus on technologies tackling speeding and drink driving. In particular, the inclusion of "in-vehicle systems providing real-time information on prevailing speed limit" was recognized as a potential first step to introducing Intelligent Speed Assistance (ETSC 2010). This was a long-standing important priority of ETSC; ISA was recognized as an important life-saving measure and part of the Vision Zero philosophy of safety, creating a system which absorbs errors (ETSC 2010), in this case speeding, often a simple error of overseeing a speed limit sign. Other types of in-vehicle safety technologies such as Advanced Emergency Braking Systems and Lane Keeping Assist could also be classed in the same way. These were also finally included in the final adopted legislation. But it would take another 8 years until a legislative proposal was made.

In late 2016, the European Commission presented its report "Saving Lives: Boosting Car Safety in the EU," which listed 19 priority measures for improving vehicle safety. Its preface stated that "In order to reach the EU strategic target of halving the number of road deaths from approximately 31,000 in 2010 to 15,000 in 2020, as stated in the Policy Orientations on Road Safety 2011–2020, additional efforts are needed as it is entirely likely that the target is not going to be reached" (European Commission 2016). ETSC was very supportive of the chosen measures and called for the swift adoption of the regulation.

The report was however not accompanied by a legislative proposal that would take even longer. This long delay was heavily criticized by ETSC who, together with thirteen other stakeholders, formed a strong coalition to make the case for bringing it forward (ETSC 2017b). Member States were also demanding action. The Valletta Declaration on Road Safety of 2017 by all EU transport ministers included a call to accelerate work on new vehicle safety standards (Valletta Declaration 2017). This followed a letter sent in February by eight ministers of transport, asking for better car and truck safety and for new vehicle safety measures to be published before the end of 2017.

Still, the proposal did not come. In the meantime, the European Parliament increased the political pressure. It adopted an own-initiative report responding to the Commission's report, in which it primarily set out its vision for the improvement of vehicle safety in the context of the revision of the GSR (European Parliament 2017). It repeated the same appeal for increased action to reach the 2020 target but also added a call for a Vision Zero goal. "Every year on Europe's roads around 25 500 people die and some 135 000 are seriously injured, so that more – and more effective – measures need to be taken, in consultation with Member States, if the vision zero goal of 'no fatalities' is to be achieved" (European Parliament 2017).

After a long wait and pressure from all sides, the European Commission finally presented its proposal revising the General Safety Regulation on 17 May 2018 as part of the Mobility Package III (European Commission 2018d). The proposal included a set of new vehicle safety measures, including mandatory installation of new driver assistance technologies, as well as revised minimum crash testing standards and measures to protect pedestrians and cyclists, to be introduced from 2022. Although repeating the need to improve road safety in Europe, the proposal did not make a specific reference to its contribution to Vision Zero nor any of the four key elements. Although there was no specific reference, as this legislation is about new vehicle safety requirements to be delivered to European consumers by industry, it does fit under "shared responsibility." Thus, industry will have to build safer vehicles, which contribute to the longer-term fulfilment of Vision Zero. As mentioned previously, industry itself has taken on the Vision Zero language with, for example, the Vision Zero pledge from ACEA (2018).

The GSR text missing a reference to the EU's Vision Zero as set out in its road safety strategy is in contrast to the Road Infrastructure Safety Management Directive proposal presented below where there was a strong reference in the introduction as well as other supporting elements such as "forgiving roads."

The GSR was drafted by DG GROW, whereas the Road Infrastructure Safety Management Directive was drafted by DG MOVE, who are also the primary authors of the EU's road safety strategy which fully adopts the Vision Zero philosophy.

Stakeholders including the consultants TRL who were charged by the EC with preparing the proposal were encouraging an approach which would embrace Vision Zero also within the important area of the EU's vehicle safety legislation. DG GROW did stand by the principles of Vision Zero, by defending an ambitious list of mandatory safety technologies against strong pressure from industry who tried to water it down prior to publication and during the negotiations. The new GSR mandates vehicle safety improvements, which will benefit the safety of those outside vehicles, such as pedestrians and cyclists. For example, better direct vision standards will help truck drivers see more cyclists and pedestrians around their cabs.

ETSC supported all of the proposed measures, in particular those with the most potential to reduce death and injury such as overridable Intelligent Speed Assistance (ISA) and Automated Emergency Braking (AEB). Both of these technologies were already available on the market, but regulation was needed to make sure the benefits are extended to all new vehicles as standard. To garner political support for the new standards, ETSC ran a campaign during 2018 and 2019 called "Last Night the EU Saved My Life" (ETSC 2018a).

The Council adopted its informal position on 29 November 2018 (European Council 2018), which was warmly welcomed by ETSC as a "massive step for road safety" (ETSC 2018b). The European Parliament adopted its informal position on the proposal on 21 February 2019. This included two proposed amendments to include Vision Zero.

Firstly in a preamble, "The Union shall do its utmost to reduce these figures drastically aiming at the Vision Zero goal of 'no fatalities' and also proposing, under the review clause recommendations, in order to support the developments towards Vision Zero driving" (European Parliament 2019), though, regrettably, these proposed references to Vision Zero were not included in the final agreed text.

ETSC welcomed the new safety proposals and also the fact that MEPs argued that the new rules should be fast-tracked and the request that eCall should also be fitted to lorries and buses in the future (ETSC 2019).

The institutions then conducted a series of informal negotiations and reached an agreement on the file on 29 March 2019 (European Parliament 2019). ETSC called the new rules "a big leap forward for road safety" and praised the leadership of EU decision-makers in concluding the negotiations (ETSC 2019b). Following the formal adoption by the co-legislators, the revised General Safety Regulation was officially published in mid-December 2019 (European Council 2019b).

The new GSR requires, as of July 2022, that all new vehicle types have to be fitted with Intelligent Speed Assistance (ISA) and all new vehicles as of July 2024. Besides a handful of high-level requirements, the new GSR however does not specify exactly how ISA is supposed to function and perform. These technical requirements are instead to be set out in a delegated act prepared by the European Commission.

The technical requirements for many of the safety measures and systems required by the GSR will be set out in UN Regulations developed by the United Nation Economic Committee for Europe's World Forum for Harmonization of Vehicle Regulations (UNECE's WP.29).

Adoption of the Infrastructure Safety Directive

The EC published a proposal to revise the Road Infrastructure Safety Management Directive in 2018 (European Commission 2018e). Included within it is a clear reference to Vision Zero and the importance of implementing the Safe System Approach for infrastructure. As one of the first pieces of legislation proposed by the EC in the area of road safety, alongside the GSR, since the adoption of Vision Zero, this inclusion was significant:

> It is the strategic objective of the Union to halve the number of road deaths by 2020 compared to 2010 and to move close to zero fatalities by 2050 ("Vision Zero"). However, progress towards achieving these objectives has stalled in recent years. (European Commission 2018e)

The proposal also emphasized the importance of infrastructure safety design in preventing road traffic collisions, in line with the "Safe System Approach" and also embracing the main elements of the Vision Zero.

> According to the Safe System approach, death and serious injury in road accidents is largely preventable. It should be a shared responsibility at all levels to ensure that road crashes do not lead to serious or fatal injuries. In particular, well-designed and properly maintained roads should reduce the probability of road traffic accidents, whilst "forgiving" roads (roads laid out in an intelligent way to ensure that driving errors do not immediately have serious consequences) should reduce the severity of accidents. (European Commission 2018e)

In its position paper, ETSC called upon EU Member States to work toward similarly high levels of safety on all Trans-European Transport Network (TEN-T) roads, motorways and main rural and urban road networks (ETSC 2018c).

ETSC recognized that the measures in the original infrastructure safety and tunnel safety directives helped to reduce deaths in the early part of the 2010 decade. A study commissioned by the European Commission found that the impact has been positive for road safety in a number of key areas (TML 2014).

According to the European Commission, the proposed updated measures would save over 3,200 lives and avoid more than 20,700 serious injuries over the decade 2020–2030 (European Commission 2018e). ETSC's main priorities for the revision of the directive included the extension of the scope to other roads, ensuring that any road funded or co-funded from the EU budget must also be covered by EU safety rules and adapting the instruments to ensure that all road users including cyclists, pedestrians and motorcyclists are prioritized for safety measures.

The European Parliament endorsed the inclusion of Vision Zero in the outset of the proposal and also called for more ambition in various elements of the original EC proposal (European Parliament 2018).

The Council was more conservative in its position, attempting to water down the new requirements and give the Member States the possibility to designate which roads would be covered by the new directive. This was strongly criticized by ETSC as it was thought that this might reduce the safety impact should Member States choose only a small number of roads (ETSC 2018).

A compromise was struck in most areas in February 2019 with the final legislative text being published in October 2020 (ETSC 2019c). A revised version of the rules agreed extends the infrastructure safety measures from the ten TEN-T network to all motorways, all "primary roads" and all non-urban roads that receive EU funding. ETSC, and other organizations, called for all main urban and rural roads to be covered. But EU policymakers representing the European Commission, Parliament and Member States did not agree to extend the scope of the mandatory rules that far, though countries will still be able to go further if they wish.

The final text adopted included all of the original Vision Zero elements proposed by the EC. It covers shared responsibility and creating a system which absorbs errors especially with the inclusion of "forgiving roads." Regarding "providing a mechanism for change," the directive also asks governments to prepare "prioritised action plans to ensure that. . ..the findings of the network-wide road safety assessment should be followed up either by targeted road safety inspections or, if possible and cost-efficient, by direct remedial action aimed at eliminating or reducing the road safety risks" (European Council 2019).

Conclusion

This chapter documents the roots of Vision Zero in EU road safety policymaking, from the very beginning in the mid-1980s to present day, showing that the Vision Zero approach is now integrated into the new EU road safety strategy. First examples of implementation are illustrated by references within recently adopted pieces of important road safety legislation. Yet, road safety policy needs to be supported by effective institutional management in order to achieve long-term effects on road safety and Vision Zero.

More capacity will be needed to fully expand the EU's road safety governance structures. In the area of governance, there are still some missing elements. Of help could be the creation of a cross-DG coordination group reporting both to the relevant commissioners, the road safety coordinator, and to the European Commission's High Level Group on Road Safety.

DG MOVE's lead road safety unit capacity also needs to be strengthened particularly in any further developments of its road safety strategy and targets, coordination, monitoring and evaluation functions.

The creation of a European Road Safety Agency would also aid in this regard. It could be responsible for the collection and analysis of data, helping speed up developments in road safety and providing a catalyst for road safety information and data collection.

The EU Strategic Action Plan proposes a new package of funding measures which will be further supported by the 2021–2027 EU budget, once adopted. This will also support implementation of measures on the ground to help further progress toward Vision Zero.

Specific measures need to be introduced to reduce serious injuries, in light of the new target for 2030. Specific policy measures, not just further research, are also needed on important areas such as distraction and drug-driving enforcement. There is an urgent need for a comprehensive EU regulation for vehicles with automated driving systems on-board.

Full implementation of Vision Zero is still a way off. Institutional changes are essential to make sure that commitment to Vision Zero is not just lip service to road safety. However, there are reasons to be more cautiously optimistic for the decade to come on progress, not only in reaching the 2030 road safety targets in the EU but also implementing all of Vision Zero's elements: the setting up of key performance indicators, targets and a plan for 2030 as well as the creation of a post of road safety coordinator within the European Commission. The adoption of the two latest regulations on vehicle and infrastructure safety once implemented should also bring progress. The renewed political will at the level of the European Commissioner Vălean at the start of the new political mandate should also help in working toward Vision Zero in Europe.

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The Development of the "Vision Zero" Approach in Victoria, Australia

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Abstract

For many decades, road safety measures in Australia focused almost exclusively on behavioral approaches. When Claes Tingvall was appointed Director of MUARC, he introduced the concept of "Vision Zero" to Australia and, with it, the "Safe System" approach. While political leaders initially regarded a vision for zero deaths as unachievable, they supported the inherent logic of the Safe System.

Initially the Safe System was applied as four independent pillars. While this lack of integration had limitations, it did enable road safety measures to move beyond road user behavior to focus more on safer road infrastructure and vehicle safety.

The initial Safe System approach became "Towards Zero" an approach that accepts humans are fragile, and the road system designed to protect from death or serious injury was adopted across all Australia jurisdictions between 2004 and 2018.

Public education has been used to introduce and explain Towards Zero and bring greater attention to the importance of purchasing a safe vehicle. Infrastructure investment has moved from a "blackspot" approach to the Safe System approach. However, shifting community and decision-makers' understanding of the importance of speed limits being set to match the safety standard and design of a road remains a challenge. Future opportunities involve better integration of the components of the Safe System, focusing on serious injuries and improving strategy delivery, performance reporting, management, and accountability.

Keywords

Towards Zero · Safe System · Road Safety Strategy · Road Infrastructure Investment · Drink Driving Case Study · Vehicle Safety · Speed Management

Introduction

The aim of this chapter is to chart the progress of the Vision Zero approach across Australia. To do this, it is important by way of background to understand a little of the country's governance structure.

In January 1901, the Australian colonies united to become a nation, with the colonies becoming Australia's six states. Through this process of federation, the British Parliament passed legislation allowing the six Australian states to govern in their own right as part of the Commonwealth of Australia. While regulatory powers with regard to road-based vehicles rested with the Commonwealth, powers with regard to traffic law and penalties, driver licensing, vehicle registration, road infrastructure, traffic management, and planning (with the exception of large, joint projects) sat with each state. This has meant developments that influence road safety outcomes have to some degree evolved differently across state boundaries. The collaborative process across states has also meant that there are significant areas of commonality.

The approach to this chapter, then, is to focus on development of the Vision Zero approach within the State of Victoria (the home state of the chapter's authors) while drawing attention to the main areas of commonality and departure across jurisdictions.

The Years Before Vision Zero

Early Years

Road transport across Australia evolved in a relatively haphazard way. With the introduction of motorized transport, emphasis was placed on providing roads and streets in areas of high population concentration and arteries to connect the major towns. The demand for roads far outstripped the system thinking needed to ensure that the network was efficient and safe for all road users. Professor Ian Johnston reinforced this view by stating, "We evolved inappropriate policies, practices and designs from an unmotorised era of personal transport because we had nothing else to go on and struggled to react to the rate of growth" (Johnson 2015).

In the 1940s and 1950s, the appetite for owning personal transport was fueled by population growth, as well as the novelty, convenience, and efficiency offered by the private motor car. The relatively slow development of public transport and the long distances that separated major population centers also added to the appeal.

Bourke Street, Melbourne CBD, 1950

Scientific knowledge to guide safe development of the road traffic system grew slowly until the late 1960s. According to Johnson, the next decade saw “the discipline of ‘traffic safety science’ [emerge] – not a science in its own right but a confluence of the disciplines of epidemiology, public health, engineering, psychology, mathematics and statistics, and trauma medicine” (Johnson 2005). Trauma medicine provided an important impetus for introducing key safety policies by identifying severe injury types associated with unrestrained vehicle occupants and alcohol-related crashes. These findings, together with a rising road toll, galvanized bipartisan support for an agenda for change (Johnson 2015).

Safety in the 1970s and the Haddon Matrix

The 1970s heralded a move to develop the scientific evidence to support well-founded, effective safety policy. The Haddon Matrix (Haddon 1968; Haddon 1972) provided one of the earliest systematic frameworks through which to assess the safety contributions of key elements of the traffic system along a crash timeline (refer below). Under this epidemiological approach to road safety, discrete injury factors were systematically examined in order to identify which countermeasures could be implemented, often guided by benefit-cost analysis. At the same time, the first major in-depth accident study in Australia was conducted by the Road Accident

Research Unit at the University of Adelaide (Roberston et al. 1966). Increasingly, the disparate but related elements that give rise to crashes and subsequent injury outcomes were coming under investigation.

Haddon's Matrix

		Factors		
Phase		Human	Vehicle/ Equipment	Environment
Pre-crash	Crash prevention	Information, Attitude, Police enforcement	Roadworthiness Speed m/m, Lighting	Road design & layout, speed limit, pedestrian facility
Crash	Injury prevention during crash	Use of restraints	Occupant restraints, crash protective design	Crash protective roadside objects
Post-crash	Life sustaining	First aid skill, Access to medics	Ease of access Fire risk	Rescue facilities

Source: Haddon 1968

Behavioral Approaches Predominate Throughout the 1970s, 1980s, and 1990s

Despite increasing exploration into the multiple factors that contributed to crashes and injury, behavioral approaches to implementation remained the norm. Legislative reform, public education, and police enforcement were widely adopted by road safety agencies across Australia in the 1970s and 1980s.

In the early 1970s, the State of Victoria had the poorest road safety performance nationally. Victoria recorded the highest number of lives lost in a year in 1970 with 1061 deaths (equating to a rate of 31 deaths per 100,000 population). Landmark reforms addressing compulsory seat belt wearing and drink-driving were introduced in response. Stepped-up enforcement together with promotional support saw these reforms provide a strong platform for shifting key high-risk behaviors, to achieve the adoption of more protective behaviors and norms across the population.

Legislative change introduced throughout the 1970s, 1980s, and 1990s included:

- Compulsory Seat Belt Wearing

  Victoria's first compulsory seat belt law was introduced in 1970 and applied to all occupants where a seat belt was fitted. Following this, further measures were introduced to mandate availability of belts in the rear seat upon resale of a vehicle.

By 1972 all other Australian states and territories introduced compulsory seat belt wearing laws for front seat occupants (Jessop 2009). An evaluation published in 1977 reported that seat belt legislation had effectively reduced the number of deaths and injuries by approximately one-third for car occupants involved in motor vehicle crashes (Trinca and Dooley 1977).

- Bicycle Helmet Wearing

  In Victoria, public education about wearing a helmet while riding a bicycle began in 1983. There were some improvements in wearing rates among primary school-aged children, but the uptake was lower among older children and adult cyclists (Vulcan et al. 1992). In 1990, Victoria was the first jurisdiction in the world to introduce compulsory bicycle helmet wearing for anyone riding a bicycle. Evaluations showed an increase in helmet wearing and reductions in head injuries (Cameron et al. 1992b).

- Speed Management

  As speed management emerged internationally as a crucial trauma prevention strategy, speed compliance remained a challenge with general policing capacity. Development of an automated speed surveillance system using a few speed cameras in the late 1980s led to the first large-scale speed camera program in the world (Cameron et al. 1992a). Progressive introduction of 54 speed cameras and an automated Traffic Infringement Notice penalty system increased detection of speeding drivers from 20,000 per month to 40,000–80,000 per month. Combined with an intensive statewide TAC mass media campaign, the camera program significantly reduced casualty crashes and their severity, particularly across arterial roads in Melbourne and on 60 km/h roads in rural Victoria where the majority of the speed camera operations occurred. Public education focused on the difficult task of building a dialogue with community around the legitimacy of speed enforcement, as well as building a community agenda about speeding and safety (Cameron et al. 1992a).

- Drink-Driving

  Despite Victorian laws introduced in 1966 requiring drivers to have a blood alcohol concentration (BAC) limit under 0.05, drink-driving was rising in the community. In the mid-1970s, around 50% of all drivers and riders killed had an illegal BAC. As a consequence, Victoria introduced a radical new law in July 1976 that would permit random breath testing of drivers at the roadside. This law then provided the impetus for progressively increased and highly visible random breath testing from the mid-1970s and throughout the 1980s. Mass media campaigns educating the public about the level of enforcement and the increased risk of detection created a strong deterrent effect. By 1990, random breath testing (RBT) had increased to 500,000 tests annually, supported by bursts of mass media publicity and a series of legislative reform aimed at behavior and social change (South 1990; Cavallo and Cameron 1992). Experimentally designed evaluations found trauma reductions during intensified periods of RBT. As a result, the number of tests rapidly doubled from 500,000 to 1 million annually through bus-based RBT. This, combined with intensive TAC mass media campaigns, resulted in 19–24% fewer fatal crashes and 15% fewer serious casualty crashes in high alcohol times (Cavallo and Cameron 1992).

Change Case Study: Drink-Driving in Victoria

Victoria's drink-driving strategy has been evolving since the late 1970s, combining legislative, policing, and public education activity designed to influence behavior change. The timeline below includes milestones and data outlining the progress made over the past 50 years (sourced from a range of papers: Vulcan and Cameron 1997; Moloney 1995; South 1990; Healy 1997; Cavallo and Cameron 1992; Victoria Police 2016; McIntyre et al. 2011; Watson et al. 2015). The behavioral approach can be characterized by understanding the nature of drink-driving behavior, patterns, perceptions, and risks and progressive targeting of legislative reform where elevated risk demanded. This approach was complemented by an escalating level of enforcement activity capitalizing on new technology and equipment, coupled with public education to further enhance the perceived risk of detection. In parallel, separating drinking and driving has increased in focus through the expanded use of alcohol ignition interlocks and community education.

Year	Measures	Level of trauma
1966	Victoria introduces 0.05 BAC limit	
1976–1980	Random breath testing (RBT) introduced at designated breath testing stations Approximately 40,000 RBTs conducted Increase in tax on alcohol	~50% of drivers killed had BAC over 0.05
1981–1988	Police adopt electronic alcohol detection devices – "breathalyzer" technology Zero BAC limit for learner drivers and first- and second-year probationary drivers Mandatory license cancellation escalating with BAC Immediate license suspension for drivers over 0.15 BAC	~38% of drivers killed had BAC over 0.05 (Cavallo and Cameron)
1989–1999	Police branch established with sole purpose of conducting RBT Roll out of 13 highly visible "booze buses" for RBT "Drink Drive Bloody Idiot" advertising campaign launched in December Number of RBTs increased to almost 1 million Total of 12 advertising campaigns targeting drink-driving	~25–30% of drivers/ motorcyclists killed had BAC over 0.05
2000–2010	Approximately 1.5 million RBTs conducted Alcohol interlocks for repeat offenders, followed by high BAC first offenders Advertising becomes more pointed, focusing on those "only a little bit over" The zero BAC requirement for young probationary drivers extended to four years	~20% of drivers/ motorcyclists killed had BAC over 0.05 (TAC, May 2010)
2011–2019	Expansion of alcohol interlock program to more offenders and by 2019 to all offenders Approximately 3–4 million RBTs per year Advertising shifts focus on separating drinking and driving Mandatory license bans, interlocks, and completion of behavioral change program for all drink-driving offenders	~18% (avg 2015–2018) of drivers/motorcyclists killed had BAC over 0.05 (Austroads)

Legislative reform, generally high levels of enforcement, and ongoing public education were successful in changing some highly problematic, pervasive behaviors and significantly reduced road trauma from the record highs of the early 1970s. Seemingly, the principle underlying the adopted approaches was that "behavioural problems require behavioural solutions," and this proved successful when levels of serious crashes involving deliberate behaviors were high. However, there remained significant numbers of crashes leading to serious trauma that were not being addressed. In particular, the 1970s and 1980s saw little progress in reducing the high travel speeds across Australia, in recognizing the relationship of travel speed with the quality of road infrastructure, and in improving the relatively poor safety standards of the Australian vehicle fleet.

Establishment of MUARC

Throughout the 1980s, safety problems and solutions were progressively identified and devised, drawing upon the findings of Safety Science and subsequent evaluative work that helped to refine and guide future countermeasure pathways. Safety Science received a boost in 1987 with the formation of the Monash University Accident Research Centre (MUARC) with the support of the Victorian Government. Importantly, the remit of MUARC was to support government, industry, and the community to devise and introduce effective safety measures to reduce accidental deaths and injuries in all settings by marrying academic excellence with practical significance. The Centre's aim, therefore, differed from that of many university faculties in that it was grounded in practical outcomes in collaboration with key stakeholders. Similar developments had taken place in other jurisdictions with high-quality safety centers having been already established within the Universities of Adelaide and New South Wales together with Curtin University in Perth. A new safety center was later established at the Queensland University of Technology in 1996.

The Beginning of Towards Zero

Moving Beyond Behavioral Approaches

Despite the significant focus on influencing driver behavior to achieve reductions in road trauma, some Australian road safety professionals were beginning to identify the relationship between decisions regarding the road transport system and questions of risk and morality. Professor Soames Job posited that "*many fatalities occur not because of driver error but because of driver error combined with a negligent designed road system and a politically acceptable but technically substandard vehicle*" (Job et al. 1989).

The most significant catalyst for the adoption of the Vision Zero philosophy in Australia was the arrival of Professor Claes Tingvall, a Swedish road safety expert who was appointed Director of MUARC in 1998. In November of that year, Prof. Tingvall introduced Vision Zero as a new paradigm for injury prevention at the

Australasian Road Safety Research, Policing and Education conference in Wellington, New Zealand (Tingvall 1998).

A year later, Prof. Tingvall together with his MUARC colleague Dr. Narelle Haworth published a paper recommending that Victoria adopt a Vision Zero approach to road safety (Tingvall and Haworth 2000). They advised that the only way to radically reduce or eliminate deaths and serious injuries was to lower vehicle travel speeds and gradually align speeds to the inherent safety of the road system. Lower maximum speed limits for differing types of road infrastructure were recommended, assuming best practice vehicle safety design and 100% restraint use.

In parallel, with a view to providing a beacon into the future and with the support of Prof. Tingvall, the world-first TAC SafeCar project was established in partnership with MUARC and Ford Motor Company (Regan et al. 2001). The aim of the project was to showcase and evaluate human performance with regard to the operation of multiple intelligent transport system (ITS) safety technologies installed within a vehicle. Technologies included haptic Intelligent Speed Adaptation (ISA), forward collision warning, and seat belt reminder systems.

Introducing Vision Zero and Safe System to Victorian Decision-Makers

Many road safety researchers and practitioners who were exposed to Prof. Tingvall's explanation of Vision Zero were very engaged with the possibility of adopting the approach. In 2003, Eric Howard, General Manager of Road Safety at VicRoads (the Victorian Government's lead road safety agency), undertook a study tour to Sweden to learn more about Vision Zero. Upon his return to Victoria, Mr Howard shared the concept with senior leaders in Victoria and encouraged the adoption of developing a safe systems approach to road safety and committing to Vision Zero.

Mr Howard and his colleagues at the TAC worked to move Vision Zero beyond research and into a political arena and tried to have the Victorian State Government adopt his approach. However, a key sticking point was the premise of reducing speed limits to align with the inherent safety of the road network. Lowering speed limits is a highly contestable road safety issue with the broader Australian community and one that Victoria's political leaders at the time were not willing to address. According to Mr Howard, "*the lead road safety practitioners in Victoria understood the logic of 'Safe System' and the importance of committing to achieving zero deaths and serious injuries. However, convincing political leaders of the need for lower speed limits was a bridge too far*" (personal correspondence, 14 February 2020). The full adoption of the Vision Zero approach was subsequently rejected by policy-makers.

Instead, Victoria's road safety leaders decided to adopt the Safe System as the basis for its strategic approach to road safety in late 2003. While this approach raised the fundamental question of how much trauma the community was prepared to accept on our roads, it did not specifically adopt a vision for zero deaths and serious injuries

(Howard 2004). Government endorsement of the Safe System approach and the ensuing Arrive Alive Victorian Road Safety Strategy in 2007 signaled an "in principle" acceptance of the paradigm shift in road safety thinking, research, and strategy. However, full realization of the approach through implementation of safety improvements faithful to the new paradigm was not achieved over the life of the Strategy.

Use of Safe System Across Australia

As well as Victoria, Western Australia adopted the Safe System approach early on. Iain Cameron, General Manager of Road Safety in Western Australia, together with his Victorian counterpart Eric Howard, were involved in a number of international projects that exposed them to Safe System and Vision Zero thinking. As a result, Western Australia's Road Safety Strategic Plan for 2003–2007 was underpinned by the Safe System philosophy. Like in Victoria, the actions of the Western Australian government in the early years were concentrated on behavior management, especially speed limit compliance. But unlike Victoria, there was not the significant investment in safe road infrastructure. The Western Australian approach evolved with the establishment of a Parliamentary Reference Group to socialize developments in road safety among decision-makers, and a program of consultations with industry and community was introduced to further build understanding and support for the Safe System approach (Mooren et al. 2011). Iain Cameron reflected that "*the shift to a safe system is a social, political and professional challenge, not a technical or economic one*" (Cameron 2016).

Most other Australian states gradually adopted a Safe System approach to underpin their road safety strategies between 2003 and 2010. In 2004, the Safe System approach was adopted by Austroads (a collective of Australian and New Zealand transport agencies representing all levels of government) as a framework to guide road safety research programs and a prominent guiding principle in the draft National Road Safety Action Plan for 2005–2006.

Implementing a Safe System in the 2000s

Early Implementation of Safe System

While Victoria and other Australian states were quick to adopt the Safe System approach, its implementation fell short of the ideal. The ethical underpinnings of Vision Zero, which sought to place human health and well-being above all other considerations and acknowledged that the road system should be built to accommodate human failings, were not at the heart of the Australian approach. Rather, a simplified "four pillar" interpretation of the Safe System was quickly adopted. Often referred to as "RSVP" (Roads, Speeds, Vehicles, People), this approach saw actions developed under each of the four pillars (see the diagram below). However, the interactions between the pillars were rarely considered, meaning that the road network could not be considered a true system. In addition, not all measures were consistent with the Safe System philosophy.

However, use of the four pillar interpretation of the Safe System did have the advantage of road safety agencies balancing more of their actions across all components of the Safe System. This resulted in far greater emphasis on vehicle safety and Safe System infrastructure and less reliance on behavioral measures than had been seen previously.

A "fifth pillar" addressing post-trauma care is prominent in the application of the Safe System approach in other countries. However, it receives less focus as a road safety pillar in Victoria due to the establishment of the Victorian State Trauma System in 2000, following a major review of trauma and emergency services conducted in 1999 (Victorian Department of Human Services 1999). At the heart of the new system were triage and transfer guidelines that ensure the right patient is delivered to the right hospital in the shortest time. In particular, severe trauma victims across the State were to be transferred to one of the three specialist trauma hospitals based in Melbourne to ensure appropriate triage and expert treatment. Operational and financial support for the Victorian State Trauma System largely came from the Transport Accident Commission (TAC).

The outcomes of this support and other initiatives are captured within a study by Gabbe and Lyons (2015). From July 2001 to July 2011, the Gabbe study investigated the burden of road transport-related trauma in Victoria using a variety of measures of mortality and morbidity. Since the introduction of targeted investment in trauma care systems in Victoria, the annual health cost burden of road transport-related serious injury decreased from AUD$1.85 billion to AUD$1.34 billion. The study also demonstrated that while "there was a significant reduction in the incidence of death and an increase in the incidence of hospitalised major trauma over the ten years, there was a rapid and sustained reduction in risk-adjusted mortality for hospitalised road-related major trauma," with the overall disability-adjusted life year (DALY) burden of serious injury falling by 28% over that ten-year period.

The TAC's support for the Victorian State Trauma System provides ongoing funding for trauma research activity such as neurotrauma research to provide sophisticated tools for ambulance care. For example, one such activity piloted the cooling of spinal injury patients to both decrease the severity of damage and extend the time window for likely effective treatment beyond the time for transfer to specialist care. TAC also supported the establishment and operation of an effective Victorian State Trauma Registry (VSTR) and currently supports the ongoing operating costs for data collection (including monitoring of patient outcomes at 6-, 12-, and 24-month intervals after the crash).

Advancing Vehicle Safety

In the early 2000s, vehicle safety was given attention by road safety agencies for the first time. The Australian passenger vehicle fleet was one of the oldest in the developed world. In addition, many of the vehicle safety features commonly installed in European and North American vehicles were not available on the same models sold in Australia. Across Australia, programs promoting the Australasian New Car Assessment Program (ANCAP) and Used Car Safety Ratings (UCSR) produced by MUARC were developed. Following the establishment of US NCAP in 1978, ANCAP published its first ratings in 1993 and was the first NCAP to conduct a frontal offset crash test. Euro NCAP was to publish its first star ratings in 1997.

The establishment of ANCAP and the production of UCSR were of great significance in promoting the importance of purchasing safe cars across Australia. The aim of these programs was to encourage car buyers to choose the safest car they could afford and to expose the practices of vehicle manufacturers selling vehicles with lower crash safety ratings and fewer safety features than those in North America and Europe. ANCAP safety ratings posited safety as a focal point of competition and promotion for vehicle manufacturers, as was occurring in other parts of the world (McIntosh 2008).

In Victoria, a major mass media campaign and website (howsafeisyourcar.com.au) was launched in 2001. The television campaign introduced the message that "*Not all cars were created equal*" and compelled Victorians to buy the safest car they could afford by searching on howsafeisyourcar.com.au. This campaign encouraged greater consideration of safety among consumers' vehicle purchase decisions and over time assisted in some key safety features such as electronic stability control (ESC) and sidehead protecting airbags being more commonly available and eventually being mandated. The commencement of promotional activities and public education campaigns was associated with an increase in new vehicles sold in Victoria with ESC and curtain airbags, rising from 22% and 24% in 2006 to close to 60% and 50%, respectively, by 2009. Importantly "*public awareness and demand for these safety features encouraged the Victorian Government to mandate ESC in new vehicles sold in Victoria*" (Truong et al. 2010).

Investing in Safe Infrastructure

The early 2000s also saw infrastructure being considered more specifically as a road safety measure across Australia. Treatments such as flexible barriers and roundabouts (which were already in use) were being encouraged as best practice, while measures such as creating clear zones and concrete barriers were phased out.

The TAC in collaboration with VicRoads began investing in safe road infrastructure in Victoria in the early 1990s, commencing in 1992 with an AUD$85 million "blackspot" program designed to address sites or lengths of road with high casualty crash numbers (early criteria meant a site needed a minimum of five fatal or serious injury crashes to be considered for funding). By the early 2000s, it was recognized that by targeting crash clustering at specific high-risk locations, the blackspot approach had been highly successful in reducing fatal and serious injuries at treated sites. However, it was failing to address the broader dispersion of crashes and, thus, was not creating a safe road network. After evaluating many of the blackspot treatments under early TAC-funded programs, traffic safety consultant Dr. Bruce Corben concluded that "*results from successive evaluations indicated a need to modify the treatment approach and move from a focus on high crash concentrations to treating more spatially disperse route problems*" (personal correspondence, 10 July 2020).

Environmental scans of international best practice revealed new ways of thinking about the road system. Specifically, the underlying risk and energy across the road system needed to be managed systematically, together with the specific sites where injury crashes clustered. Infrastructure treatments needed to be applied in areas where higher speeds were to be retained, while reduced speeds were appropriate in areas where the installation of tailored Safe System measures would be highly cost-inefficient. Both approaches were concerned with managing system energy such that death or serious injury would not arise. This thinking and practice was not occurring in Australia at this time. Against this background AusRAP internationalized with partner agencies such as IRAP and established a valuable service in providing guidance nationally for investing in road and roadside infrastructure via a star system that rated the risk of the main road network across Australia (Smith et al. 2006). While five stars was the ultimate goal, three stars or better was deemed to be an appropriate performance target.

In 2002, the TAC in collaboration with VicRoads commenced investing in infrastructure treatments through its AUD$130 million Safer Roads Infrastructure Programs (SRIP1). Treatments addressed run-off-road and intersection crashes, the two key crash types seen in Victoria. Long-length flexible barrier treatments and roundabouts were installed to more systematically address fatal and serious injury crashes. Successive SRIP programs (SRIP2 and SRIP3) invested a further AUD$760 million in infrastructure treatments between 2004 and 2016. However, these treatments were a mixture of Safe System treatments and more conventional blackspot-style treatments.

Transitioning Victoria to the systematic rollout of Safe System infrastructure required engagement and coordination from all parties involved in planning, design, and delivery of road infrastructure. Initially, this proved very difficult. In presentations to the Victorian road safety fraternity, Alavi (2019) noted numerous barriers to fully implementing the Safe System approach in the Australian context, including the limited incorporation of Safe System and Vision Zero thinking in current standards and guidelines, and in network and town planning practices. In addition, conventional standards, procedures, and processes were counterproductive to planning investments, as well as to developing, delivering, and evaluating projects. Moreover, investment in Safe System infrastructure was further hampered by a lack of available training in universities and an absence of graduate programs for road safety professionals.

Australian engineers had been trained to work within decades-old standards that guided thinking towards conventional safety treatments, thus creating a barrier to transitioning to planning for a network, designing treatments that aimed to eliminate rather than reduce injury and crash types, and addressing roads and sites that had not yet recorded serious injury crashes.

The development of a new Victorian Road Safety Strategy along with further investment via the Safe System Road Infrastructure Program (SSRIP) saw conventional blackspot treatments finally transition into a program that systematically treated the road network in late 2013 through until 2015.

The key differences from SRIP3 to SSRIP were:

(a) Transition from conventional safer road treatments to Safe System treatments
(b) Safe System transformation of some high-risk high-volume highways linking key major towns to Melbourne
(c) Trials of innovative treatments such as 2 + 1 roads and vehicle-to-infrastructure communication technologies
(d) Consideration of lowering of speed limits and other traffic calming measures where cost-benefit calculations see other treatments being unaffordable

Similarly, in urban areas where infrastructure investment would prove to be cost-inefficient, safe speeds were advocated, but no wide-ranging review of speed limit setting was recommended. Reduced 40 km/h limits, however, continued to be supported in locations where vulnerable road users congregated including outside schools, in busy shopping centers, and across the Central Business District (CBD) of Melbourne.

In recent times, the only default speed limit to change in Victoria was the reduction in 2001 of the built-up environment speed limit from 60 km/h to 50 km/h. Other states had introduced, or were to introduce, a similar change to the default speed limit in built-up areas.

The transition towards the Safe System was facilitated through the development of engineering tools and the publication of national practitioner guidance on road safety infrastructure, such as Austroads (2018). Victoria adopted Safe System Assessment Guidelines for all VicRoads and government-funded projects "*to assist planners, designers and project managers to progress the Safe System approach from theory to practice of determining how well a project proposal aligns with Safe System principles*" and "*information on design and scope changes that will move a project proposal closer to the Safe System objective of eliminating the risk of fatalities and serious injuries*" (VicRoads 2019).

The graph below maps the number of lives lost on Victorian roads since 1970 with some of the significant policy and programmatic measures introduced to reduce road trauma.

Towards Zero

Adopting the Vision Zero Principles

The Safe System approach continued throughout Australia during the early to mid-2000s. Jurisdictions such as Victoria had undertaken study tours to Europe to understand how some of the best performing countries such as the Netherlands, Norway, and Sweden were achieving their impressive reductions in fatalities. The more principle-based Vision Zero approach was increasingly being understood and coveted by Victorian road safety professionals. However, it was not gaining any traction within the community nor with governments, local government authorities, or the corporate sector (TAC Social Research Centre 2013).

In 2013–2014, Victoria started to consider how it could better adopt and socialize the Vision Zero principles within the community. The key was to address two long-held beliefs among some of those working in road safety and more broadly within the community. The first belief was that it was inevitable, and thus accepted, that Victoria would always have a "road toll." The second belief, somewhat related to the first, was that most crashes resulted from people taking deliberate risks and "*doing stupid things*" (Truong et al. 2015).

In setting an ultimate goal of zero deaths, it was deemed important to educate the community that most road deaths in Australia (an estimated 57%) were related to simple human error or mistakes which the system failed to accommodate (Wundersitz and Baldock 2011). Via this path, road safety agencies hoped to not only gain community support but also stimulate a greater desire by road network planners and designers to think longer term about eliminating rather than reducing deaths on Victoria's roads.

Adopting Towards Zero

The use of "Towards Zero" as the brand or name for Victoria's further adoption of the Vision Zero approach came about through market research undertaken to develop supporting public education campaigns. Victorians felt that "Towards" was inspirational and implied actions would be taken to push the State forward to reach the ideal of zero road deaths. In comparison, they felt "Vision" implied an ideal or aspiration but not a solid plan.

Alongside the public education campaign, individual road safety agencies undertook their own actions to socialize the Towards Zero approach. At an academic level, MUARC commenced a five-day Road Safety Leadership Program available internationally but used extensively by road safety agencies across

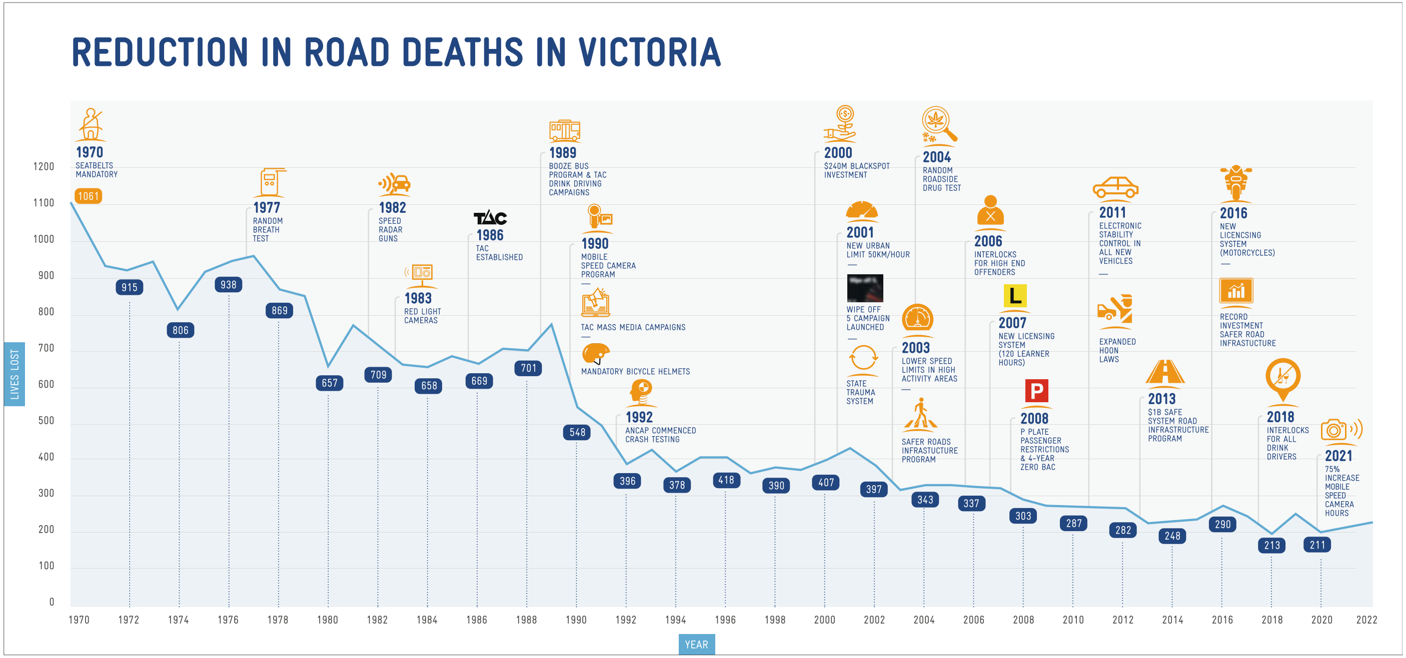


Fig. 1 Road deaths and landmark road safety initiatives in Victoria, Australia Source: Transport Accident Commission

Australia to induct and develop their people. VicRoads refined the MUARC leadership program into a tailored two-day embedment program for all its executive staff. The TAC developed on online learning program that was undertaken by its entire staff and was provided to VicRoads, police, and other agencies to educate their staff. This online learning program has since been used by local government and corporate organizations to create understanding about the Towards Zero approach (Waller and Cockfield 2014).

Towards Zero gained its greatest momentum and acceptance in Victoria with the development of the Towards Zero 2016–2020 Strategy and Action Plan which was endorsed by the Government and sought to further embed some of the key aspects of the Vision Zero approach. Key features of this Strategy included:

- Explicitly endorsing the ultimate aim of eliminating death and serious injury on Victoria's roads
- Clear interim targets for reducing trauma as steps towards the ultimate aim of zero trauma and explicit use of the Safe System approach to reach interim targets
- Adoption of three guiding truths – acceptance of human fallibility, limits of the human body's physical vulnerability to crash forces and impact speeds, and shared responsibility for safety of the road system
- A plan for a systematic network-wide approach to address the key risks faced by road users, specifically:
  – By looking to a systematic roll out of Safe System infrastructure with a goal to gradually treat all high-volume, high-speed roads with flexible barrier treatments
  – Provide interim treatments on medium-volume roads together with speed moderation on low-volume roads in rural and urban areas
  – Complemented by traffic calming and greater separation of active transport movement from motorized traffic
- Community engagement to build understanding of safe speed
- A greater focus on technology to address behavioral issues
- The Victorian Government's introduction of a 5-star purchase policy for its fleet vehicles, with local government authorities and corporate Australia encouraged to become involved

In terms of implementation, not all treatments would be fully Safe System to start, but over time the plan combined large-scale investment in infrastructure with location-specific speed limit reviews being considered for low-volume roads which infrastructure investment wouldn't reach for some years.

However, managing speeds to safe levels consistent with road function and infrastructure treatments across the road network remains a challenge. Within urban areas some gains have been made at specific locations – 40 km/h limits now apply in several local government authorities, outside schools, along busy shopping centers, and within the CBD. A more broad-based systematic approach to speed limit adoption that recognizes human tolerances to injury under differing road and roadside conditions is yet to be realized.

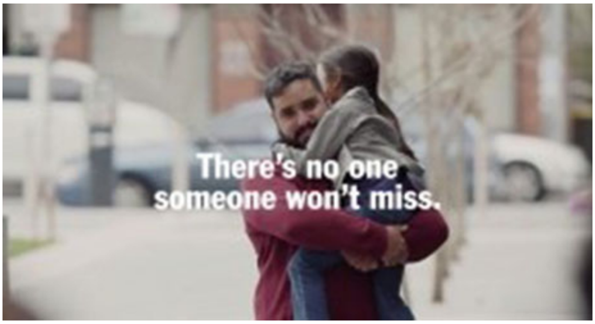
Public Education and Towards Zero

Under the Towards Zero strategy introduced in 2016, the TAC has also used mass media public education to set the agenda around key principles of the Vision Zero approach, aiming to:

- Challenge the community to think about the acceptability of death and injury on the roads
- Educate the community about human vulnerability
- Inform the community about the value of Safe System road infrastructure and vehicle safety

Specifically, three public education programs relate directly to Safe System concepts:

- *Man on the Street* – a campaign that asks the public to consider if it is acceptable for people to die or be seriously injured on the roads
- *Graham* – an artwork installation that illustrates human vulnerability by portraying what our bodies would have to look like to survive crashes
- *Safety Barriers Save Lives* – mass media campaign demonstrating how flexible barriers work to help build understanding and support for their implementation



TAC Man on the Street Campaign

'Graham' art installation

In 2018, the TAC opened the Road to Zero Education Complex within the Melbourne Museum. The aim of the Education Complex is to engage and empower young people, road safety stakeholders, and the broader Victorian community in understanding what we need to do to achieve Towards Zero's vision of a future where no one is killed or seriously injured on our roads.

Drawing upon road safety evidence and educational research, the complex was co-created with young people and Victorian road safety and education experts. Road to Zero features:

- A permanent interactive exhibition (open to visitors) that explains the key tenets of Towards Zero
- A curriculum-based education program for secondary school students
- A mobile "pop up" exhibition to visit rural and remote communities
- Programs for other road user groups and road safety practitioners

The intention is that the Road to Zero Education Complex will operate, in partnership with Museums Victoria, until at least 2028. In 2019, over 70,000 people visited the interaction exhibition, and 11,000 young people completed road safety education programs at the Complex.

Road to Zero Exhibition, Melbourne

Speed and Crashes – Road to Zero

Community Support for Towards Zero

Survey research shows that 87% of the community agrees that Victoria should aim for zero road deaths. However, the high level of in-principle support does not translate into the belief that the zero target is achievable, held by only 18% of the community (TAC 2019).

Over the past three decades, behavior change campaigns have educated the public about road safety risk. Victorians look to the behavior of individuals as the "problem" requiring intervention for improvements in road safety. Surveys show that distracted drivers, drink-driving, and speeding are the road safety issues which are of most concern to Victorians (TAC 2019). Unsafe roads and vehicles are cited by far fewer as issues of concern. Victorians believe that how people drive is more important in saving lives than road design (TAC 2019).

However, there is public support for investing in infrastructure. On average, survey participants asked to allocate $100 to road safety interventions thought that $31 should be spent on roads, $27 on police enforcement, $23 on public education, and $19 on treatment for drug and alcohol addiction (TAC 2019). Encouraging the public to look beyond "blaming" driver behavior and to instead understand the contribution of the wider system remains a challenge.

Adoption of Towards Zero Approach Across Australia

Across Australia there are signs that positive steps are being taken in adopting the Vision Zero approach.

In August 2019, the Transport and Infrastructure Council (TIC) reported that they were "*strongly committed to developing the next National Road Safety Strategy based on a target of zero fatalities.*" They also noted that "*all investments in road infrastructure planning, design and construction will require application of Safe System principles and inclusion of safety treatments that align with these principles*." This was the first time that all states and territories within Australia had looked to plan for the long term and agreed to the adoption of an ultimate 2050 target of zero road fatalities for Australia. Importantly, the TIC defined "*the principles of a Safe System approach are: Human fallibility – People make mistakes on the road; Human vulnerability – Humans are physically frail with limited ability to tolerate the forces in a crash; and a Forgiving system – a road transport system must be 'forgiving' of mistakes within these limitations. (This) applies to all roads and investment sources*" (Australian Transport and Infrastructure Council 2019a).

Across the nation, states, territories, and cities are taking actions to realize the key principles of Vision Zero. Some specific examples are highlighted below.

- In Tasmania, the Safe System approach has been adopted, and action can be seen in its plans to upgrade the Midland Highway, its key north-south road. A combination of speed limit reductions (to 80 km/h) and barrier systems in conjunction with some low-cost tactile edge-lining is being used to make the road safe.
- The Hume Highway, Victoria's key north-south route and already a divided road, has been upgraded to be completely covered in flexible barrier systems. An early success came in 2019 when this 300-kilometer, high-volume road saw no fatalities, months before the road was fully completed.
- In South Australia, a large project aligning speed limits on rural roads to Safe System principles was undertaken in late 2011. This saw 52 roads (864 kilometers) reduced from 110 km/h to the rural default speed limit of 100 km/h. The public education campaign that accompanied the changes ensured the new speed limits were well understood and supported (Dua et al. 2013).
- Also in Victoria, some local government areas are making great headway. The City of Melbourne implemented a 40 km/h speed limit for the CBD in 2012, and in 2019 its draft transport plan outlined a program to trial lower speed limits on pedestrian priority streets also in the CBD (City of Melbourne 2019).
- Commencing in 2018, New South Wales has aligned the Towards Zero vision with Future Transport 2056, which aims to have a NSW transport network with zero trauma. It has embarked on an ambitious Road Safety Plan 2021 that included:

– Accelerated safety infrastructure investments of $820 million under "Saving Lives on Country Roads" and "Liveable and Safe Urban Communities" programs. The Plan commits to establishing road safety targets to drive the investment strategy for the state network, including targets for the proportion of travel on four- and five-star roads and the proportion of the road network with safety features, including median and roadside barriers.
– Expanded Fleet Policy with a focus on protective future vehicles to include safety features in the fleet in addition to the existing 5-star policy and new vehicle and technology testing facilities.
– Introduced lower speed zones in high pedestrian areas, a world first MotoCAP safety rating system for motorcycle protective clothing widely promoted to motorcyclists and business engaged to integrate road safety as part of work, health, and safety.
– Introduced the world's first mobile phone detection camera enforcement technology using artificial intelligence, broad-ranging drink- and drug-driving reforms including immediate sanctions upon detection and vehicle ignition interlocks for most drink-drivers, and a target of 200,000 random roadside drug tests.

• In 2018, the Queensland Department of Transport and Main Roads (TMR) developed a Road Safety Management Plan (RSMP) to embed Safe System principles and culture throughout the organization, meaning Safe Systems frameworks will be actively applied in the planning and design of road infrastructure (Peterson and Harrison 2018).
• Nationally, the Federal Government has committed to the deployment and uptake of proven vehicle technologies, looking to the UN 2022 Regulations and the World Forum for Harmonization of Vehicle Regulations (WP.29) as a guide for what could be adopted through the Australian standards (Australian Transport and Infrastructure Council 2019a).

Implications for the Future

Challenges Remain

The application of Safe System thinking to the road safety problem across Australia over the past two decades has given rise to significant safety gains. The continuing rollout of protective roadside and center-line infrastructure, reduced speed limits in areas of high pedestrian and cyclist concentrations, and the vigorous promotion of safer cars with passive and active safety features have all played a part. Targeted enforcement with supporting public education alongside technologies such as alcohol interlocks has served to nudge behaviors into safer forms.

And yet, across Australia over 1195 people continue to die on the roads each year, and approximately 40,000 more require hospitalization (BITRE 2020). These figures alone are stark reminders that the vision of achieving zero fatalities remains a distant aspiration and that the current road transport system remains inherently risky for the user.

Road Safety Management

A very detailed and high profile review of the National Road Safety Strategy was conducted in 2018 (Wooley and Crozier 2018) with strong support from the Australasian College of Road Safety, a body of road safety professionals and those interested in road safety that encourages professional development and information sharing while serving as a strong advocate for change at government level (see acrs.org.au). This review escalated the urgency within government circles in attending to a number of key safety priorities. In response to the review's recommendations, the Federal Government has now established an Office of Road Safety, reporting to a designated Federal Cabinet Minister, with key responsibilities including developing a new national strategy in collaboration with states and territories.

With a view to ensuring the success of these arrangements, a recommended governance review was also undertaken to provide advice with regard to agency structure, charter, and its relationship with external partners. Stronger action was urged in relation to "road safety" becoming "business as usual" across all government departments and related bodies as well as within the private commercial sector. The authority and resources vested in the new Office of Road Safety will be critical to its success.

In relation to the development of the next 10-year national road safety strategy (2021–2030), the review further recommended that a Vision Zero target of zero fatalities be set for the year 2050, consistent with the goal set by the European Commission, and that meaningful performance indicators be developed and adopted that accurately reflect interim safety progress across a range of safety-related domains (Wooley and Crozier 2018). The review also noted that targets have been framed mainly in terms of death and serious injury tallies within defined categories, their interim results rarely giving rise to a substantive change in safety directions. Establishment of safety performance indicators for key elements of the road transport system that will drive and achieve trauma reduction targets is a critical ingredient of effective and transparent road safety management into the future.

The Australian Transport and Infrastructure Council (TIC) that brings together Commonwealth, State, Territory, and New Zealand Transport Ministers as well as the Australian Local Government Association issued official statements in August and November 2019 (Australian Transport and Infrastructure Council 2019b) that confirmed the above commitments. The TIC also stressed that the new national strategy will complement jurisdictional strategies and that responsibility or delivery will be shared across all tiers of government.

History suggests that effective realization of the above recommendations is by no means straightforward. A commitment to a Safe System approach within strategies at the national and jurisdictional levels does not guarantee its full realization in practice. Many of the key road safety responsibilities relating to transport safety and regulation rest with the jurisdictions, while the Commonwealth manages vehicle safety regulations plus funding support for key infrastructure projects. Leadership at each tier of government will be required to realize the commitments made by all Transport Ministers.

Nevertheless, actions taken to date and commitments made by federal, state, and territory governments in response to the National Road Safety Strategy Review findings represent a very promising foundation upon which to build an effective attack on serious road trauma. Achieving genuine cultural change flowing down from the national government through the jurisdictional and local government entities to operational practice reflecting Safe System thinking represents a significant multifaceted challenge.

Furthermore, given the commitment to achieve zero road fatalities by 2050, it is incumbent upon governments to shape a pathway for how this target is to be achieved and what a safe and sustainable transport system should look like in 2050. In so doing, the main external forces that will shape the future together with the key safety and transport developments that will help to achieve the safety goal need active consideration. This issue is discussed further below.

Finally, the efficacy of achieving zero road deaths by 2050 is given a boost in the eyes of system builders and the community alike by achieving staged milestones that reflect genuine progress. To this end, the TIC agreed in principle to interim targets of Vision Zero for all major capital city business centers and high-volume highways by 2030 (Australian Transport and Infrastructure Council 2019c). In the meantime, the Federal Government has introduced a Vision Zero map that presents municipalities with zero deaths over specified time periods across Australia (see the Vision Zero maps at www.bitre.gov.au/statistics/safety).

Reporting and Accountability

The role of a strategy is to provide a blueprint for plotting an evidence-based pathway to achieving a defined goal at the end of the strategy's timespan. In the case of the new national road safety strategy under preparation, the aim is to achieve a 30% reduction in serious road trauma by 2030 on the road to its elimination by 2050. Future state and territory strategies concerning trauma targets will need to support these accordingly.

In parallel with the rollout of future national and jurisdictional strategies, a set of intermediate performance indicators needs to be established to track trauma trends at a macro level over time, to help build an understanding of progress in key aspects of the strategy's performance, and to underpin the progress made in reaching the nominated trauma target. The intermediate targets play a vital role in determining which safety programs are successful, which are not, and what adjustments are the most appropriate.

Given the very significant investment in public funds, it is incumbent upon government to be accountable and transparent in terms of progress made against targets and the future directions of implementation. Accordingly, governments need to establish mechanisms to ensure that the public is so informed and the governments are open to public scrutiny and enquiry as appropriate.

Adoption of the principles of accountability and transparency at the government level signals to the community its true commitment to achieving the desired trauma outcomes and its preparedness to accept responsibility for underperformance where relevant.

Future Challenges and Opportunities

How to Improve Speed Management and Road Infrastructure?

Australia has one of the largest networks per capita anywhere in the world, with a road network stretching more than 877,000 kilometers. Australians are very car dependent, with 75% of all passenger travel being road-based (Roads Australia 2020).

More than half of the roads in Australia are unsealed roads (IPWEA 2017). As many rural roads across Australia are low-standard, low-volume roads, this makes creating Safe System-compliant roads impossible through infrastructure treatments alone.

Strategically, the approach adopted in Victoria and consistent with many other jurisdictions is to invest in infrastructure treatments where cost-efficient to do so in order to maintain current travel speeds on roads that require a high "level of service." This has involved extensive flexible barrier rollout on high-speed freeways and highways. However, it is simply not financially viable to apply similar treatments to the long stretches of secondary and tertiary roads that crisscross the State. Managing speeds to within Safe System limits on these road types is likely to be the best option but in many instances remains a challenge.

All jurisdictions are facing pushback via intertwined political and sectoral community interests. In urban areas, some success has been enjoyed where speed limits have dropped at locations with high concentrations of pedestrian and cyclist activity. With some notable exceptions, neither the extensive local street system nor high-speed low-to-medium volume roads have enjoyed similar success. In this context, it is critical that revised standards and guidelines for road design including infrastructure support are linked to recommended speed limits consistent with Safe System principles. Improved design standards for roads alone do not guarantee Safe System solutions in many circumstances in the absence of harmonized speed management.

To date in Victoria, and to a large extent across Australia, speed has often been addressed as a stand-alone issue despite being linked to road function and the level of infrastructure support. Yet potentially its salience can grow as it is integrated within a broader sustainability agenda. The issues of climate change, health and well-being, reduced road maintenance, mobility, alternative and public transport, and accessibility are becoming increasingly prominent on the political and community landscape. Their mutual dependence has been little explored and promoted to date. Population growth and migration to the large cities only serve to heighten the need for sustainable solutions.

A future in which speed is integrated within a broader vision for transport holds considerable promise as a fruitful avenue for successfully promoting speed management in the context of a safe and sustainable transport system. This approach has received broad coverage and support internationally through the development and promotion of the Sustainable Development Goals (Trafikverket 2020). Aligning objectives and actions where relevant across environment, health, and transport portfolios represents an outstanding opportunity.

One area of recent progress in speed management that holds promise for the future has been the more active role of local government in agitating for reduced speed limits, especially in local streets on secondary high-speed roads. For example, speed limits are being lowered on nearly 40 roads within a large outer urban municipality of Melbourne as a two-year trial. The Western Australia government has committed to working with local government on an ongoing review of speed limits across the road network (Main Roads Western Australia 2020). In New South Wales, many local government authorities in inner Sydney have reduced urban speed limits in their municipalities to 40 km/h and 30 km/h.

Revising speed management practices to reflect Safe System principles and be more sympathetic to road quality and function ironically represents one of the least costly and most impactful road safety options, and yet receives the most resistance. There is no substitute for leadership committed to achieving a safe road transport system.

Finally, it should be noted that changing the speed limit on the vast network of secondary and tertiary roads does not in itself necessarily achieve a Safe System outcome. Increasingly, active and passive features in the vehicle fleet in conjunction with local travel speeds and infrastructure will assume greater safety importance.

Realizing the Benefits of Safer and Autonomous Vehicles

Vehicle replacement rates are slow across Australia, with the average age of a vehicle on-road being approximately 10.4 years (Australian Bureau of Statistics 2020). In 2019 in Victoria, the average age across all vehicles involved in fatal and serious injury crashes was 13.5 years (TAC 2020).

As new vehicles replace older vehicles in the Australian fleet, passive safety features such as side curtain airbags and improved cabin integrity will improve the safety outcomes for vehicle occupants (Wooley and Crozier 2018). ANCAP has provided an important advocacy role in reporting the safety performance of new cars and derivatives entering the market to consumers and bringing forward voluntary fitment and purchase.

It is, however, the road to automation in Australia that holds the greatest promise for the future. Given the high dependence on car usage in Australia, the progressive transfer of control from the driver to the vehicle will be particularly important to address the errors humans will inevitably make as well as a vast road network which is almost impossible to make safe. In a submission to the Victorian Parliamentary Inquiry to the Road Toll, Victoria's automobile club, RACV noted, "At the current rate of funding we estimate it would take over 1000 years to upgrade every road to an acceptable safety" (Hewitt 2020).

Technologies such as automatic emergency braking (AEB) and lane keep assist (LKA) are common features of newer vehicles, with evaluations testifying to their safety impact (Fildes et al. 2015; Sternlund et al. 2017). Moreover, technologies may combine to yield an even better safety outcome – for example, ESC (electronic stability control) and AEB together stabilize the vehicle and then reduce the impact speed respectively when a driver mistake cannot be corrected.

However, the uncollected safety dividends are substantial. There is an unacceptable gap between a proven technology being available in the marketplace and stipulating it as mandatory in new vehicles as part of the Australian Design Rule process. Every vehicle that rolls off the assembly line bound for Australia without the proven safety technologies fitted is an opportunity lost. For the life of that vehicle, it will operate at an inherently elevated level of risk that could have been avoided.

We can learn much from the European Union that in 2018, through the European Commission, announced a range of new safety technologies, variously applying to cars, vans, trucks, and buses for introduction by 2022 (European Commission 2019). Encouragingly, the Australian Government committed in August 2019 to streamlining the process of instituting regulatory changes to vehicle safety standards and will endeavor to align Australian regulations with the proposed European safety package (Australian Transport and Infrastructure Council 2019a). Achievement of this commitment in the future will greatly assist in saving lives on Australia's roads.

Further, there are two areas in the early phases of implementation that can have a very positive influence on vehicle safety in the longer term. The first is shared transport or shared self-driving car services in which the government can play an active role in encouraging its adoption and guided expansion within the private sector (International Transport Forum 2015). In simple terms, shared services can require fewer vehicles with higher occupancy travelling much greater distances in less time leading to faster vehicle replacement rates. Therefore, as new safety technologies enter the market, they will penetrate and benefit the on-road fleet much more rapidly.

The second is demonstrating the efficacy, convenience, and safety of autonomous vehicles through trials conducted with technical partners. Importantly, trials help to align technology advancements and operational practice with the regulatory framework together with supporting infrastructure and communication requirements. The journey towards a fully autonomous vehicle fleet holds great promise if the safety expectations for the future vehicle are clearly and unequivocally set to prevent the patterns of trauma typified in driver-controlled vehicles. A glimpse into the future helps to galvanize action as well as build community acceptance. Safety is an integral partner in this development.

Improved Data and Research

The value of life and health lies at the heart of Vision Zero, and leading jurisdictions have incorporated measures of injury severity and injury burden in their thinking (e.g., Risk of Permanent Medical Impairment in Sweden; see Berg et al. 2016). The focus on serious injury in Australia remains largely on hospitalization, a coarse measure of injury outcome.

A challenge in the Australian context is to better understand injury outcomes and the factors that contribute to, and which can prevent, the injury burden carried by crash-involved road users. Linkage of hospital data to crash data is required and has been achieved with some success in Western Australia and New South Wales (see Harrison et al. 2019) and more recently agreed to in Victoria following a linking of one year of data (Ziekemijjer and McIntyre 2018). An in-depth understanding of the long-lasting or permanent health impacts will allow for a more strategic approach to reducing the injury burden on the community and permit more precise measures in the future of safety performance by tracking trends over time in the most severely injured road users by categories of interest.

A constant companion of valid, reliable, and relevant data is the road safety research community. Australia is very fortunate as it has reputable, high-quality research centers in the majority of states. Resourcing a coordinated program of research and development across the safety centers with the focus firmly on advancing the practical application of Safe System principles to the road and traffic system represents a key plank in supporting effective implementation of the next national strategy. Investigations of the interrelationships between all the pillars of a Safe System deserves a strong presence in a future research program.

Conclusion

The introduction of Vision Zero, later termed as Safe System, has had a profound influence on road safety thought and practice across Australia.

The professional communities in the government and academia have largely embraced the approach and its ethical underpinnings. Road safety strategies across Australia invariably cite Safe System principles as the approach to guide the various safety measures to be implemented. Significant safety gains have been made, thanks to rollout of protective barriers on high-speed roads, reduced speed limits where vulnerable road users congregate, and vigorous promotion of safer new and used cars. Targeted legislative reform and stepped-up enforcement with public education support have also played a part.

But the Safe System approach has been delivered in part only. The challenge of managing speeds within safety thresholds on roads and streets where infrastructure treatments are cost-prohibitive is one prime example of an undelivered initiative. A reduction of travel speeds on lower-quality roads coupled with the increased prominence of advanced active and passive safety features in the vehicle fleet will greatly assist in the elimination as opposed to reduction of serious road trauma on Australia's roads. Understanding the interrelationships across Safe System pillars is key to plotting the most cost-effective pathway into the future.

Encouragingly, the Transport Infrastructure Committee, which includes the Ministers of Transport federally and from each state and territory, has made significant commitments for the new strategy, which include:

- A target of zero road deaths in 2050 together with intermediate targets.
- All major infrastructure investments will be subject to Safe System compliance.
- The safe vehicle design rule process will be streamlined to close the gap between the safest cars operating in Europe compared with Australia.

Importantly, the principles of Safe System will be faithfully applied in developing the new national 10-year strategy.

These are promising developments, and their realization is a significant challenge to be met as the new strategy takes shape and is then rolled out.

For Australia to succeed in achieving both the interim goals and the ultimate goal of zero road deaths in 2050, there is now no substitute for political will and accountability. People's lives and health depend on it.

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Vision Zero on Federal Level in Canada

16

Pamela Fuselli

Contents

Abstract

This chapter will provide a summary of high-level details regarding Vision Zero implementation in Canada, looking specifically at research, strategies, and implementation experiences in British Columbia, Edmonton, Calgary, and Fort Saskatchewan in Alberta, Toronto in Ontario, and Montreal in Quebec. This chapter

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will speak to the differences between Vision Zero implementation in Canada compared with Sweden, considering the viewpoint and circumstances of the unique governmental structure in Canada and implementation in municipalities versus entire provinces or territories. Priorities for the future of Vision Zero will also be discussed, along with the intersections and role of public health and other applications of Vision Zero.

Keywords

Vision Zero · Road Safety · Road Injury · Collisions · Active Transportation · Countermeasures · Speed · Distracted Driving · Impaired Driving · Aggressive Driving · Enforcement · British Columbia · Edmonton · Calgary · Fort Saskatchewan · Alberta · Ontario · Quebec · Montreal · Toronto · Sweden · Canada

Introduction

Canada is the second-largest country in terms of land mass in the world, with a land area of 9,093,507 km^2 and a population of 36.9 million (Canada Facts n.d.). The governmental structure in Canada creates a unique environment for road safety and road safety countermeasures, with federal, provincial or territorial, and municipal governments, First Nations governments, and other organizations and police forces each having a say in legislation, budgeting, and enforcement related to road safety. Adopting Vision Zero takes a sense of urgency in combination with time, patience, and collaboration to be successful, and means making a public commitment to road safety, setting targets, and allocating resources. Numerous cities and provinces of various sizes across Canada, both rural and urban, have been inspired by the success of Vision Zero in Sweden and numerous other countries around the globe. Seeing what can be achieved has driven road safety advocates from multiple fields and jurisdictions across Canada to get involved in conducting research on road safety and adopting Vision Zero.

Overview of Canada

With a wide range of geographical and weather differences, along with a unique jurisdictional framework, many facets can impact road safety. Canada has three ocean borders: the Pacific Ocean in the west, the Atlantic Ocean in the east, and the Arctic Ocean to the north (Government of Canada 2017a). Canada borders the United States in the south and in the northwest and has many different types of landscape, including: high mountains, the foothills, prairie grasslands, different types of forests, and the Arctic tundra, where the ground is permanently frozen (Government of Canada 2017a).

Picture source: Canada Facts (n.d.)

In Canada, there are four seasons: winter, spring, summer, and autumn. Winter is cold in most places, with temperatures often below zero degrees Celsius. Snow covers the ground from around December to March or April each year. In Southwest British Columbia (around Victoria and Vancouver), many winters have no snow at all but only rain (Government of Canada 2017a). Summer lasts from around June to September and the weather varies from warm to hot. Daytime temperatures are generally between 20 and 30 degrees Celsius or Centigrade (68 and 86 degrees Fahrenheit), or higher. In southern Ontario and Quebec, it can often be very humid (Government of Canada 2017a). Finally, fall and spring are transition seasons, meaning the weather starts getting colder or warmer, and there is a lot of rain (Government of Canada 2017a).

Federal, Provincial, or Territorial Structure

Ottawa is the capital city of Canada and is located on the Ottawa River between Ontario and Quebec. Canada has ten provinces and three territories, each with its own capital city. These provinces and territories are grouped into five regions: the Atlantic Provinces (Newfoundland and Labrador, Prince Edward Island, Nova

Scotia, New Brunswick); Central Canada (Quebec and Ontario); the Prairie Provinces (Manitoba, Saskatchewan, Alberta); West Coast (British Columbia); and North (Nunavut, Northwest Territories, Yukon Territory) (Government of Canada 2017a). Most people live in southern Ontario and Quebec, Southwest British Columbia, and Alberta. Much of the north has a very low population because of the cold climate.

Government Structures

Canada has three main levels of government: federal, provincial or territorial, and municipal and First Nations. The federal government is based in Ottawa, Ontario, which handles both national and international matters (Government of Canada 2017b). Provincial and territorial governments are the next level in each province and territory in Canada. Finally, there are municipal and First Nations governments.

The provincial and territorial governments have the power to change their laws and manage their own public lands. They are in charge of education, health care, and road regulations (Government of Canada 2017b). Further, municipal governments run cities, towns, or districts. They are in charge of parks, parking, libraries, roadways, local police, local land use, fire protection, public transportation, and community water systems (Government of Canada 2017b). Across the country, band councils govern First Nations communities. Band members elect the band council, which make decisions that affect their local community (Government of Canada 2017b).

Road Safety Efforts Leading up to Vision Zero in Canada

While the introduction of the Vision Zero approach was an impactful step for road safety in Canada, Canada's road safety work began long before Vision Zero was first introduced. Given the plateau in road safety progress in the mid-1990s in Canada and the desire for improved cooperation among Canada's road safety stakeholders, experts from various levels of government, nongovernmental organizations, and other key stakeholders participated in a national forum on road safety. The forum led to the creation of Canada's first national road safety plan, called *Road Safety Vision (RSV) 2001*, in 1996 (Canadian Council of Motor Transport Administrators 2013). Canada was one of the first countries to implement a national road safety strategy, and since the introduction of the *RSV 2001,* three national strategies have been adopted (Canadian Council of Motor Transport Administrators 2016). During *RSV 2001*, Canada saw a 10% decrease in fatalities and a 16% decrease in serious injuries, despite an increase in road user population (Canadian Council of Motor Transport Administrators 2016).

The second strategy, *RSV 2010* was approved by the Council of Ministers in 2001. The vision and strategic objectives were based on *RSV 2001* and included a national target and sub-targets. The targets provided road safety stakeholders with key road safety indicators to measure the impact of intervention efforts (Canadian Council of Motor Transport Administrators 2016). The national target was a 30% decrease in the average number of road users killed and seriously injured from 2008 to 2010 compared to 1996–2001, with an aim to reduce Canada's road fatality total to less than 2,100 by 2010 through achievement of the sub-targets (Canadian Council of Motor Transport Administrators 2016). While the 30% reduction in fatalities and serious injuries was not met by 2010, it was achieved in 2011 (Canadian Council of Motor Transport Administrators 2016).

In 2011, *Road Safety Strategy (RSS) 2015* was introduced. *RSS 2015* moved away from numerical targets, approaching road safety in a new, holistic way, and introducing the safer systems concept to tackle road user, vehicle, and road infrastructure issues (Canadian Council of Motor Transport Administrators 2016). This strategy introduced a framework of best practices, consisting of a multicell matrix of key risk groups and contributing factors, and an inventory of road safety initiatives that could be adopted to address priorities (Canadian Council of Motor Transport Administrators 2016). Jurisdictions were encouraged to develop their own road safety plans to meet their individual needs and adopt interventions to reduce fatalities and serious injuries (Canadian Council of Motor Transport Administrators 2016). In 2013, the number of fatalities and serious injuries on Canada's roads decreased by 21% compared to the 2006–2010 period (Canadian Council of Motor Transport Administrators 2016).

Finally, *Road Safety Strategy (RSS) 2025* is focused on the ambitious vision of "Toward Zero," and is based on the Vision Zero approach in Sweden and adopting the Safe Systems Approach to road safety (Canadian Council of Motor Transport Administrators 2016). Canada's Vision Zero approach can be characterized by the focus on helping and encouraging individual jurisdictions to implement road safety programs that meet their own needs, focused on the Safe Systems Approach and with an aspiration to achieve downward trends in fatalities and serious injuries on Canada's roads (Canadian Council of Motor Transport Administrators 2016).

Overview of Vision Zero in Canada

Vision Zero efforts in Canada began in a number of places including Edmonton, Alberta in 2015, and have continued to spread across the country since. Vision Zero has been adopted at the local or municipal level, such as in the City of Toronto, Ontario in 2016, to the provincial level, such as across the Province of British Columbia in 2016, and finally, at the national level, with the Road Safety Strategy 2025 also being developed in 2016. Several cities and regions, both rural and urban, continue to adopt Vision Zero in their jurisdictions.

Each level of government in Canada maintains unique road safety responsibilities; thus, when implementing Vision Zero in Canada, it is important to understand the governmental jurisdictional responsibilities and address each one, taking a collaborative approach to Vision Zero and road safety as a whole. This collaboration is exemplified through Canada's national road safety approach, which formally adopts

Vision Zero in principle. The Canadian Council of Motor Transport Administrators (CCMTA) developed Canada's Road Safety Strategy 2025 in 2016. The CCMTA is composed of representatives from all levels of the Canadian government, from the smaller-scale municipal level to the provincial, and finally the federal level. Each level contributes to the development of different road safety countermeasures.

To provide an example, standards for vehicle manufacturing are solely a federal responsibility, whereas built roadway design, maintenance, and re-design are shared among provincial or territorial, municipal, and First Nations governments. Further, while traffic laws are developed by federal, provincial/territorial, and municipal governments, they can be enforced by police at any level, such as the Ontario Provincial Police (OPP) at the provincial level, First Nations police, and the Royal Canadian Mounted Police (RCMP) at the national level (Government of Ontario 2019). Each level of government has a role to play in road safety in Canada and in the adoption of Vision Zero.

Vision Zero National/Federal

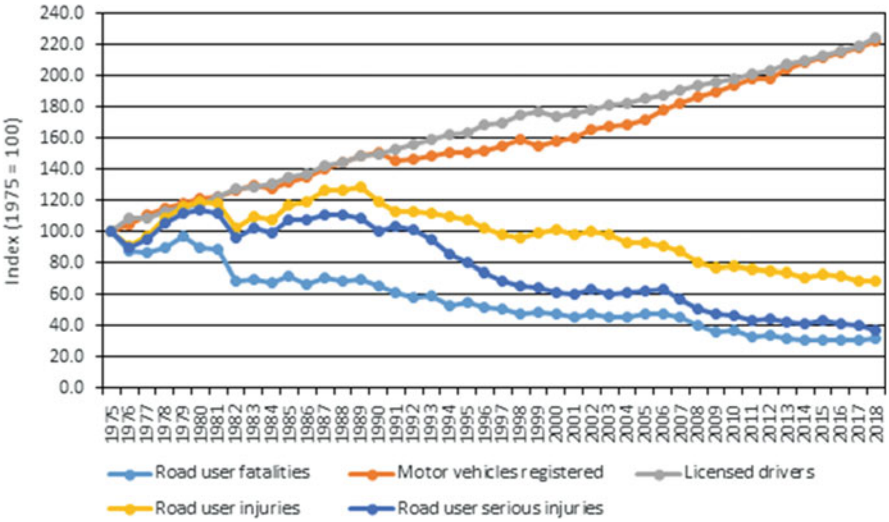
Transport Canada

Transport Canada is committed to keeping Canadian road users safe. As a federal regulator, the department updates vehicle safety regulations, standards and requirements for passenger vehicles, commercial vehicles, tires, and child car seats in Canada. The department plays an active role in crash test research and conducts tests on vehicle control technology and safety systems. Transport Canada is a leader in vehicle-defect reporting and investigations, and maintains the motor vehicle safety recalls database – the largest of its kind in Canada. The department also fosters innovation through its support, testing, and funding of projects related to automated vehicles, connected vehicles, and vehicle cybersecurity.

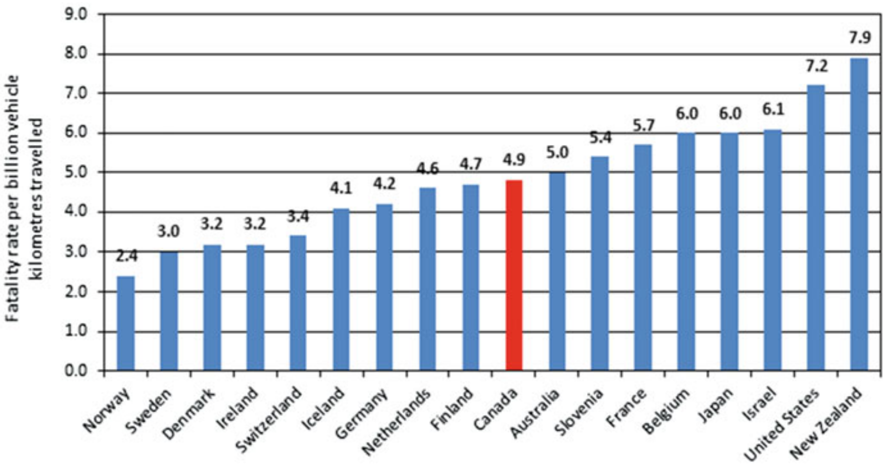
To advance a cohesive, national approach to road safety, Transport Canada works closely with the provinces and territories through the CCMTA on a range of national road safety issues, including commercial motor vehicle safety and vulnerable road users safety. Similarly, Transport Canada also works closely with the Transportation Association of Canada (TAC) to advance collaboration on safe road and highway infrastructure.

Overall Level of Road Safety

Over the last several decades, there has been a significant downward trend in motor vehicle casualties. Fatalities have decreased by almost 68%, while serious injuries have declined by 62% (Transport Canada, National Collision Database 2017). This notable progress was achieved despite significant growth in Canada's population, number of licensed drivers (+122%), number of registered vehicles (+124%), and vehicle kilometers travelled (Transport Canada as compiled from information provided by provinces and territories; Statistics Canada 2020).



In 2017, Canada was ranked 10th in terms of fatalities per billion vehicle kilometers travelled compared to other member countries of the Organization for Economic Cooperation and Development (OECD) (OECD International Transport Forum 2019). Safer vehicles, road infrastructure, and road user behavior have contributed to this greater level of safety. Seat belt use, for example, has increased from about 20% in the 1970s to 97% in 2016–2017.



Despite this tremendous progress, there is still significant work to be done. Transport Canada is a strong supporter of the international Vision Zero initiative to advance road safety. Our work in support of Vision Zero is facilitated through Canada's own Road Safety Strategy 2025. The Strategy has been endorsed by all ministers responsible for transportation and highway safety at the federal and provincial/territorial levels. An overview of key road safety issues and priority areas of Transport Canada's work in support of this strategy are discussed in further detail below.

Impaired Driving

Transport Canada continues to work collaboratively with provinces and territories through the CCMTA to address impaired driving. This includes assisting the provinces and territories in conducting roadside surveys to assess the number of drug-impaired drivers on the road. Through collaboration with the provinces and territories and partners from the road safety community, the percentage of fatalities involving a driver considered by police to be under the influence of alcohol has decreased from 21% in 2008 to 14% in 2017 (Transport Canada, National Collision Database 2017). Data also indicates that the percentage of Canadians that were fatally injured in road crashes involving a drinking driver has decreased from 34% in 2008 to 29% in 2016 (Lyon et al. 2019).

Further progress to address impaired driving will be supported by 2018 amendments to the Criminal Code of Canada (CCC). These amendments included new offenses related to driving under the influence of cannabis as well as new authorities for police to demand that any lawfully stopped driver provide a breath sample to test for alcohol.

Distracted Driving

Distracted driving is a serious safety concern for all Canadians. To address this challenge, all levels of government are working together through the CCMTA to implement an action plan on distracted driving. Key initiatives include: creating nationally consistent penalty regimes; supporting the development and refinement of data sources; and developing a best practice model for addressing distracted driving, including legislative measures, enforcement tools, and techniques to assist police.

As part of this action plan, the department worked closely with the CCMTA and the provinces and territories to develop a report on distracted driving, which includes best practices for addressing this issue. Published in December 2018, the report is available at https://ccmta.ca/en/ccmta-s-distracted-driving-white-paper-now-available.

Transport Canada also encourages vehicle and electronics manufacturers to design devices that are compatible with safe driving. In February 2019, the department published the Guidelines to Limit Distractions from Visual Displays in Vehicles, which can be found at http://www.tc.gc.ca/en/services/road/stay-safe-when-driving/guidelines-limit-distraction-visual-displays-vehicles.html.

Vulnerable Road Users (VRUs)

Transport Canada is taking action to better protect vulnerable road users, including pedestrians and cyclists. In October 2018, the Council of Ministers Responsible for Transportation and Highway Safety published its report Safety Measures for Cyclists and Pedestrians around Heavy Vehicles – Summary Report outlining 57 safety measures to better protect vulnerable road users. Further, in January 2019, the Council of Ministers approved next steps for the implementation of the report, with an emphasis on pilot projects, knowledge exchange, and reviewing safety standards and regulations. To build momentum in this area, Transport Canada has launched on-road field trials, in collaboration with municipal partners, to evaluate the effectiveness of a detection and visibility system on commercial vehicles.

Heavy Commercial Vehicles

Commercial motor vehicle safety is also a shared responsibility among federal, provincial and territorial governments, and owners/operators. Under the Motor Vehicle Safety Act, Transport Canada is responsible for establishing the Canada Motor Vehicle Safety Standards, which includes specific safety requirements for commercial motor vehicles, such as brake systems, stability control, tires, and lighting, among others. The Department works with all levels of government to keep these standards up-to-date, and performs tests to ensure compliance. Under the Motor Vehicle Transport Act, Transport Canada is also responsible for certain operational matters relating to commercial motor vehicle activity (e.g., hours of service and safety ratings).

Our collaborative work with provinces and territories through the CCMTA to strengthen commercial motor vehicle safety includes measures to prevent fatigue and distracted driving. For example, in June 2019, the department published a regulation mandating electronic logging devices (ELDs) for commercial carriers to reduce the risk of fatigue-related collisions. The work with the CCMTA also includes finalizing a national standard for entry-level training for commercial drivers. This standard represents an important milestone for road safety in Canada and will help ensure drivers have the necessary knowledge and skills to safely operate commercial vehicles.

While school buses are recognized as the safest way to transport school children in Canada, Transport Canada, together with provincial and territorial partners, recognizes that there are ways to make school buses even safer. To advance this important issue, on January 21, 2019, the federal, provincial, and territorial Council of Ministers Responsible for Transportation and Highway Safety established an expert Task Force on School Bus Safety, composed of the aforementioned governments, fleet operators, bus manufacturers, school boards, driver unions, and safety associations, to identify opportunities to further strengthen school bus safety. Specifically, the Task Force was mandated to review safety standards and operations, both inside and outside the school bus, with an emphasis on seat belts.

Automated and Connected Vehicles

Transport Canada has undertaken a number of initiatives to support the safe testing and deployment of connected and automated vehicle technologies, building on recommendations found in the January 2018 report Driving Change, prepared by the Senate Committee on Transport and Communications. Since the report's publication, Transport Canada has amended the Motor Vehicle Safety Act (MVSA - March 2018) to afford greater flexibility to keep pace with emerging technologies (e.g., modernized/new authorities to grant exemptions, take enforcement action, and modify or suspend outdated regulations).

In February 2019, the department also released Canada's Safety Framework for Automated and Connected Vehicles, which articulates the department's vision for the safety of these technologies. The Framework is supported by a number of guidance documents including the Safety Assessment for Automated Driving Systems in Canada, and Testing Highly Automated Vehicles in Canada: Guidelines for Trial Organizations. All of these documents as well as additional information on the Government of Canada's work to address automated driving systems can be found at: http://www.canada.ca/automatedvehicles.

Transport Canada is also conducting research into advanced driver assistance systems, which in many cases feature low-level automation features that can enhance the safety of road users. Transport Canada continues to explore ways to support consumer awareness of the safe use of these features, including publishing information at: https://www.tc.gc.ca/en/services/road.html.

Canadian Council of Motor Transport Administrators Road Safety Strategy 2025

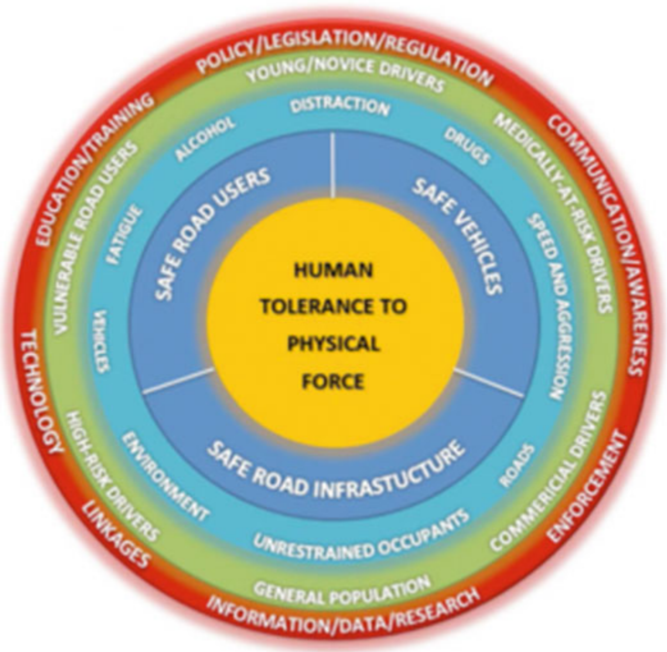
The Canadian Council of Motor Transport Administrators (CCMTA) coordinates matters dealing with the administration, regulation and control of motor vehicle transportation, and highway safety. CCMTA members represent provincial, territorial, and federal governments and are committed to shared road safety goals in Canada. CCMTA works for Canadians by ensuring that government and road safety stakeholders have a national forum to come together and share knowledge on current and emerging road safety priorities that impact jurisdictional and national policy. This approach is built on the values of engagement and accountability, and respects jurisdictional autonomy to adopt or adapt specific programs as appropriate. Canada is one of the first countries in the world to adopt a national road safety strategy in 1996 and, to date, three national strategies have been launched (2001, 2010, and 2015). With the help of CCMTA's road safety programs, research, collaborative partnerships, and public education campaigns, Canada has seen continued downward trends in fatalities and serious injuries on roads despite more drivers, vehicles, and kilometers travelled since 2001(CCMTA 2016).

Road Safety Strategy 2025 is intended to continue to encourage road safety stakeholders from all levels of the government, as well as private sector, and non-governmental stakeholders, to collaborate in making Canada's roads the safest in the world and unite efforts to reach the long-term vision of zero fatalities and serious injuries on Canadian roads. It was developed with the intention of helping jurisdictions implement road safety programs that meet their own needs. Road Safety Strategy (RSS) 2025 is similar to its predecessors in a number of ways. It retains the long-term vision of making Canada's roads the safest in the world but combines this with the vision of **Toward Zero**. A number of principles key to the strategy's success have been aligned with international best practices in road safety. These principles include adopting the Safe System Approach, a 10-year timeline, and providing an inventory of proven and promising best practices to address key risk groups and contributing factors.

RSS 2025s vision, "Toward Zero – The safest roads in the world" is based on an international best practice first adopted by Sweden in 1997, where Vision Zero was approved by parliament and has permeated the country's approach to road safety ever since. It has resulted in Sweden having among the lowest traffic-related fatality rates worldwide and has led to other countries and municipal governments initiating similar approaches. Toward Zero is not a target to be achieved by a certain date; it is aspirational. This vision will continue beyond RSS 2025s timeline and highlights the desire for the best road safety outcomes for all Canadian jurisdictions.

The following strategic objectives form the cornerstone of RSS 2025 and focus on safer road users, road infrastructure, and vehicles: raising public awareness and commitment to road safety; improving communication, cooperation, and collaboration among stakeholders; enhancing legislation and enforcement; improving road safety information in support of research and evaluation; improving the safety of vehicles and road infrastructure; and leveraging technology and innovation. Core to the strategy is an inventory of best-practice interventions used by leading road safety countries that have been effective in reducing fatalities and serious injuries.

RSS 2025 further lays out guiding principles to adopt a Safe System Approach. The Safe System Approach (SSA) is how many countries leading in road safety are achieving their vision of eliminating deaths and serious injuries. SSA contains the following principles: Ethics (human life and health are paramount and take priority over mobility and other objectives of the road traffic system and life and health can never be exchanged for other benefits within the society); Responsibility (providers and regulators of the road traffic system share responsibility with users); Safety (road traffic systems should take account of human fallibility and minimize both the opportunities for errors and the harm done when they occur); and mechanisms for change (providers and regulators must do their utmost to guarantee the safety of all citizens; they must cooperate with road users; and all three must be ready to change to achieve safety). It is recognized that Canadian jurisdictions will implement the SSA in a manner that is appropriate to their environments.



Source of picture: CCMTA version specifically developed for RSS 2025 adapted from the 2009 WHO report on the Global Status on Road Safety which was in turn modified from work commissioned by the Government of Western Australia.

RSS 2025 seeks to achieve directional downward trends in the rate-based number of fatalities and serious injuries rather than in the actual numbers of fatalities and serious injuries. These trends will be measured at the national level annually, using multi-year rolling averages to smooth out short-term fluctuations since year-over-year reductions may not be practical or attainable. In Canada, the rate-based indicators are fatalities and serious injuries per billion kilometers traveled and fatalities and serious injuries per one hundred thousand population. These rate-based indicators are commonly used internationally as well. Although RSS 2025 does not include hard quantitative targets, it does not preclude individual jurisdictions or organizations from establishing their own targets when there is government, law enforcement, and/or road safety stakeholder support for doing so.

Canadian Association of Road Safety Professionals: A Multidisciplinary Approach to Vision Zero

The Canadian Association of Road Safety Professionals (CARSP; CARSP.ca), founded in 1985, is a national organization dedicated to enhancing road safety at home and abroad. CARSP currently has a membership of 551 members (both individual and corporate). CARSP supports Canada's road safety community by providing access to multi-disciplinary information, research, and networking opportunities. CARSP is a diverse group of professionals involved in the research, management, delivery, and promotion of road safety programs, from a broad array of disciplines (from engineering to social science and health promotion) and employers (public, private, at the federal, provincial, and local levels). CARSP encourages the sharing of professional experience; facilitates communication and cooperation among road safety groups and agencies; promotes research and professional development; and provides an influential voice for road safety professionals to communicate knowledge-based advice to policymakers.

CARSP members belong to various disciplines: Government (Federal, provincial/territorial, or local); Police/enforcement (federal, provincial/territorial, and local); University/College (e.g., Engineering, Psychology, Epidemiology, and Health Sciences); nonprofit safety organizations (e.g., Safety Councils, Injury Prevention units, and Drinking and Driving Counterattack groups); private consultants (e.g., in Engineering, Planning, Geography, and Technology); research agencies (e.g., Traffic Injury Research Foundation, Canadian Centre on Substance Abuse), driving institutes, motor associations (e.g., Canadian Automobile Association), insurance organizations (e.g., Saskatchewan Government Insurance, Insurance Corporation of British Columbia, and Manitoba Public Insurance); and legal professionals.

CARSP's vision statement is: "Professionals collaborating in research and practice to make our roads the safest in the world." Vision Zero and other related statements with an ultimate goal of zero fatalities and serious injuries on public roads are consistent with CARSP's vision. CARSP's position is that statements of Vision Zero, while important, are unlikely to accelerate progress toward such a goal without quality data, rigorous evaluation, bold leadership, sustainable funding, and significant changes in both the public and institutional culture. The expansion of dedicated facilities for vulnerable road users, the continuing shift from personal vehicle to public transit use, significant changes to land use planning and speed management and the evolution of vehicle automation are all critical toward achieving these goals.

To help spread knowledge about Vision Zero in Canada, CARSP has given it a strong emphasis in the planning of its activities. CARSP hosts an annual conference that attracts Canadian and international delegates. The conference features keynote speakers, panel discussions and paper sessions in both "Policy and Practice" and "Research and Evaluation" streams. Vision Zero topics have been included since 2015 and were the overall conference theme in 2019.

The 2019 conference included sessions on the Safe Systems Approach and city-wide road safety plans, distracted driving and crossing, vulnerable road user safety, speeding and risky driving, cycling safety, driver training and driver fitness, truck safety, pedestrian safety, autonomous vehicles, connected vehicles and networks, and advanced vehicle technology and built environment's relationship to road safety, to name a few. A special "fireside chat" panel session on Vision Zero was also held, in which themes such as the public health approach and the power of the media and the general public in Vision Zero were explored. A full-day workshop, "Vision Zero – Understanding and Action," was also held as part of the conference, which translated the principles of Vision Zero into decision and action using real-life examples.

CARSP regularly offers in-person workshops and webinar presentations on Vision Zero, delivered by a wide range of practitioners from across Canada and abroad. Its monthly publication, *Canadian Road Safety News Digest,* covers the latest news stories across the country related to Vision Zero; and a quarterly newsletter, *The Safety Network*, covers initiatives and research by road safety professionals on topics such as Vision Zero. Finally, in support of its vision to make Canadian roads the safest in the world, CARSP continues to coordinate with other national organizations – such as Parachute and the Transportation Association of Canada – to collaborate on areas of common interest related to Vision Zero. CARSP maintains the clear and persuasive position that only through a complete multi-disciplinary approach endorsed by organizations such as CARSP can the ultimate goal of zero be achieved.

Transportation Association of Canada: Road Safety and Vision Zero

The Transportation Association of Canada (TAC; www.tac-atc.ca) is a not-for-profit, national technical association that focuses on road and highway infrastructure and urban transportation. Its 500 corporate members include governments, businesses, academic institutions, and other associations. TAC provides a neutral, nonpartisan forum for those organizations, and their thousands of staff, to come together to share ideas and information, build knowledge and pool resources in addressing transportation issues and challenges.

TAC celebrated its centennial in 2014 and, with more than 100 years of history in the transportation sector, is continuing its important work to identify best practices and encourage harmonization of those practices across jurisdictions. While TAC does not set standards, it produces credible transportation planning, design, construction, management, operation, and maintenance guidelines that emphasize safety. Safety is one of six focus areas in TAC's strategic plan, which encourages efforts to address road safety through a combination of engineering, education, and enforcement, and by adopting Safe Systems Approaches to plan, design, and build infrastructure, and deliver transportation services. To that end, almost every TAC technical guideline offers means, directly or indirectly, to improve and ensure transportation safety.

TAC's volunteer councils and committees share knowledge, exchange information, and discuss a wide variety of issues to advance the state of transportation. The Road Safety Standing Committee (RSSC), formed in 2000, is concerned with raising awareness of road safety issues among TAC members; identifying and prioritizing road safety issues; promoting safety-conscious, knowledge-based approaches; emphasizing the need for dedicated roadway safety staff at all levels of government; and providing road safety training for transportation professionals.

For several years, the RSSC has endorsed the Safe Systems Approach, with engineering as a critical component. Since 2015, the RSSC has discussed Vision Zero and organized several conference sessions, workshops, and webinars related to the development of road safety plans. In its newly adopted strategic plan, the RSSC commits to be a catalyst for Vision Zero and Safe Systems Approaches. This direction is supported by three initiatives: (1) Create a Vision Zero and Safe Systems Subcommittee; (2) Conduct a constructive review of TAC publications with respect to safe systems concepts; and (3) Enable Vision Zero and safe systems knowledge exchange.

TAC has spent several years developing a series of publications on road safety for Canadian practitioners and is now planning future enhancements to consolidate this knowledge into a comprehensive guide. Finally, road safety will also be the theme of TAC's 2020 Conference and Exhibition in Vancouver, British Columbia. Through these and other endeavors, TAC and its RSSC will continue to support research and development, knowledge transfer, and the development of guidelines in support of Vision Zero and Safe Systems principles.

Traffic Injury Research Foundation: Strategies to Support Vision Zero in Canada

The Traffic Injury Research Foundation (TIRF; www.tirf.ca) is one of Canada's road safety research institutes and a world leader in research, program and policy development, evaluation, and knowledge transfer. Established as a registered charity, TIRF studies the human causes and effects of road crashes. Its focus is on people on the roads and behaviors that result in driver error and account for more than 90% of road crashes.

For more than four decades, TIRF has maintained a National Fatality Database to enhance understanding about why road users behave as they do. These data have been the foundation for the development and implementation of solutions aimed at addressing underlying causal factors. TIRF's work has evaluated a broad spectrum of road safety policies and programs and helped stakeholders identify effective solutions. Its research has been widely shared to inform decisions and action by government, business and industry, traffic safety agencies, and nonprofit organizations in many countries. Findings published by TIRF have contributed to crash reductions and improved safety for all Canadians by creating and sharing knowledge about current and emerging issues and trends that place road users at risk.

Most importantly, TIRF has developed its own knowledge transfer model using a "Systems Approach" to promote shared understanding of issues with a focus on implementation. This has enabled TIRF to bridge gaps and build partnerships among agencies and practitioners across the many sectors affected by road crashes. Collectively, these activities are important to help support Vision Zero initiatives at all levels in Canada. As jurisdictions increasingly adopt strategies to achieve zero deaths, research and best practices are essential to guide the development of programs and policies, just as evaluation research is vital to determine if investments in countermeasures are wise and will produce a return on investment in the form of fewer deaths and injuries. Of equal importance, communities need tools to help them use research as they embark on the pursuit of road safety strategies. Today, many communities are better informed about what needs to be done to make roads safer, but they struggle with how to do it.

To fill this gap, in 2017 TIRF turned its attention to creating knowledge and a series of tools to help communities do just that. TIRF, in partnership with Desjardins, used its knowledge and expertise gained over five decades to design a web-based suite of road safety resources, the Action2Zero Centre. The objective of this Center was to help communities use research to guide the development and implementation of strategic road safety plans based on Vision Zero and Safe System philosophies. In particular, the Center can enable communities to raise awareness and build capacity for effective road safety initiatives, to monitor and measure program outcomes and improvements in road safety, and to support the work of local governments and their road safety partners.

A key feature of the Center is an automated, online tool that communities can use to assess the status of road safety in their community across several domains, such as speed management, infrastructure for vulnerable road users, distracted driving, and leadership. The assessment tool developed by TIRF uses a set of road safety criteria for a five-star community based on international research and best practices. This five-star community approach is in line with other areas of safety that describe five-star ratings for roads (e.g., International Road Assessment Program or IRAP) and vehicles (e.g., five-star safety ratings for vehicles used by the National Highway Traffic Safety Administration or NHTSA, and the Insurance Institute for Highway Safety or IIHS). As such, the assessment tool helps communities track progress toward five-star status.

The Center meets the needs of a wide spectrum of road safety stakeholders including local government, public health, law enforcement, schools, community-based organizations, engineers, and city planners. The online tool enables communities to identify which measures have been implemented and areas where greater efforts are required. Ultimately, outcomes of the tool provide a clear picture of potential components of a strategic plan and suggest the types of knowledge, expertise, and resources needed to achieve further reductions in road deaths and injuries.

It is structured in several stepwise modules to help communities build support, buy-in, and partnerships for the implementation of plans to accelerate action and improve road safety outcomes. A suite of templates and tools, links to relevant research, and best practices are contained within the Center to share experiences from other jurisdictions and help communities implement a variety of road safety strategies, such as creating effective road safety campaigns, improving safety in school zones and reducing speeds in residential areas. It also provides guidance on approaches to engaging stakeholders, building partnerships and communities of practice, and organizing committees for specific tasks. This initiative is being piloted in three jurisdictions in Canada and will launch in 2019 at act2zero.tirf.ca.

Parachute: Vision Zero Network

Parachute is Canada's leading national charity dedicated to injury prevention, with a vision of a Canada free of serious injuries, with Canadians living long lives to the fullest. Parachute Vision Zero works to share current research and best practices in road safety, support data-driven models, create and disseminate evidence-based resources, and bridge key multisector players together to increase the overall awareness and effectiveness of the Vision Zero approach. By building awareness of Vision Zero, Parachute also builds capacity for more jurisdictions across Canada to integrate a Vision Zero approach. At an individual level, implementing the Vision Zero approach in communities will ultimately lead to a shift in thinking about motor vehicle collisions, moving away from the belief that these are *accidents* and toward the understanding that collisions are predictable and preventable.

Parachute Vision Zero provides case studies and infographics on important road safety topics, such as safe school zones, cannabis- and drug-impaired driving, collision avoidance systems in vehicles, and data-driven approaches, alongside summaries of Vision Zero implementation experiences across Canada, including videos and interviews with key stakeholders. Further, Parachute Vision Zero gathers Vision Zero resources worldwide and has also created several of its own resources and tools to help communities move from thinking about Vision Zero to adopting and implementing this road safety approach successfully.

Parachute, with support from Desjardins, created the Parachute Vision Zero Network to bring together road safety experts and advocates across Canada. Parachute acts as a facilitator to create positive change by bringing network members together to exchange information and ideas, and to work together to improve safety on Canada's roads. The Network continues to grow, with more than 335 members as of October 2019.

Parachute has remained active as a leader in Vision Zero in Canada, participating in panel discussions, holding events such as summits for Parachute Vision Zero Network members, and speaking at major conferences, such as the CARSP conference in Calgary, Alberta in May 2019. In 2017, Parachute held a two-day conference for Vision Zero Network members, bringing together grassroots organizations, enforcement, public health professionals, and researchers to discuss the implementation of Vision Zero in Canada. In 2019, Parachute's President and CEO, was a keynote speaker at the CARSP Conference, delivering a presentation on Vision Zero in Canada. Parachute was also active in panel discussions and a post-conference workshop at the CARSP conference.

Health Canada Substance Use and Addictions Program (SUAP) provided funding to Parachute for a three-year project entitled *#KnowWhatImpairedMeans*. The project looks at drug-impaired driving in Canada, particularly among Canadians between 15 and 24 years of age. As cannabis became a legal drug in Canada in 2018, Parachute launched a small-scale #KnowWhatImpairedMeans campaign to point out that, while cannabis was now legal, it is still illegal to drive high and can have a negative effect on a person's reaction time and focus. The national #KnowWhatImpairedMeans campaign launched in fall 2019 and was designed to raise awareness around the dangers of drug-impaired driving, in a way that resonates with online youth audiences. Messaging is informed by the population of interest, is evidence-based, and focuses on why cannabis impairs one's ability to operate a motor vehicle safely. Learn more about the #KnowWhatImpairedMeans campaign at parachute.ca/knowwhatimpairedmeans.

Canadian Research Related to Vision Zero

There is a significant volume of road safety research taking place in provinces across Canada. These research studies cover a number of key topic areas, including: active transportation and safe school zones, impaired driving, road safety countermeasures (technology and infrastructure), and vulnerable road users (cyclists, pedestrians, and older adults), to name just a few.

Active Transportation and Safe School Zones

Active transportation refers to any human-powered form of travel, such as cycling, walking, and skateboarding. Often, research may look at active transportation and safe school zones in combination, given the overlap in the subject areas and the need for children to be able to travel to and from school safely, regardless of their mode of transportation. Safe school zones often include measures such as traffic calming, built environment changes, and enforcement. Some Canadian research studies in these areas include:

- *Alberta*
  - *Child Active-transportation Safety and the Environment* (CHASE), Hagel et al.
  - *Before and After Evaluation of School Zones*, El-Basyouny.
- *Ontario*
  - *Effectiveness of Built Environment Interventions Around Schools in Improving Road Safety and Increasing Active School Transportation*, Rothman et al.
- *Quebec*
  - *Children and social interaction outside school: what are the roles of transport and information and communication technologies (ICTs)?*, Owen Waygood.

Impaired Driving

With the legalization of cannabis in Canada and continuous monitoring of drinking and driving regulations, there is a need for research on different influences, environments, and interventions around impaired driving. Impaired driving research studies in Canada are looking at the effects of driving under the influence of drugs (including cannabis), alcohol, and prescription medications. Canadian research in this area includes:

- *British Columbia*
  - *Monitoring and Preventing Drug-Impaired Driving in Canada*, Brubacher et al.
  - *Prescription Medications and the Risk of Motor Vehicle Crashes,* Brubacher et al.
  - *Evaluation of the Effect of Cannabis Legalization on Road Safet*y, Brubacher et al.
  - *Cannabis and Motor Vehicle Crashes: A Multicentre Culpability Study,* Brubacher et al.
- *Quebec*
  - *Team in Transdisciplinary Studies on Driving While Intoxicated at the Douglas Research Centre, McGill University,* Marie Claude Ouimet and Thomas Brown.

Road Safety Countermeasures

Road safety countermeasures are steps that are taken to improve road safety for all road users. Road safety countermeasures can include technology advancements, such as driver feedback signs, photo enforcement, and red light cameras, built environment changes such as roundabouts, cycling lanes, and intersection improvements, or policy changes such as speed limit reductions. Some Canadian research in this area includes:

- *Alberta*
  - *A Safety Assessment of Driver Feedback Signs* (DFS) *and Development of Future Expansion Program*, El-Basyouny and Kwon.

  - *Deployment Strategies for the City of Edmonton's Mobile Photo Enforcement* (MPE) *Program,* El-Basyouny and Kim.
  - *Before and After Evaluation of Intersection Safety Devices* (ISD) *Evaluation,* El-Basyouny.
- *British Columbia*
  - *Evaluation of Traffic Safety Interventions in British Columbia, Brubacher et al.*
  - *Evaluation of Speed Limit Changes in British Columbia, Brubacher et al.*

Vulnerable Road Users (VRU)

Vulnerable road users (VRU) are unprotected against the speed and mass of vehicles on our roadways and thus tend to suffer more severe consequences in collisions (European Road Safety Observatory 2018). Studies in this area cover VRUs such as cyclists, pedestrians, and older drivers, considering factors such as the influence of the built environment on VRU crashes. Canadian research in this area includes:

- *British Columbia*
  - *Bicyclists' Injuries and the Cycling Environment (BICE) study*, Teschke et al.
- *Quebec*
  - *CHASE project: Child Active Transportation Safety and the Environment, Marie-Soleil Cloutier.*
  - *Pilot project on the road safety of all-way stops intersections using surrogate safety methods, Luis Miranda-Moreno.*

Another major trend in research on driving behavior and mobility is related to the growing older adult population. Older adults often require monitoring of their driving through education, evaluation, and intervention, and help to cope with the eventual end of their driving "career" in certain cases. Canadian research in this area includes:

- *Quebec*
  - *Impact of two functional capacity training programs on the ability to drive of older drivers*, Martin Lavallière.
  - *To drive or not to drive? Understanding the influence of the complex relationships between personal and environmental factors on the driving mobility of older Canadians,* Mélanie Levasseur.

This is not a comprehensive list of research being conducted in Canada related to Vision Zero. Dr. Karim El-Basyouny's study, *Assessing the Safety Effects of Achieving Bare-Pavement Road Conditions for Winter Maintenance* and Dr. Jeff Brubacher's study, *Predictors of Poor Health and Functional Recovery Following Road Trauma: An Emergency Department Inception Cohort Study.*

Vision Zero Implementation

British Columbia

Background

British Columbia (B.C.) is home to more than five million residents, ranking as the third-highest populated province in Canada (Government of British Columbia 2019; Statistics Canada 2019). With a long history of natural resource use, B.C. hosts a large, unpaved road network – covering 66% of the entire province's land base. There are precisely 57,100 km of paved roads in comparison to the massive 662,000 km of unpaved roads (Environmental Reporting BC 2018). Although there is a smaller paved road network compared to land mass, safe roadways and systems are critical to the residents, businesses, and visitors who travel the vast province using multiple modes of transportation each day. On average, B.C. receives nearly 20 million visitors each year, with more than seven million visitors using key highways throughout the province (Destination British Columbia 2019).

The province has a diverse and lush natural landscape, with rapidly changing weather and climate conditions, which can create a unique challenge when analyzing roadways and infrastructure. In addition, B.C. is located along Canada's Pacific Gateway, moving people and goods between North America and the world through marine ports, railways, roads, and airports to provide efficient and reliable market access.

In Vancouver, the province's largest city, there is a higher percentage of residents walking or cycling to work than any other major city in Canada (City of Vancouver 2017). Fifty-two percent of residents drive, 16% travel by transit, 25% walk, and 7% cycle (City of Vancouver 2017). Fifty-five percent of fatal collisions on Vancouver roads in 2017 involved pedestrians, cyclists, or skateboarders (City of Vancouver 2019). In Surrey, a major city in British Columbia, 81% of residents drive, 15% travel by transit, 3% walk, 1% travel via motorcycle, and 0.4% cycle (City of Surrey n.d.). In Vancouver, 55% of fatal collisions in 2017 involved pedestrians, cyclists, or skateboarders (City of Vancouver 2019). On Surrey roads, a pedestrian is 42 times more likely to die in a collision than a person driving a motor vehicle (City of Surrey n.d.).

Vision Zero in British Columbia

In 2016, B.C. became the first Canadian province to adopt Vision Zero. After success with *British Columbia Road Safety Strategy 2015*, the province released an updated report: *Moving to Vision Zero: Road Safety Strategy Update and Showcase of Innovation in British Columbia*, aligning with Canada's Road Safety Strategy and officially adopting Vision Zero (RoadSafetyBC 2016). B.C.'s approach to Vision Zero focuses on the four pillars of the Safe Systems Approach: safe road users, safe vehicles, safe roadways, and safe speeds, and incorporates evidence-based practices and in-depth study into how road safety is managed across the province.

B.C. uses 10-year collision data from police reports to monitor the effectiveness of their Vision Zero initiatives. The reports consider fatalities, serious injuries,

injuries, as well as the contributing factors for the collision(s) (RoadSafetyBC 2018). Factors include speeding, distracted driving, impairment and aggressive driving, driver error, and environmental factors. The most recent report (2008–2017) states speeding and impairment were the contributing factors that had the highest rate of fatal victims per police-reported crash. However, the most common factors for collisions can be attributed to distracted driving and aggressive driving.

Countermeasures

Collaborative Projects

The Ministry of Transportation and Infrastructure recently released its new active transportation strategy – *Move. Commute. Connect.* – designed to encourage active transportation use with a variety of incentives and work with communities to create policies and plans that support complete active transportation networks around the province (CleanBC 2019). This strategy includes a focus on safety and integrating transportation and infrastructure planning to ensure that projects such as new bridges and interchanges are designed to make walking, cycling, and transit safe and convenient for everyone. As part of this work, the Ministry released the B.C. Active Transportation Design Guide in June 2019, which is available free of charge to anyone in the world.

Further, led collaboratively by a Steering Committee of Senior Level Officials, and a cross-section of partners from across the Province, the B.C. Road Safety Strategy (BCRSS) aligns Vision Zero with the strategic direction for five working committees, each with a diverse group of experts in their fields, collaborating on road safety issues. The BCRSS Working Committees meet on a regular basis to identify issues and priorities, propose solutions, provide their diverse expertise and perspectives, and support the implementation of various initiatives.

Most recently, as part of the BCRSS, RoadSafetyBC released the B.C. Community Road Safety Toolkit to provide information for local governments on proven road safety best practices, including those that can improve safety for vulnerable road users, such as cyclists and pedestrians (Government of British Columbia n.d.-a). In addition to the development of the toolkit, the organization met with hundreds of local government representatives at their annual regional meetings, along with partners from the Insurance Corporation of British Columbia (ICBC), to talk directly to the communities about their unique road safety concerns.

The Ministry of Transportation and Infrastructure and the ICBC work on the Community Safety Enhancement Program and Road Safety Partnership, with the goal to address and improve local road safety priorities – based on community safety and requirements. The programs are driven by community input and could include roadside delineation, dedicated left-turn signals, improved pedestrian crosswalks, and additional traffic signals.

Enforcement

B.C has advanced its enforcement techniques and tools over the past few years through several initiatives and projects. Some of the key areas are listed below, in addition to established and new programs, such as the Counterattack Drinking and Driving Campaigns, an Automated License Plate Program, and targeting prolific prohibited drivers.

The province has improved its legislation and policies to combat unsafe and high-risk driver behaviors. In 2010, B.C. introduced a comprehensive new law for distracted driving (electronic devices) and since that time the penalties associated with these offenses have been increased on two separate occasions. B.C. increased the fines and penalty points for anyone caught talking, texting, or emailing on a phone while driving. Using an electronic device while driving has now been classified as a high-risk offense, leading to mandatory driver improvement training. Currently, anyone with two distracted driving tickets in a three-year period will see their total financial penalties rise to as much as $2,000.

Additionally, the B.C. Government, police, and ICBC conduct two distracted driving education and enhanced enforcement campaigns each year, which also include advertising and social media support. Further, ICBC is also looking to use telematics to determine whether using this technology can improve road safety and driving behavior for inexperienced drivers.

Between 2012 and 2016, Intersection Safety Camera (ISC) sites in B.C. reported an average of 10,500 vehicles a year going at least 30 km/h over the posted speed limit, as detected by red-light cameras, which also monitor vehicle speeds. Speed has been one of the top contributing factors in casualty crashes at these intersections, which have had a combined total of more than 11,500 collisions per year. Speed cameras were activated in summer 2019 (Government of British Columbia n.d.-b). B.C. has recently activated new technology to ticket the registered owners of vehicles speeding through these intersections well over the posted limit on a red, yellow, or green light. New signs warn approaching drivers about the enhanced intersection speed enforcement.

Further, in summer 2019, the Ministry of Transportation and Infrastructure, in partnership with ICBC, applied High Friction Surface Treatment to 14 locations to reduce the frequency of rear-end collisions at key intersections and ramps. The treatments improve friction, allowing drivers to stop more quickly, reducing both the severity and number of collisions from occurring.

In 2018, B.C. with partner support from Mothers Against Drunk Driving (MADD) and Transport Canada, also conducted its eighth Roadside Survey. The survey measured the prevalence of alcohol and drug-affected driving, compared long-term trends, and established a baseline for measurement of the effects of cannabis legalization. More than 2,500 vehicles were randomly sampled from the traffic flow for participation in the survey (Beirness 2018). The number of vehicles that entered each of the survey sites ranged from 13 to 56 and depended on the volume and pattern of traffic, the time of night, day of the week, the number of refusals, the numbers of drivers who required transportation home, and the capacity of the survey crew to process drivers (Beirness 2018).

Finally, the province passed legislation in spring 2019, giving police new tools to remove drug-affected drivers from roads. The province introduced a new 90-day

Administrative Driving Prohibition (ADP) for drug-affected driving, and a zero-tolerance restriction for the presence of THC for new drivers in the Graduated Licencing Program (GLP). This proposed change mirrors what is now in place for the presence of alcohol for new drivers.

Adapting to the Environment

The goal of variable speed limits is to improve driver safety during adverse weather conditions and to reduce serious crashes in areas where weather patterns are prone to change quickly, which has the potential to make driving conditions more hazardous. The Ministry of Transportation and Infrastructure implemented variable speed signs on three corridors throughout the province as part of a pilot project to help reduce the frequency and severity of weather-related crashes. Ministry staff constantly monitor the system by analyzing the data and improving the algorithms to optimize recommended speed limits that best meet driver expectations and are in line with current conditions. The pilot resulted in 6.7% reduction in serious (fatal and injury) collisions. Flashing lights installed above each variable speed limit sign are activated when a reduced speed limit is in effect. Variable speed limit signs are regulatory; therefore, police have the authority to enforce the speed that is on the electronic sign.

Additionally, the Shift into Winter campaign includes more than 20 organizations working together to form the Winter Driving Safety Alliance. Shift into Winter is geared toward educating drivers and workers about the increased risk when winter weather makes roads more hazardous due to fog, rain, snow, and ice. The program includes an online resource kit for employers, trip planning, online courses, videos, presentations, and meeting guides. Further, each winter the Alliance combines digital highway displays, social media, and advertising to encourage all drivers to plan before traveling during the winter months.

Summary

The province's Vision Zero initiatives have been improving road safety through countermeasures, enforcement, public education and awareness, and through collaboration with partner organizations. In 2017, there were 276 fatal victims of motor vehicle crashes in B.C. While this number is still too high, this represents a decrease of approximately 22% since 2008. The Province has committed to tracking progress in absolute fatality numbers, as well as rate-based targets.

Role of Partners

One of the main principles of Vision Zero is collaboration, and B.C. works with more than 150 representatives from nearly 60 road safety partner organizations – with the common goal of zero traffic fatalities and serious injuries. In 2012, B.C. created the BCRSS, a unique made-in-B.C. approach designed to leverage the efforts of the diverse network of B.C. road safety partners including government, the insurance sector, Crown entities, the health sector, law enforcement agencies, nonprofit organizations, road safety groups and partners, and academic researchers.

Alberta

City of Edmonton

Background

With a population of 972,223, Edmonton is the second-largest city in Alberta and the fifth largest in all of Canada (City of Edmonton 2019; World Population Review 2019). In response to more than 8,200 residents being injured and/or killed on the city's roads that year, Edmonton developed the first municipal Office of Traffic Safety in North America in 2006 (City of Edmonton n.d.-a; Parachute 2017). Since then, Edmonton has been taking major steps to improve road safety, resulting in a 59.8% decrease in the number of people injured from 2006 (8,221) to 2018 (3,307) (City of Edmonton n.d.-b).

Vision Zero Edmonton

City council approved *Edmonton's Road Safety Strategy 2016–2020* in September 2015 and, in doing so, made Edmonton the first Canadian city to adopt Vision Zero (City of Edmonton n.d.-c). Edmonton's Road Safety Strategy takes an evidence-based, Safe Systems Approach, and focuses on the five E's of Traffic Safety: Engineering, Enforcement, Evaluation, Education, and Engagement. Each of the five E's outlines strategies for improving road safety.

Countermeasures

Engineering

The city's goal for engineering is to design the transportation system in a way that anticipates human error, with an aim to prevent serious injuries and fatalities. Road safety audits and assessments, as well as network screening programs and an overall review of data, including collision data, provide the evidence needed to design and implement measures to make Edmonton's roads safer.

Engineering countermeasures include the increased use of prohibited and protected left-turn signals, improved right-turn designs, signalized right turns, upgraded pedestrian signals, improved crosswalk markings, increased use of amber flashers and rapid flashing beacons, implementation of pedestrian scrambles, use of driver feedback signs (speed display), and the use of retroreflective tape on signal heads and additional traffic signal fixtures to improve signal visibility. The strategy further outlines traffic calming strategies to reduce shortcutting, as well as the need for neighborhood speed reduction programs. Safe speeds are addressed through speed limits and speed management. Edmonton uses a continuum of speed management strategies, ranging from the placement of community signs with messaging such as "Give our kids a brake" and speed display signs, to enforcement.

Education

Edmonton's strategy recognizes the importance of education for increasing traffic safety. In 2014, Edmonton established a biennial Traffic Safety Culture Survey to better understand the behaviors and attitudes of road users (City of Edmonton 2015). The city uses these findings and additional research to inform new educational programs, create an annual traffic safety communications plan and to review existing programs. More than 5,000 residents participated in the 2018 survey (City of Edmonton n.d.-d).

Another unique method Edmonton is using to support education is the Vision Zero Street Team. This team was created in 2017 and brings traffic safety messaging to local events, traffic safety hotspots where new infrastructure has been installed and various locations across the city where there is an opportunity to interact with the public and share information about traffic safety. Most recently, the Vision Zero Street Team was out teaching drivers and pedestrians how to use “pedestrian scramble” style crosswalks. The strategy further encourages collaborative, educational traffic-safety projects with stakeholders to increase exposure and frequency of primary prevention initiatives.

Enforcement

Edmonton’s strategy includes the use of enforcement to help reduce risky behaviors, placing an emphasis on speeding, impaired driving, and failure to wear seatbelts, as well as following-too-close, driving distracted, and identification of high-risk drivers. Edmonton employs a data-driven approach, which includes analyzing traffic hotspots to determine priority areas for enforcement. To minimize red-light running and speed-related collisions, Edmonton has installed Intersection Safety Devices that capture red light and speed violations, as well as automated mobile photo enforcement, with a focus on playground zones and high-collision locations. The Edmonton Police Service and the city work together on traffic-related initiatives and targeted enforcement.

Evaluation

Edmonton’s strategy involves leveraging the work of the Edmonton Urban Traffic Safety Research Chair at the University of Alberta to evaluate ongoing transportation-related initiatives and develop new methodologies and best practices. The city also conducts research into automated enforcement for collision reduction and optimization of resource deployment. Other evaluation measures include advanced video-based road safety analytics to identify collision risk and the creation of road safety audit criteria.

Engagement

Public engagement is critical to the success of Vision Zero in Edmonton. Engagement activities are conducted to consult with the public about various traffic safety initiatives, such as changes to residential speed limits. Edmonton also engages citizens in other ways. For example, the Annual Run Walk Ride for Vision Zero is a family-friendly event that welcomes people affected by traffic crashes to honor the loved ones they have lost or who have been injured in a crash. There were 120 participants in 2018 (City of Edmonton n.d.-d).

Summary

Edmonton's Road Safety Strategy continues to improve traffic safety. A comparison of 2015 (pre-Vision Zero) to 2018 shows that pedestrian injuries have decreased by 21%, cyclist injuries by 29%, motorcyclist injuries by 26%, and injuries to vehicle occupants by 11% (City of Edmonton n.d.-c, n.d.-e). Overall, serious injuries have declined 17% while fatalities have dropped 41% (City of Edmonton n.d.-c). In 2018, compared to 2017, the Edmonton Police Service issued 2,319 fewer speeding tickets and overall speeds in Edmonton are decreasing (Edmonton Police Service, COGNOS Database 2019; City of Edmonton, Photo Enforcement Ticketing System 2019).

Some of the key successes during the first 3 years of Vision Zero in Edmonton include: the installation of 34 left-turn signal phase improvements; contributing to the redesign of 14 right-turn lanes; addition of 54 signal visibility improvements including retroreflective tape and new signal fixtures; installation of 48 pedestrian signals and/or amber flashers, plus 50 flashing beacons at schools (City of Edmonton n.d.-e); installation of 215 driver feedback signs, which have shown to reduce speeding by up to 12 km/h (City of Edmonton n.d.-d); upgrades to 64 school areas; and the implementation of 30 km/h playground zones, which have led to decreases in speed by 12 km/h (City of Edmonton n.d.-a). In addition, automated mobile photo enforcement has reduced fatal and injury collisions by 20% and speed-related collisions by 18%, while the installation of intersection safety devices have reduced angle collisions by 43% (City of Edmonton n.d.-a).

Role of Partners

The Edmonton experience has highlighted the significance of partnerships in the success of their Vision Zero approach. The city partners with numerous stakeholders, such as the Edmonton Police Service on targeted enforcement and collaborative media events, the University of Alberta and other academic institutions on research and evaluation, School Boards to understand, discuss, and work collaboratively to improve traffic safety around schools, and Community Leagues, community groups and organizations in relation to traffic calming and as part of neighborhood renewal, advocacy groups, businesses, and many others. As Edmonton moves toward the launch of the next iteration of its strategy in 2021, the Safe Mobility Strategy, there will be an increased focus on the lived experience of all road users and ensuring traffic safety for all.

City of Calgary

Background

Calgary is the largest city in Alberta, with a population of 1,267,344 (City of Calgary 2018a). The city currently has 300 km of roadways, nine Light Rail Transit stations, and a 138 km Greenway, a pathway that connects 55 Calgary communities and connects to Calgary paths and trails, creating more than a 1,000 km network (City of Calgary 2016; Parks Foundation Calgary n.d.). The Greenway accommodates a 40% increase in cyclists in Calgary, resulting in more than 17,100 cycle trips every day

(City of Calgary n.d.-a). Downtown, the city also has the Plus 15 network, with 83 enclosed bridges connecting office towers to allow a safer way for pedestrians to travel (City of Calgary n.d.-b).

Despite the variety of options available for multimodal travel in the city, there were 517 major injury collisions and 11 fatal collisions on Calgary's roads in 2017 (City of Calgary 2018b). To take action against preventable tragedies, Calgary adopted Vision Zero and introduced its most recent *Safer Mobility Plan 2019–2023* in 2018.

Vision Zero in Calgary

The City of Calgary's movement toward Vision Zero first began in the *Calgary Safer Mobility Plan 2013–2017*. This document is aligned with the Province of Alberta Traffic Safety Plan, Transport Canada's Road Safety Strategy, and the Global Decade of Action. The plan is based on a vision of safe mobility for all users and a mission to strive for zero... "pursuing transportation completely free of fatalities and injuries" (City of Calgary 2014). The plan is also built around the values of the Safer Systems Approach (safer infrastructure, safer users, safer speeds, and safer vehicles), continuous improvement (short-term target toward the long-term goal), evidence-based strategies (Engineering, Education, Enforcement, Evaluation, and Engagement), collaboration (internal, external, and community), and best practices (research, technology, and innovation).

The *Calgary Safer Mobility Plan 2019–2023* builds on the work completed during the previous term (2013–2017) with simplification of targets, increased funding, and investment in infrastructure, and continued focus on partnerships, collaboration, and engagement. Vision Zero takes a more-prominent position in the document continuing the vision of "mobility free of major injuries and fatalities" (City of Calgary 2018b, p. 2). The numerical target of 25% reduction over a five-year period is set for both major injuries and fatalities, as well as for all road users and vulnerable road users. The City of Calgary has supporting documents that identify improvements to its transportation infrastructure to support safer outcomes for users. These documents include the Calgary Cycling Strategy, the Complete Streets Guide, the Pedestrian Strategy, and the Traffic Calming Guide, and the overarching policy documents the Calgary Transportation Plan and the Municipal Development Plan.

Countermeasures

Community Traffic Safety Meetings

Community traffic safety meetings are a joint activity between City staff and Calgary Police Service, and are attended by partners of the Safer Mobility Operations and Community Teams. These events include presentations about traffic safety issues and initiatives by City and police staff as well as discussions with citizens about their concerns. Concerns are received and form another piece of information to guide safety improvements and citizens are made aware of ongoing work and programs that they can access for assistance with their concerns.

Rectangular Rapid Flashing Beacons

Calgary led the national development of traffic control guidelines for the use of Rectangular Rapid Flashing Beacons (RRFBs) through TAC (Transport Association of Canada n.d.). RRFBs use LED lights in rectangular arrays and with a varying flash pattern to alert motorists to the presence of pedestrians at signed and marked crosswalks. The pilot study in Calgary demonstrated dramatic improvements in yielding behavior, from about 70% before, to 90% + post installation (Mishra et al. 2015).

Traffic Calming Policy and Investment in Changing Infrastructure

The Calgary Police Service (CPS) has a dedicated Traffic Safety Unit that responds to community concerns through their Traffic Service Request program. The CPS also runs staffed enforcement of traffic laws through its Districts and with Mobile Photo Enforcement vehicles using Traffic Section staff, as well as static enforcement at intersections using Intersection Safety Devices that enforce red-light-running violations as well as speed infractions during green lights. Calgary Intersection Safety Devices were included in studies completed by the Province of Alberta about the effectiveness of red-light cameras and speed cameras (AECOM 2014a, b).

Calgary has also invested in changing infrastructure. Roundabouts have increasingly become a traffic-control method of choice when traffic conditions allow. Many new communities are being built with roundabouts as the preferred intersection type for larger roads within communities. A network review of roundabouts in Calgary found that collision rates at roundabouts are less than half of those at signalized intersections (J. Domarad, personal communication, April 15, 2016). Calgary was also the first city in Canada to have an operational Diverging Diamond Interchange (City of Calgary 2019a). This interchange type applies principles of roundabouts to an interchange design by changing left-turn conflicts to merge/diverge type movements.

Further, one of the many network reviews completed in the city as a part of the Safer Mobility Plan was a review of all divided roadways to assess the need for median barriers to prevent or reduce cross median collisions and to prioritize based on collision history (Mishra and Churchill 2014). The use of High Tension Cable Barriers, where space and conditions allow, has been adopted to minimize the risk to vehicle occupants.

Calgary has also piloted and adopted Traffic Calming Curbs to rapidly change the built environment at a low cost (Churchill et al. 2017). These devices are best used as temporary measures to prototype potential changes and evaluate the benefits to advocate for more permanent changes. The City of Calgary received the TAC 2019 Road Safety Engineering Award for the invention and use of this device (City of Calgary Newsroom 2019).

Calgary has been using computer vision technology to quantify near misses using Video- Based Conflict Analysis as well. The proactive collection of conflicts allows evaluations and adjustment to designs to minimize risk, rather than waiting for collisions to occur so that they have data to analyze. Although this is a developing field, the benefits of making corrections to designs are clear, and the City is looking to move beyond traditional reliance on collisions as a design input.

Harmonization of School Zones and Playground Zones
Calgary had reduced speed zones (30 km/h) near school zones and playground zones that had different start and end times and days during which they were in effect. Two stages of harmonization took place: the first stage harmonized the times to start at 7:30 a.m. and end at 9:00 p.m.; the second stage converted all school zones (only in effect on school days) to playground zones that are in effect 365 days a year. The pre-post study revealed that speeds reduced by 6 km/h on average and resulted in a significant improvement in safety in those zones (Mishra and Kattan 2017).

Review of Neighborhood Speed Limits
The City is reviewing unposted and posted speed limits for neighborhoods in 2019 (City of Calgary 2019b). The review includes extensive education and stakeholder engagement, evaluation of alternatives, supporting traffic calming, and potential changes to enforcement. Council has requested a recommendation by the end of 2019 and this may be a significant step toward Vision Zero.

Role of Partners
Collaboration is a focal point of the plan and internal and external stakeholders are engaged through four groups that work in concert to advance the actions in the plan. These groups are the Safer Mobility Leadership Team, The Safer Mobility Operations Team, The Safer Mobilities Communities Team, and the Safer Mobility Research Team; additional information about membership of these teams is provided in the Safer Mobility Plan. The City of Calgary is actively involved in the exchange of information with other municipalities directly and through the TAC, CARSP, Institute of Transportation Engineers (ITE), Canadian Association of Chiefs of Police (CACP), and other organizations.

City of Fort Saskatchewan

Background
Located in Alberta's industrial heartland, and to the northeast of Edmonton, The City of Fort Saskatchewan is home to 26,942 residents (City of Fort Saskatchewan 2019a). The city hosts many community events throughout the year, encouraging residents to use the city's roads and more than 75 km of paved walking and biking trails to travel throughout the community (City of Fort Saskatchewan 2019b). Two major highways transect the city and accommodate about 50,000 vehicles per day through each major intersection, many of which transport dangerous goods (City of Fort Saskatchewan 2019b). It has been estimated that about 608,090–680,849 commercial vehicles travel annually through the corridor (City of Fort Saskatchewan 2019b).

In 2018, Fort Saskatchewan had 43 fatal and injury collisions (City of Fort Saskatchewan 2019b). While this is a significant decrease from previous years, the city remains committed to reducing this number to zero. Fort Saskatchewan introduced a new traffic safety plan for 2019–2022, which continues their commitment to Vision Zero.

Vision Zero

The City of Fort Saskatchewan adopted Vision Zero and the Safe System Approach in 2018 as their main approach to traffic safety. The five E's of traffic safety – engineering, education, enforcement, engagement, and evaluation – form the foundation of their effort to make the city's roads safer. While the plan supports Alberta's traffic safety strategies for community-based delivery of traffic safety programs, initiatives, and communications, as well as the Capital Region Intersection Safety Partnership joint vision, Canada's Road Safety Strategy 2025, and RCMP Traffic Services Safety Strategic Plans, it is also designed to meet the needs of Fort Saskatchewan (City of Fort Saskatchewan 2019b).

The plan aims to enhance the safety of motor vehicle drivers, bicyclists, and pedestrians on roads, pathways, and trails, with four main objectives: reducing the number and severity of injury and property damage collisions through identifying top five collision locations and the causal factors, and developing a strategy to reduce frequency and severity; enhancing traffic education; identifying and removing impaired drivers from roads; and identifying and sharing engineering concerns with the City's infrastructure department to improve road safety.

Countermeasures

Education

Fort Saskatchewan places a focus on working with the public and partners to educate all road, pathway, and trail users in the city. The City implements countermeasures, such as speed display boards, to increase driver awareness of speed, and encourage them to comply with applicable traffic laws. Option 4 programs are also available as an educational opportunity. Enforcement is focused on a specific risk factor. Any resident who receives a ticket can attend an educational session to learn about the risks associated with their violation and, upon proof they have attended a session, the ticket will be converted to a warning. The City notes that the results from this option have been exceptional, with residents commenting on their new understanding of traffic risks and desire to change their behavior.

Various education opportunities are available for youth as well. Bicycle rodeos are designed to teach youth about riding bicycles safely and each participant's bicycle is fixed if there are any safety issues present. If participants need new helmets, they are donated by Protective Services and Prairie EMS. Further, school traffic safety training is offered by RCMP and municipal enforcement. Officers deliver classroom presentations on topics such as school bus and pedestrian safety, drug and alcohol topics, and the laws around motor vehicle equipment.

Finally, internal education is offered to officers to increase their awareness of collision contributors in the city, which also involves ongoing data analysis, and development of strategies to reduce collisions. The Municipal Enforcement Services supervisor also distributes messages to the public through local media and their website on a weekly basis, which focus on emerging traffic safety needs.

Enforcement

The City of Fort Saskatchewan uses both conventional and automated enforcement to help enforce traffic laws, create awareness about traffic safety, and encourage compliance from the public. Enforcement is enhanced in key areas, including school, playground, and high- collision locations. Photo-laser and intersection safety cameras are also installed to provide automated enforcement.

Engineering

The City also places an emphasis on designing safe roads and creating and implementing effective traffic control devices. To do so, a portion of revenue from traffic fines goes toward furthering traffic safety in priority areas. Engineers in Fort Saskatchewan have also developed a policy for traffic calming that will be considered in the development of any new roads.

Evaluation

Fort Saskatchewan also assesses the effectiveness of its education, enforcement, and engineering initiatives. The City's Protective Services department has an analyst responsible for traffic analysis who provides the RCMP and Municipal Enforcement Services officers with weekly collision reports, making note of any trend updates. Any repeat violators or violators considered to be high risk are contacted to engage in a discussion on traffic safety. Further, Protective Services also partners with Capital Region Intersection Safety Partnership, supporting traffic safety priorities in the province every year, including participating in Selective Traffic Enforcement Program initiatives. The City notes that, regardless of the strategy used, it evaluates the strategy for efficacy and adjust in any way necessary to meet the needs of the community.

Engagement

Fort Saskatchewan works with members of the community in determining areas of concern and aims to engage the community to resolve traffic safety issues in the city. A Traffic Safety Working Group has been formed, including multiple departments in the City and members of the community, to discuss road safety concerns and enforcement trends to help contribute to innovative road safety solutions. Protective services also have held a Town Hall session for members of the community to share concerns, and it also offers an online service tracker where community members can submit service requests, including traffic-related services.

Summary

The rural city of Fort Saskatchewan has seen immense success with its traffic safety initiatives and countermeasures. Since 2008, the city has seen a 59.1% decrease in the rate of fatal and injury collisions (City of Fort Saskatchewan 2019b). Thus far, the city has installed nine intersection safety cameras and additional photo-laser devices, has conducted eight pedestrian safety presentations, and has also lowered speed limits in select areas, redesigned major roadways, and improved street lighting (City of Fort Saskatchewan 2019b). There has been a 71% decrease in red light violations at intersections with intersection safety cameras, a 35.8% reduction in overall fatal and injury collisions despite population growth, and $6.98 million in savings due to collision costs in 1 year (City of Fort Saskatchewan 2019b).

Role of Partners

The Director of Protective Services chairs a Traffic Safety Working Group that brings together traffic engineers, transportation and roads staff, Municipal Enforcement Services officers, RCMP traffic officers, the Fire Services, representatives from both School Boards, and the Regional Coordinator for Alberta Infrastructure and Transportation. On an ad-hoc basis, subject matter experts contribute to the group's planning and discussions. Their contributions have been incorporated into the traffic safety plan. The Traffic Safety Working Group also includes members of the community, and the group meets to discuss road safety concerns and enforcement trends to help contribute to innovative road safety solutions.

Ontario

City of Toronto

Background

Toronto is Canada's largest city, with more than 2.8 million residents (City of Toronto 2016). One quarter of Toronto's public space is made up of roads (Toronto Centre for Active Transportation n.d.), and more than three million trips are made to destinations across the city on any given weekday (City of Toronto 2016). Toronto currently houses 5,600 km of roads, 130 km of expressways, 9,500 streets, 26,300 intersections, a 900 km cycle network, 8,000 km of sidewalks, 480 pedestrian crossovers, and one million traffic signs (City of Toronto 2016).

In 2018, there were 66 people killed and 346 people seriously injured on Toronto's roads (City of Toronto 2019a). Nearly 82% of traffic fatalities involved vulnerable road users, such as pedestrians, cyclists, and motorcyclists (City of Toronto 2019a). Of all those involved in fatal collisions in Toronto in 2018, 62% were pedestrians, 18% were in cars, 14% were on motorcycles, and 6% were on bikes (City of Toronto 2019a). Safe streets in Toronto are critical to ensure that residents and visitors can move about safely, regardless of location, time of day, or mode of transportation.

Vision Zero in Toronto

After 2 years of development with 12 partner agencies and approval from Toronto City Council, the City of Toronto introduced its 5-year *Vision Zero Road Safety Plan (2017–2021)* in 2016. Given the size and complexity of Toronto, the City takes a data-driven approach to effectively prioritize safety improvements based on location and specific needs. Considering KSI collision trends and geospatial analysis, the City identified collision patterns, such as most vulnerable road users, circumstances surrounding KSI collisions, and collision hotspots (City of Toronto 2016). This data was used to establish emphasis areas and countermeasures.

The *Vision Zero Road Safety Plan* outlines six emphasis areas: pedestrians, school-age children, older adults, cyclists, motorcyclists, and aggressive and distracted driving. The 2016 plan outlines more than 50 countermeasures to address each emphasis area and related road safety risks. In year one, Toronto focused on the reduction of Killed or Seriously Injured (KSI) collisions. As the plan has continued to evolve, the city has been looking to prevent collisions before they happen with collision forecasting and a focus on causal factors. To refocus efforts and enhance progress, Toronto City Council approved *Vision Zero 2.0* in 2019.

Vision Zero 2.0

Vision Zero 2.0 represents a renewed commitment to the Vision Zero approach and an updated focus on efforts that will be most effective in achieving Toronto's road safety goals, as well as the addition of Heavy Trucks as a seventh emphasis area. The plan will focus on proactive systemic safety analysis of collisions involving vulnerable road users, speed management strategy, and geometric safety improvements, among various other goals such as additional mid-block crossings, increased police enforcement, and development of district safety plans (City of Toronto 2019b).

In keeping with the City's data-driven approach, staff working on Vision Zero 2.0 are reviewing demographic data, travel behavior, built road environment, five-year KSI trends, type of road users involved in KSIs, severity of collision outcomes, top KSI collision types in emphasis areas, road user actions contributing to KSIs, age of drivers and collision victims, relationship between road classification and KSI trends, relationship between time of day, month, light condition and KSI trends, hotspot mapping of intersection and mid-block KSIs, and public opinions on road safety (City of Toronto 2019c).

Countermeasures

Programs, Initiatives, and Strategies

There are a number of programs in place to address each emphasis area in Toronto's plan. The "Missing Links" Sidewalk Program includes a policy to install sidewalks in areas with no sidewalks or where there are gaps in the sidewalk network to ensure that all pedestrians can travel safely to and from their destination. The Geometric Safety Improvements Program implements road improvements and changes to intersection design to address safety issues. New in the plan, pedestrian safety corridors are being installed and include measures such as targeted speed limit reductions, signal timing adjustment, and enhanced crosswalk markings. A local road pedestrian crossover pilot has been conducted to assess the possibility of new types of pedestrian crossovers to enhance protection for pedestrians as well.

School-age children are an emphasis area in Toronto's Vision Zero plan, with the establishment of School Safety Zones around all schools being a key undertaking to help raise awareness of drivers to the presence of school-age children in the area and lower speeds. School Safety Zones include lower speed limits, increased enforcement, improved pavement markings, and flashing beacons and LED display signs. The School Crossing Guard Program is being reviewed as part of a recent transition of the program from the Toronto Police Service to City of Toronto. The plan also outlines a community-based initiative to plan active, safe routes to school, and the bicycle helmet initiative promotes helmet use and wheeled-transportation safety among school children.

To address the safety of older adults, Toronto has implemented “Senior Safety Zones” to introduce measures to improve senior road safety at high-priority locations. These include lower speed limits, advance green lights for pedestrians, watch your speed driver feedback signs, additional mid-block crossing opportunities, increased crossing times at signals, decreased crossing distance, increased enforcement, and improved pavement markings. A Priority Snow Removal Program is also offered, which allows adults over the age of 65 to apply to have snow removed in front of their residence. Bringing an Awareness of Senior Safety Issues to the Community (B.A.S.S.I.C.) delivers safety seminars and a safety calendar to improve the safety of older adults on Toronto’s roads. The City’s overall “Senior’s Strategy” features an accountability table to ensure all issues affecting senior citizens, including transportation and road safety, continue to be a priority.

In 2016, Toronto introduced the Ten Year Cycling Network Plan, which aims to improve safety for cyclists. The City has installed cycle tracks, bike lanes, shared lane pavement markings, and multiuse trails (City of Toronto 2019d). The City will continue to improve cycling infrastructure in the coming years. There are also a number of intersections across Toronto that are being protected for cyclists as part of a pilot project. Further, motorcyclists are at risk on busy city roads, due to the lack of protection, higher speeds, and their limited visibility for other drivers on the road. Project E.R.A.S.E is supported by Toronto Police to address motorcyclist safety and reduce illegal street racing.

Enhanced Enforcement

Enforcement activities are emphasized in Toronto’s Vision Zero plan and are done in collaboration with Toronto Police Service and Ontario Provincial Police (OPP). Enforcement strategies are data-driven, meaning police are provided with reports identifying the locations where there have been the most collisions in each emphasis area. Automated enforcement, such as speed enforcement and red-light cameras, are being installed in priority areas. The Red Light Camera program will be doubled in size in 2020 to meet growing demand, Areas where new safety measures are implemented, such as new mid-block crossings, receive enforcement support as well (City of Toronto 2016).

Enforcement strategies are tailored to each emphasis area and focus on priority locations. In school zones, enforcement focuses on offenses relating to pedestrian crossovers, school zone speed limits, intersections, school crossing guards, stopped school buses, and parking regulations. Additionally, enforcement will be enhanced around driver behavior that compromises cyclist safety, such as improper use of bicycle lanes and cyclist infractions to improve understanding of laws. Motorcyclist safety and aggressive and distracted driving will be targeted with enhanced enforcement efforts and enforcement has also increased in areas frequented by older adults (City of Toronto 2016). Police have also run "Operation Impact," an enforcement campaign targeting distracted and aggressive driving.

Educational and Awareness Campaigns

Education and awareness initiatives are run by various road safety delivery partners including Toronto Public Health, Toronto Transit Commission, School Boards, Toronto Police, and City of Toronto and are developed for each emphasis area. These initiatives help build skills, educate and raise awareness of safety risks and steps to improve safety for road users. Targeting pedestrian safety, the "March Break March Safe," "Stay Focused Stay Safe," and "Step Up Be Safe" campaigns enhance education, awareness, and enforcement of pedestrian safety, including issues such as unsafe mid-block crossings and vulnerable road users committing offenses near pedestrian crossovers. Further, road safety of older adults is addressed through Sunnybrook Health Sciences Centre's iNavigait campaign, which helps to ensure the safety of seniors, addressing dangers for older adults on roadways.

Additional campaigns, including the "Please Slow Down" campaign by the City, which provides residents with lawn signs to encourage drivers to slow down, and "You Know You Shouldn't... So Don't" campaign, a series of YouTube videos addressing aggressive driving, have also been implemented to target aggressive driving. To address motorcyclist safety, the Spring Motorcycle Awareness Campaign was designed by Toronto Police to coincide with the start of motorcycle season, focusing on equipment safety, rider protection, and training. Similarly, educational materials exist for cyclists, including helmet safety videos and the Toronto Cyclists handbook, which teaches about traffic laws and safe cycling. "Space to Cycle," an educational campaign led by Toronto Police Service that focuses on motorists whose actions endanger the lives of cyclists and risky cyclist behavior on roadways, and the "Stay Safe, Stay Back" campaign, which promotes safe interaction between cyclists and large trucks, are also run to promote cyclist safety.

Pavement Markings

Pedestrian crosswalk enhancements have been made, including pavement markings, zebra stripes at crossings, increased crosswalk widths, and stop bars. Toronto has also designated cycling conflict areas, where green pavement markings are implemented at or near intersections to highlight conflict areas between cyclists and motor vehicles. Bike boxes are painted to ensure that cyclists can proceed first at a green light and cross intersections safely and existing pavement markings delineating cycling infrastructure are refreshed on an ongoing basis. The City is also implementing painted intersection corner bump-outs with bollards as interim geometric safety modifications in advance of capital road work.

Traffic Control Signal Changes and Enhancements

The installation of LED blank-out signs is being piloted to depict prohibited left and right turns (City of Toronto 2016). Signalized crossings and advanced green lights for pedestrians and cyclists are also being expanded across the City, as well as no-right-turn-on-red prohibitions at key locations (City of Toronto 2016). Additionally, street lighting and accessibility measures at signals are being improved in the plan. Automated cyclist detection is another possible countermeasure under study as a means to optimize intersection operations and reduce the risk of cyclists being unable to pass through an intersection before vehicles (City of Toronto 2016).

Speed Management

The City advocates for and plans to pilot automated speed enforcement in school zones and continue to include permanent "watch your speed" display signs in school zones. The mobile "watch your speed" program has been implemented in multiple emphasis areas to address dangerous speeding behavior, as well. The city has also reduced speed limits from 60 km/h to 50 km/h on majority of major arterial roadways with further reductions from 50 km/h to 40 km/h on select roads. The multi-year plan is to reduce most collector roadways to 40 km/h and local residential roadways to 30 km/h in some areas, using neighborhood gateway signage and pavement marking. Additionally, new corner radius design and right slip lane replacement is being looked at to reduce speed and improve safety.

Data-Analysis and Safety Assessments

Toronto regularly analyzes collision data to determine trends and the need for interventions. When the data show that collisions are increasing or failing to improve, this represents the need for more countermeasures in those areas and a look at which are effective, and which may not be doing what they are intended to do. The City of Toronto analyzes data to understand the needs of the public and priorities to ensure they spend their budget appropriately. An example is a systemic review of high-risk mid-block crossing locations. The analysis will help identify the location of new signalized mid-block crosswalk by taking into account pedestrian desire lines and attractors in addition to other variables. Another example is the data-driven approach to the widescale rollout of Leading Pedestrian Intervals (LPIs) over the next several years.

Further, the city developed a "Traffic Calming Guide for Toronto" to review typical traffic calming options, including their cost and effectiveness, and the City and Toronto police aim to implement data-driven enforcement strategies as well. Road safety reviews will be required to address pedestrian safety and the approach to aggressive and distracted driving outlines enhanced data collection, analysis, and reporting (City of Toronto 2016).

Summary

In 2018, the City launched the Active and Safe Routes to School pilot at five schools, deployed mobile watch your speed signs in every Toronto ward, made numerous cycling enhancements, ran a pilot for rapid deployment of geometric safety improvements, improved street lighting, and held various public education campaigns, to name just a few achievements (City of Toronto 2018). To date, the City of Toronto has also installed 510 community safety zones, 64 senior safety zones, 156 school safety zones, 63 traffic signals, and pedestrian crossovers, 146 pedestrian head-start signals, 78 red-light cameras, 239 accessible pedestrian signals, and 21 LED blank-out signs (City of Toronto n.d.).

Role of Partners

The City of Toronto's *Vision Zero Road Safety Plan* was developed using a collaborative approach with partner agencies, external stakeholders, advocacy groups, and the public. Partners on the plan include those that have supported and worked on road safety, including Toronto Police Service, Toronto Public Health, Toronto Transit Commission, the Disability, Access, and Inclusion Advisory Committee, CARP, Toronto Seniors Forum, the Canadian Automobile Association (CAA), Cycle Toronto, Walk Toronto, Toronto District School Board, Toronto Catholic District School Board, Sunnybrook Health Sciences Centre, the Rider Training Institute, Motorcycle and Moped Industry Council, The Centre for Active Transportation, Culture Link, Friends and Families for Safe Streets, and Sick Kids Hospital. A representative from each of the five main delivery partner agencies also forms the Vision Zero Road Safety Working Group, which meets quarterly to review progress, priorities, issues, and plan future Vision Zero initiatives.

The Toronto Police Service assists with enhanced enforcement and runs a number of campaigns and projects aimed at enhancing road user safety. Partner organizations, such as Cycle Toronto, assist with producing materials such as the Toronto Cyclists Handbook. Other partner organizations, such as Sunnybrook Health Sciences Centre, Toronto Public Health, and CAA, run programs for target populations, such as older adults and school children. Each partner uses their expertise to contribute to and enhance countermeasures.

Québec

Ville de Montréal

Background

Montréal is the largest city in the province of Québec: its one million population (rising up to four million in the metropolitan region) represents a vibrant society and the city was the top economic performer in the country in 2018 (Conference Board of Canada 2018). This context led to many initiatives in transportation to boost the economy and to curb congestion and road safety issues. Accordingly, major issues were raised in the 2008 Transportation Plan and road safety was embedded in two of the 21 initiatives that are part of this plan: implement a Pedestrian's Charter and increase roads safety through education, enforcement, and engineering. These initiatives were partly implemented in the following years, including the establishment of a Transportation Safety Office within the city, and the systematic review of intersection design where there were too many collisions.

Despite these efforts, the decrease in road injuries seen in the early 2000s is now stagnant: there is still an annual mean of 14 pedestrian, two cyclist, and 10 car occupant deaths, far too many when thinking about the cost of a lost life (City of Montréal 2018). Facing this growing concern, elected officials from the city first launched a Vision Zero initiative in 2016, reinstating the road safety content from the 2008 Transportation Plan. This was seen as a first step toward a real Vision Zero action plan, which was officially launched in 2018.

Vision Zero in Montréal: Three Goals to Achieve Best Practices

Montréal's Vision Zero action plan (2019–2021) is based on three major themes: promote collaboration, change attitude, and transform the road system. Each theme has several related actions to be taken within the first 3 years. As in other Vision Zero cities, the first step to embrace Vision Zero principles relies on the creation of a strong, participative, and interdisciplinary governance, convinced of the benefits of this change in the road safety paradigm.

To promote collaboration, the city is moving forward with five actions: Provide leadership that will create a ripple effect throughout the Montréal community and bring Vision Zero to life over time; Develop collaboration to ensure the sustainability, integrity, fairness, and transparency of Vision Zero; Develop effective communication channels among the city, partners, and citizens; Share responsibility for the safety of the street network among all partners; Set common targets to help achieve the overall goal of zero deaths and zero serious injuries.

To change attitude and ways of doing things, the City suggests several actions that can be implemented first within its staff and strongly encourages partners to do the same within their workforces: mobilize road system designers and managers to increase safety and let them become change agents; foster interdisciplinary development and dissemination of new knowledge to better understand our environment; measure ways of doing things and intervene more effectively; accelerate the implementation of best road-design practices through the dissemination of guides and the revision of development standards; better coordinate awareness and education campaigns; and ensure the development and maintenance of driving skills with the appropriate training.

Finally, to transform the road system, the City and its partners target 12 actions: plan road-sharing between the different modes of transport for the entire network in order to offer accessible, safe, and effective mobility options; create safe, user-friendly, and accessible pedestrian walkways, with particular attention to intersections; ensure compliance with speed limits and reduce transit traffic on local streets and in sensitive areas; improve Montréal's standards for the upgrade and deployment of the cycle network; improve the public transit offer and promote its safety as a mode of transportation; better integrate the needs of vulnerable road users into the design and programming of traffic lights; adopt simple, clear, and durable signage and marking to help all road users to understand their meaning; harmonize street lighting to ensure better visibility for all road users; ensure that parking is no longer an obstacle to the establishment of safer infrastructures; ensure a better coexistence between heavy vehicles and vulnerable road users; better adapt construction site management to the reality of vulnerable road users; participate in the development of vehicles safety devices through technological watches or pilot projects.

Four Keys to Vision Zero Success: The Montréal Vision Zero Action Plan Has Them All!

One interesting point about the Montréal Vision Zero action plan is the clear presence of the four essential elements for Vision Zero success. First, many actions in all themes will help to develop new knowledge in road safety, both within and outside the city staff. This new know-how can then be used to change the way we see the road system to better include users' vulnerabilities and to build it so potential mistakes are forgiven.

Secondly, the strong will found in the action plan to work in partnership is the right answer to the four "Ps" needed to achieve Vision Zero: strong support from the Politics in power, the Public servants, including City and police staff, the Press (a major communication plan is related to this plan), and the Population. This support is first seen by asking as many partners as possible, including Montréal's own city division and teams to be "committed to road safety" by signing the declaration of commitment on its website. There are already several partners committed and more signing each month, either simple citizen or bigger organizations. In addition, the consultation prior to this plan highlighted more than 400 local initiatives in road safety across the city, coming from either city's services, nonprofit, or private firms. This confirms the partners' awareness of the role they can play in improving the safety of the road system.

Third, there are many evaluation and feedback opportunities embedded in the action plan, two major points when it comes to evaluating the success of actions in a Vision Zero approach. The first feedback loop is within the governance plan, where there are three thematic working groups (crosswalks, heavy vehicles, and speed management), one advisory committee (vulnerable road users), and one committee on data management in charge of producing an annual road safety statistics report. All these committees will be listened to by the city staff responsible for the VZ action plan.

Finally, this first Montréal Vision Zero plan also provides budget and dedicated staff for the implementation of actions and also for the evaluation of the effects. For example, the first theme includes an action to "create a Vision-Zero-dedicated team and filling seven additional positions for the implementation of the action plan," and the second and third theme include budget for research, including the evaluation of pilot projects.

Summary

Between road infrastructure maintenance and the need for more sustainable mobility, the city of Montréal Vision Zero action plan is a good start to make sure that road safety challenges, such as safe speed in local neighborhoods, new technologies and distracted driving, and aging of the population are addressed. This three-year plan is promising by its content and the willingness it depicts from several key actors. The whole road safety community is looking forward to seeing the impacts of this first plan.

Role of Partners

The City of Montréal outlined from the beginning that collaboration would be essential to its Vision Zero strategy. Accordingly, more than 30 local and provincial stakeholders signed a declaration of commitment in the first City's VZ Action Plan (City of Montreal, 2019: https://portail-m4s.s3.montreal.ca/pdf/vision-zero-ville-de-montreal-2019-2021.pdf). The governance model found in this first action plan is based on interdisciplinarity, including several working groups where four priorities were set by participative stakeholders: speed, heavy vehicle, road crossing, and data management (City of Montreal, 2021: https://portail-m4s.s3.montreal.ca/pdf/etat_de_la_securite_routiere_2020vdem_0.pdf).

Partners were involved in the development of Montréal's Vision Zero plan. After a synthesis of Vision Zero components was developed based on a literature review and case studies, the City of Montréal held meetings with key stakeholders. These meetings included personnel from the public health department, the police department, and public transportation agency, resulting in an evaluation of the safety of Montréal's road network in regard to each component of Vision Zero. Recommendations were then made by comparing the results and, in collaboration with City staff, actions were prioritized according to current opportunities in the city (WSP 2018).

Looking Toward the Future

Government plays a leading role in the uptake and implementation of Vision Zero as the resources for planning, development, implementation, and evaluation reside with the jurisdiction responsible for road safety, whether that is the provincial, territorial, or municipal level. Advocacy by government officials helps to make a valid case for funding and, for a plan such as Vision Zero, which aims to make large-scale changes, government co-operation, and advocacy are essential.

As important, the public drives demand for Vision Zero, setting out the expectations people have from their city and the streets that run throughout it. The public brings awareness to road safety issues, drives community engagement, plays a key role in getting Vision Zero on the agenda and in getting it implemented city-wide. Public opinion can inform effective progress, enhance cooperation, and adherence to road safety rules, help those involved in Vision Zero planning to understand perceptions and behaviors of road users, and allow the city to tailor its Vision Zero efforts to specific road user needs.

Data-driven approaches to Vision Zero allow a regular analysis of collision data to determine trends and the needs of the public and priorities for interventions. Robust evaluation methods can track the successes of countermeasures implemented and look at which are effective and which are not doing what they are intended to do. The countermeasures implemented must be convenient, appealing, and demanded by the public for them to be put to use. Evaluation data can demonstrate success and ensure support from the public, government, partners, and stakeholders for ongoing and future Vision Zero initiatives. The demonstration of a jurisdiction's success also helps encourage other cities to adopt Vision Zero in their road safety plans.

Vision Zero continues to gain momentum across Canada and the idea of creating more livable cities is sparking conversations across sectors. However, it is not without its challenges, whether that is criticism directed at the types of actions being taken, the speed or lack thereof of the implementation process, the location of interventions, the debate among road users, and their rights to use the roadways or the perception that the goal itself is not achievable. It is critical to look at the progress that has been made and consider how Vision Zero can continue to be effectively implemented and the most efficacious solutions are widespread moving forward, including application in different sectors. It is firstly important to outline Vision Zero priorities for the future. Key Vision Zero priorities include: raise awareness of the issue and tie to global initiatives whenever possible; align the efforts of various levels of government (while cities are the lead, provincial, and federal government should be involved as well); ensure there is money to implement action plans; communication between jurisdictions to exchange best practices; align the efforts of ministries and departments within the various levels of government; overall, make road safety a national priority. Ensuring road safety is at the forefront of public attention and government support will help all jurisdictions to move forward.

For Vision Zero to be successful, there needs to also be an overarching agreement on the issues and the systems nature of the problems and the required solutions. Doing so will allow for larger changes to be made, rather than taking small, and sometimes less-effective steps toward zero. A welcome opportunity is the drive to collaborate and share information among local jurisdictions and disciplines, which provides the potential to create political pressure to keep up with others and leverage lessons learned to accelerate improvements in road safety.

Vision Zero is an approach with a goal of zero serious injuries and fatalities and an emphasis on preventative measures that accommodate for human error; and this approach does not have to be limited to road safety. This approach has applicability to various public health topics and injury prevention efforts, because one preventable death is too many.

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Adoption of Safe Systems in the United States

17

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Abstract

Safe Systems are in early phases of implementation in the US. Adoption of these concepts in the USA has been slower than in a number of other nations, including Sweden, The Netherlands, UK and Australia. Whereas adoption in other nations began as early as the late 1990s, interest in Safe Systems in the USA followed by about a decade. One factor associated with this delay is the success that the USA experienced with public safety and compliance methods, such as high-visibility traffic law enforcement, during the period in which the Safe System movement took hold in other countries.

National road safety professional organizations were among the first in the USA to shift toward zero-focused strategies. City and state governments followed and the federal government took steps in this direction after local and state efforts were well underway. By 2020, discussion of Safe Systems was taking place in national professional associations and early steps had been taken toward federal institutional support.

Although implementation in the USA is not yet widespread, lessons have been learned in building public and political support for Safe Systems. Managing public expectations regarding short-term safety benefits is likely to be a key to longer-term Safe Systems support. Increased efforts are needed to inform political leaders at the local, state and national levels of the benefits of Safe Systems and Vision Zero as well as additional education for safety practitioners.

Keywords

Safe system implementation · Vision zero history · U.S. traffic safety · Safe system approach · Zero traffic deaths

Introduction

While Safe Systems and Vision Zero are synonymous or near-synonymous in many areas of the world, the terms have evolved with slightly different meanings in the USA. A number of jurisdictions across the nation have adopted programs using Vision Zero terminology that incorporate some, but not all, of the principles commonly associated with Safe Systems. These jurisdictions typically focus on the ethical imperative of reaching zero traffic deaths, but recognition and adoption of other Safe System principles varies widely, including system design that accommodates human error and reduces the level of kinetic energy in crashes, and a shared responsibility for crashes by system owners. In communities where the full Safe System concept has yet to be institutionalized, Vision Zero is sometimes used as part of public campaigns that seek behavior changes such as reduced speeding and distracted driving.

The term, Safe Systems, is used primarily among safety professionals in the USA. While the term has yet to become part of the daily professional vernacular, when it is used, the implied definition is typically close to the commonly understood Safe

Systems principles. This chapter will address the background, status, and trajectory of both Vision Zero and Safe Systems, using these US terminologies.

Early Consideration

In the late 1990s, as Scandinavian countries were securing Parliamentary endorsement for Safe Systems (Belin et al. 2012), the United States was experiencing a period of unprecedented success in behavioral road safety using a different approach, high-visibility law enforcement. The *Click-It or Ticket* seat belt program was launched in the State of North Carolina in 1993, adopting a technique that had shown promise in Canada and elsewhere, using an aggressive statewide implementation strategy (Tison and Williams 2010).

The effect of the *Click It or Ticket* high-visibility law enforcement technique was sufficiently positive that national attention was soon focused on this approach. Federal leadership, along with support from the automotive and insurance industries, further encouraged state and local adoption. In 2000, other states followed the North Carolina example, and in 2002, federal incentive funding was linked to state adoption of the *Click It or Ticket* program, and a coordinated nationwide campaign was launched to further encourage implementation (Runge 2002).

With federal, state and corporate safety leadership focusing on high-visibility law enforcement, relatively little attention was given in the USA to the road safety innovation occurring in Sweden, The Netherlands and later, Australia, the UK and other countries. As early as 1999, the Federal Highway Administration issued a technical report including a detailed description of the new Swedish Vision Zero program (Federal Highway Administration 1999), however this news did not stimulate widespread interest or action at the time. In 2000, the State of Washington became the first jurisdiction to adopt a zero traffic death policy, referring to their program as Target Zero (Washington Traffic Safety Commission 2019).

By 2007, several indicators of state and local implementation of the *Click It or Ticket* program began to show declines, including law enforcement activity as measured by seat belt tickets issued per population, investment in publicity about seat belt law enforcement, and public awareness of enforcement activity immediately following the coordinated national implementation campaign (Nichols et al. 2016). Various factors may have contributed to the decline in state and local high visibility enforcement activity. Earlier reports cited competing demands on enforcement agency budgets and personnel resources, along with increasingly complex criminal issues, as contributing to reductions in traffic law enforcement (Wiliszowski et al. 2001).

A reduced emphasis and investment in high-visibility traffic law enforcement may have stimulated interest in alternative safety approaches, including Vision Zero and Safe Systems. Among the first US cities to make public commitments consistent with Vision Zero principles was the City of Chicago. An Action Agenda published by the Chicago Department of Transportation in 2012 established a 10-year goal to eliminate traffic deaths (Chicago Department of Transportation 2012). The Action Agenda did not specifically cite Vison Zero or Safe Systems, but included several of the underlying principles, including a systemic approach to crash injury reduction and acknowledgement of human injury tolerance and its relationship to vehicle speed, in addition to the ethical imperative of a zero-fatality goal.

Focus on Zero

In 2014, a group of eight organizations representing government agencies at state and local levels released *Toward Zero Deaths: A National Strategy on Highway Safety*. The result of 5 years of development, including multiple levels of stakeholder engagement, the Toward Zero Deaths strategy was a substantial step forward in several respects.

Through a series of webinars and workshops, the development process brought together an extraordinary range of safety professionals, including representatives of agencies with responsibility for driver licensing, law enforcement, road construction and maintenance, commercial vehicle regulation, road user behavior, and emergency medical response. Reaching widespread agreement on the importance of a zero-based goal for traffic deaths among these professionals was a critical achievement with far-reaching implications.

A goal of zero traffic deaths can be viewed as contrary to conventional policy development methods that rely on cost-benefit analyses to allocate resources among social needs. A zero-death ethical imperative implies that there is no threshold of traffic deaths – other than zero – that would justify shifting resources away from road safety. This misalignment with conventional safety policy perspectives can be uncomfortable for safety professionals, as was found in Sweden during early years of Safe Systems implementation (Belin et al. 2012). The Toward Zero Deaths strategy made significant progress in overcoming such reservations among US safety professionals, achieving broad consensus on a zero-based road safety goal.

The Toward Zero Death strategy also heightened recognition of the need for a system wide approach to traffic safety. The strategy was developed and presented in a way that emphasizes the need for a comprehensive approach including behavioral, roadway, vehicle, safety management and data systems, and emergency response interventions (Toward Zero Deaths Steering Committee 2015). The strategy includes more than 180 recommended actions across these areas.

The Toward Zero Deaths strategy did not focus specifically on the Safe Systems approach. However, the broad endorsement of the zero-based goal, the inclusiveness of the development process, and the emphasis on a system wide strategy were progressive contributions to road safety thought in the U.S.

Initial Steps

Vision Zero Cities

High-profile, city-led activity towards the Safe Systems approach began in New York City (NYC) with the support of a well-organized, politically influential advocacy group, Transportation Alternatives (TA). TA developed a public report in

2011 showcasing the basic Safe Systems concepts, highlighting advances made in other nations, and laying out a blueprint for NYC adoption. The report initially gained the attention of safety advocates and later attracted a broader audience when TA effectively inserted the topic into the 2013 NYC mayoral election. Importantly, all of the leading candidates committed to TA's Vision Zero challenge during their campaigns, and the candidate who won, Mayor Bill deBlasio, tasked his staff almost immediately with developing the city's initial Vision Zero plan. The plan explicitly stated that "No level of fatality on City streets is inevitable or acceptable" (City of New York 2014), and it laid out specific actions to be pursued in roadway design, regulations, enforcement, data-tracking, local and state policy changes, and others.

This early and quick embrace of Vision Zero in NYC can be credited, in part, to the following: effective grassroots advocacy that planted the seeds in a hotly contested election; a "strong-mayor" system in NYC, in which leaders of departments, such as transportation, police, public health, etc., are directed by the city's chief executive; and the nascent and powerful movement among local residents who lost loved ones to traffic injuries and organized for Vision Zero.

This organized voice for victims accelerated change. Now called Families for Safe Streets, the group was formed by those who had lost sons, daughters, husbands, and other loved ones, as well as some who had survived serious traffic crashes themselves. The influence of these individuals in the early days of NYC's Vision Zero development was powerful because their personal and often heart-breaking stories helped move the issue of traffic safety from being viewed as a routine, technical issue to a deeply emotional and urgent rallying cry for change. NYC's Families for Safe Streets group is supported by TA, giving it organizational and administrative backing. However, the group speaks with its own distinct voice, successfully advocating for long-desired policy and legislative changes. This victim advocacy enabled important progress. For instance, members of Families for Safe Streets are credited with helping to pass key legislation in the State of New York, allowing NYC to lower speed limits from 30 to 25 mph and to add automated speed cameras in school zones. Overall, in its first years of Vision Zero commitment, NYC experienced a 31% decline in traffic deaths, from 299 in 2013, the year prior to Vision Zero, to 205 in 2018. Nationwide traffic deaths increased by 12% during the same period. An increase of 16 deaths in NYC in 2019 was a setback, but still amounted to a 26% drop since 2013, just before Vision Zero was adopted (City of New York 2020).

The second US city to adopt Vision Zero was San Francisco, also in 2014. As in NYC, interest was initiated by local advocacy groups, specifically two membership organizations that promoted bicycling and walking. The impetus was an upsurge in traffic fatalities in the city, especially among people walking and biking. Particularly compelling was the highly publicized death of a 6-year-old child hit and killed on New Year's Eve while walking with her mother in a crosswalk. That tragedy occurred on a street where advocates had long been fighting for safety improvements to little avail. Local advocates approached the Mayor, as well as leaders of the transportation, police, and public health departments, and urged adoption and implementation of Vision Zero. City officials agreed and activity built upon the city's strong base of recent work focused on data-driven pedestrian safety planning, which was co-led by transportation and public health officials.

The Beginning of a National Movement

Following the strong focus on *Click It or Ticket* during the 2000–2005 era, federal leadership in behavioral safety moved on to other emerging traffic risks. Based on the extraordinary success of *Click It or Ticket*, similar high-visibility enforcement approaches were attempted as part of an emphasis on reducing driver distraction between 2010 and 2013 and for improving pedestrian safety in 2013–2015. However, implementation of the high-visibility enforcement approach was less consistent across the nation and results were not as remarkable for these other programs as in the earlier seat belt experience (National Highway Traffic Safety Administration 2014).

By 2016, a combination of factors motivated federal transportation leaders to work with stakeholders to define a longer-term path for road safety in the USA. Changes in public support for strong laws and aggressive law enforcement were diminishing prospects for repeating prior successes with these approaches. Meanwhile, after a decade of gradual declines in road deaths associated with the downturn of the national economy during the Great Recession, traffic fatalities started to rise again (He 2016). Additionally, public interest in the emergence of self-driving cars had reached a point where some safety advocates were concerned that commitment to behavioral safety programs may wane as a result of unrealistic expectations regarding the imminent arrival of fully automated passenger cars.

Federal officials at the US Department of Transportation gathered safety stakeholders in October 2016 to consider options for progress. At this meeting, behavioral health experts reviewed existing traffic safety program strategies and compared them to techniques used in other areas of health behavior change, such as anti-smoking campaigns. This expert review concluded that the current range of program strategies used for improving traffic behaviors – including those recommended in the Toward Zero Deaths National Strategy – compared favorably to those used in other areas of public health. There were few apparent opportunities for improving traffic safety programs by adopting strategies that had proven effective elsewhere. Additionally, experts on vehicle automation pointed out that while self-driving cars promise substantial safety benefit, those vehicles will not reach widespread use for a number of decades, confirming the ongoing importance of road safety behavioral programs for at least 20–30 years.

Also discussed at this conference was the concept of Safe Systems and the experience of Sweden in using this innovative approach to improve the effectiveness of both conventional and emerging safety strategies. At the conclusion of the conference, there was interest in articulating a long-term traffic safety vision for the USA that would describe how conventional evidence-based programs, as recommended in the Toward Zero Deaths National Strategy, might fit together with the future potential of automation and the Safe Systems approach.

Formulating a Long-Term Vision

In late 2016, a larger group of safety stakeholders was invited to help formulate this long-term traffic safety vision and facilitate its implementation. A Road to Zero Coalition was launched with leadership from the National Safety Council (a non-government organization) in collaboration with three safety agencies of the US Department of Transportation, the National Highway Traffic Safety Administration, the Federal Highway Administration and the Federal Motor Carrier Safety Administration. A Road to Zero Steering Group was formed with representatives from a range of stakeholder organizations. The Swedish Transport Administration was asked for advice and was an active participant in deliberations.

A decision was made by the Road to Zero leadership organizations to develop a 30-year vision for reducing traffic deaths to zero, or near zero, a timeframe that would be long enough to consider the role of emerging vehicle automation technology in achieving this objective, but still within the comprehension or experience of many safety professionals. Assistance in articulating the vision came from the RAND Corporation, a non-profit research institution. The planning methodology presented in Fig. 1 was designed specifically for this purpose, including elements of back casting, assumption-based planning and three-horizon foresight. The vision was formulated over a series of meetings over the first half of 2017. Continued input was solicited from the Steering Group and federal collaborators as drafts were prepared, reviewed and refined throughout the remainder of the year. Coalition meetings were conducted quarterly and membership increased from 150 public and private sector organizations, including cities, nonprofits, businesses, and government agencies at the first gathering, to approximately 900 3 years later.

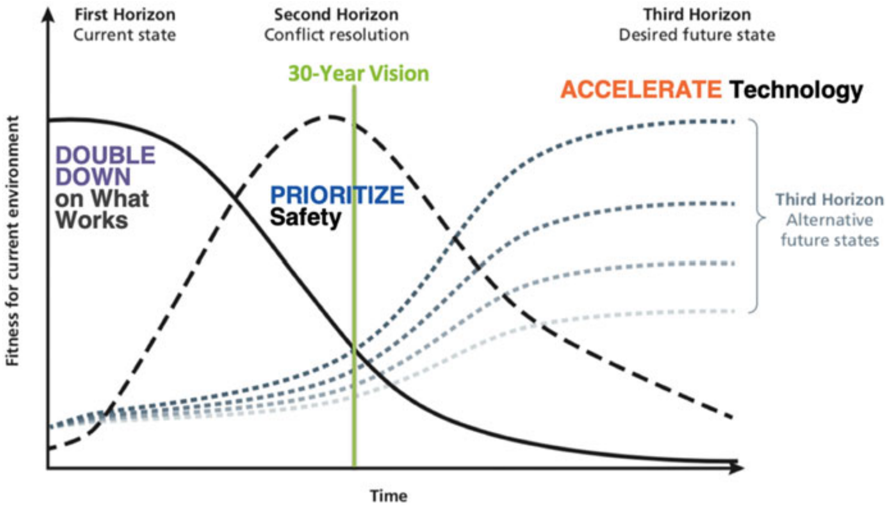

Fig. 1 Three horizons of change proposed by the Road to Zero vision. (Source: Adapted from Curry et al. 2008)

The Road to Zero Vision

The completed Road to Zero Vision, released in April 2018, presents a forecast of traffic safety in the year 2050, depicted in a series of community scenarios, along with an explanation of how that future was achieved (Ecola et al. 2018). The 30-year vision predicted by the Road to Zero describes the potential result of investment in three areas or horizons of change: Double Down on What Works, Prioritize Safety, and Accelerate Technology.

The first of these, identified as *Double-Down on What Works*, reflects the potential impact of maximizing implementation of the wide range of evidence-based strategies that have been documented in the fields of roadway engineering, driver and road user behavioral safety, vehicle safety engineering, and emergency medical response and pre-hospital care. These policies and practices are the result of decades of research, development and refinement by engineers, psychologists, physicians, academics and other professionals. They include the most effective and feasible approaches developed to improve road safety, and many of the strategies have yet to be fully implemented and therefore hold unrealized potential. The Toward Zero Deaths National Strategy lists evidence-based interventions that were available in 2015 from across these fields, such as enacting safety belt laws, installing road shoulder and centerline rumble strips, and lowering speeds and creating dedicated bike space in cities. The number of such countermeasures continues to grow as new techniques are developed and evaluated.

The second horizon of change proposed by the Road to Zero vision is *Prioritize Safety* which includes adoption of Safe Systems principles and consequent realization of a Safety Culture. The idea of Traffic Safety Culture had been discussed previously in the Toward Zero Deaths Strategy, described as the set of social values, beliefs, and attitudes concerning safety, combined with perceptions of group norms and of the degree of individual control available to affect safety outcomes. The focus on Traffic Safety Culture in the widely-endorsed Toward Zero Death Strategy could be seen as a measure of its broad acceptance among US safety constituents at the time of its release in 2015.

The concept of Safe Systems did not receive comparable widespread US endorsement until the formulation of the Road to Zero vision was completed in 2018. In the Road to Zero vision, the Safe Systems approach is presented as a complement to the Toward Zero Deaths Strategy rather than as a new set of tools or interventions to improve road safety. In the context of the overall vision, Safe Systems is positioned as a means for extending the value of conventional practices by applying them in strategic and systemic ways. Future scenarios in the Road to Zero vision depict several applications of Safe Systems principles, including how cities systematically design roads to accommodate human error, for example by replacing signalized intersections with roundabouts that prevent deadly high-speed side-impact crashes that occur when a driver mistakenly runs through a signal. Others show how crash energy levels have been lowered to accommodate human injury tolerance by narrowing streets in certain locations, slowing traffic so that a collision with a vulnerable road user is unlikely to result in a death. Additional scenarios describe how automatic emergency braking prevents a crash resulting from a combination of driver and pedestrian error and how impairment detection technology prevents a drunk driver from operating their vehicle. All of these examples of Safe Systems principles use practices included among the recommendations of the Toward Zero Death National Strategy.

The third horizon of change described in the Road to Zero vision is *Accelerating Advanced Technology*. Our current road system places very high demand on driver vigilance to avoid crashes, and lapses in road user performance result in frequent crashes. Automation of vehicle control functions that have conventionally been the responsibility of the driver has tremendous potential for reducing these crashes and associated injuries. While a few of these automated functions, such as Electronic Stability Control, Automatic Emergency Braking and Lane Keeping Assist are already in some new vehicles, decades will pass before natural market forces bring such technology to the cars driven by the highest risk drivers, such as those who are most likely to drive after drinking alcohol. Yet more time will pass before the market will permeate the fleet with fully-automated vehicles. The Road to Zero vision stresses the need to supplement market forces with incentives, subsidies and regulations that could accelerate this technology deployment trend along with its safety benefits.

Expansion of Vision Zero Cities

Following the adoption of Vison Zero by New York City and San Francisco in 2014, additional cities developed and implemented similar programs. As of April 2020, there were 43 communities in the USA with public Vision Zero commitments, mostly at the city level and several at the regional or county levels, as indicated in Fig. 2 (Vision Zero Network 2020). While it is true that most of the early adopters of Vision Zero in the USA were large cities, such as Seattle, Washington; Boston, Massachusetts; and Washington, D.C., there is an increasing number of smaller- and mid-sized communities, as well as suburban communities, making Vision Zero commitments. Rural communities have expressed interest, but have yet to move in significant numbers to make public commitments to Vision Zero.

Notably, the 43 US communities that have adopted Vision Zero planning and implementation efforts as of 2020 are independently and locally led. While their work is influenced by state and federal activities, their core work is largely separate from other governmental levels, except where specific changes are needed, such as seeking authority from the state to make changes in local speed limits.

Differences Between Local-Level Vision Zero & State-Level Toward Zero Deaths Efforts

In general, city-led Vision Zero efforts have developed differently than state-level zero-based approaches, such as Toward Zero Deaths programs. For instance, most of

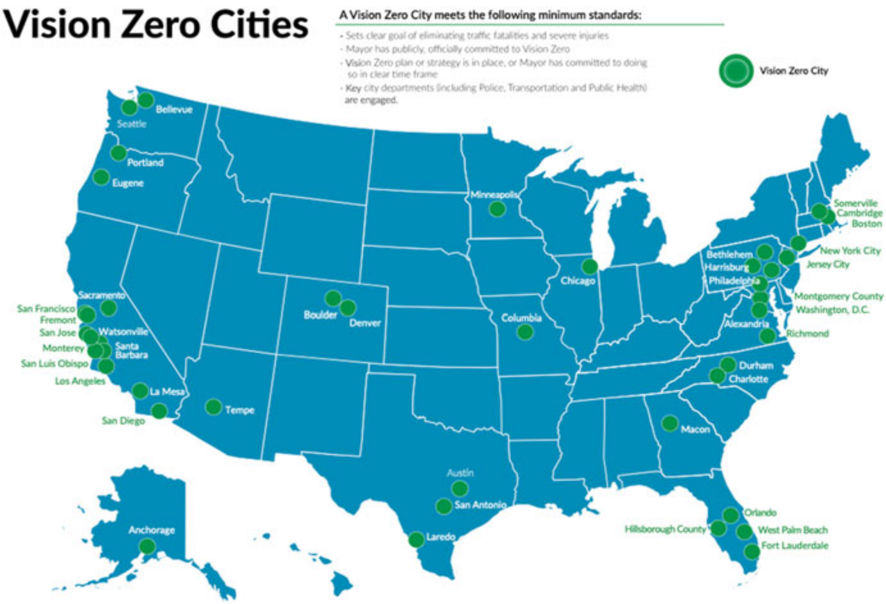

Fig. 2 US Vision Zero cities in 2020. (Source: Vision Zero Network)

the 43 Vision Zero cities set a target year for reaching zero traffic deaths and severe injuries, generally in the range of 10–15 years into the future. They develop plans based on those targets with clear, actionable strategies that can be measured over time. This has not been a widespread practice at the state level, where broader "zero deaths" language is often used in their federally required state highway safety plans. While there are exceptions such as the State of Washington, State governments have not typically linked funding priorities or policy changes to zero goals, or proposed explicit, public-facing timelines for actions and results.

Another difference is that local Vision Zero efforts have been more likely to engage non-traditional safety partners, building a strong base for change. For instance, Vision Zero cities are increasingly engaging local public health departments in traffic safety work, along with school district leaders and community members, especially those representing groups most impacted by traffic injury and death, such as seniors and communities of color and low-income residents.

In addition, many Vision Zero cities are using a data-driven approach to elevate issues of equity within traffic safety planning and practices. Research shows that people of color and low-income communities are more likely to be negatively impacted by traffic conditions, as are children and seniors, as well as people walking and bicycling. Many local Vision Zero efforts are analyzing these data to inform efforts to address disparities in communities when it comes to safe mobility. This equity-driven approach has, so far, been less prominent at the state level.

Local-level Vision Zero efforts and state-level Toward Zero Deaths programs are generally similar in their lack of explicit link to the Safe Systems approach.

Recognizing this disconnect and the potential benefits of more fully integrating in Safe Systems principles, some national organizations have focused on improving understanding of these principles among transportation professionals and facilitating their adoption through planning and implementation. These groups range from nonprofits, such as the Vision Zero Network, and professional organizations such as the Institute of Transportation Engineers (ITE), to governmental agencies, such as the Federal Highway Administration and the National Highway Traffic Safety Administration.

Promoting and Facilitating Further Safe Systems Adoption in the U.S.

Vision Zero Network

While Vision Zero cities (and regions) generally operate independently, a significant amount of information-sharing and peer-influence takes place among them. This is supported in part by the Vision Zero Network (VZN), a nonprofit started in 2015, with the goal of advancing Vision Zero in the US VZN connects these communities with a forum for sharing plans and experiences, and provides leadership and resources, including an emphasis on the Safe Systems approach as the basis of Vision Zero. VZN encourages partnerships between transportation officials and public health, law enforcement, and policymaking professionals, as well as community advocates. VZN conducts regular calls, meetings and webinars to share information, and produces resources to boost Vision Zero understanding, adoption, and implementation. Priorities of VZN include focusing on speed management strategies, elevating equity in Vision Zero and measuring the benefits of Vision Zero actions for broader adoption and effectiveness.

Vison Zero cities in the USA are evolving to fit local needs and conditions, and their level of commitment to the principles of Safe Systems varies. While the Vison Zero Network encourages this diversity of program design and focus, it also works with local program leaders to achieve greater convergence around Safe Systems principles and implementation.

Safe Systems Work Group

Following the introduction of the Road to Zero Vision, leadership from the roadway engineering profession took steps to build upon the endorsement of the Safe Systems concept. The ITE established a standing Safe Systems work group to advance acceptance and adoption in the USA. The initial objectives of the work group are to:

1. Develop a Safe Systems definition/principles
2. Identify core Safe Systems resources
3. Develop an introductory Safe Systems webinar
4. Develop a Safe Systems Action Plan

Members of the work group represent city, county, state and federal governments, academic institutions, and urban development and vulnerable road user advocates. Recognizing the extent of institutional change necessary for widespread US adoption, the work group deliberated on definitions and principles for Safe Systems that would be consistent with international thought and practice while being appropriate and feasible in the US context. Starting with the contemporary global definition as articulated by the World Resources Institute (Welle et al. 2018) and others, the work group adjusted emphasis and arrived at a practical definition that focused on two key principles:

- A Safe System is designed to *anticipate human error.*
- A Safe System is designed to *accommodate human injury tolerance*.

These two principles were viewed by the work group as a viable starting place that could stimulate change, show benefit, and establish a framework that might later be developed toward the more complete contemporary global definition (Institute of Transportation Engineers 2019). Further points of explanation were provided that touched on the comprehensive system approach and on the idea of shared responsibility:

- A Safe System seeks safety through aggressive use of *vehicle, roadway, and operational changes* rather than relying solely on behavioral changes.
- A Safe System *does not absolve the user of responsibility for safe behavior*, *but neither does it absolve the system owner or operator of responsibility for safe design or maintenance*.

The work group established a web resource for Safe Systems technical literature (Institute of Transportation Engineers 2019a) including fact sheets addressing the new framework along with a number of important Safe Systems references.

An educational webinar was developed and presented by the workgroup in November 2019, drawing nearly 300 participants. The learning objectives of the Introduction to Safe Systems Webinar were to:

- Introduce Safe Systems as an approach in the U.S.
- Recognize the foundation and elements of a Safe System
- Describe how Safe Systems may apply to roadway owners and operators in the U.S.
- Examine how vehicle design and technology are playing a role in Safe Systems

The webinar featured presentations by three widely-respected road safety opinion leaders, and focused on the role of vehicles and roadways in a Safe System. An introductory discussion reviewed the framework developed by the work group and addressed several anticipated questions from the US audience.

One of these questions concerned trade-offs that might be necessary to achieve a Safe System. Potential concessions in vehicle through-put were identified, with an example of reduced speeds in areas where vulnerable road users are present in order to reduce the probability of serious injury if a pedestrian or cyclist is struck by a car. Other potential concessions in road user freedom of choice were pointed out, such as reduced opportunity to drive under the influence of alcohol when impairment detection devices are implemented. Justifications for such concessions were offered, including the moral imperative to maximize safety and the need for a transportation system that accommodates all road users rather than prioritizing those in motor vehicles.

Another anticipated question concerned the pathway for achieving a Safe System. How could such a radical change be made in the US transportation system? The presenters offered an approach that would accomplish change through many small decisions. That is, if system owners and operators would consider the full range of options when making each decision about system design and function during their routine work, and choose the option that is best aligned with the Safe Systems framework, change would accumulate and system wide transformation could occur over time.

A third question was addressed concerning the relevance of conventional safety interventions in a Safe System. Presenters explained that many familiar interventions would be used in a Safe System. Some commonly used interventions, such as rumble strips and Electronic Stability Control systems, are completely consistent with Safe Systems principles because their function is to compensate for driver error. Others, such as lane markings and intersection treatments, may be used differently in a Safe System with the objective of separating vulnerable road users from vehicle traffic to reduce opportunities for error, or to slow traffic in high-risk areas to reduce the probability of serious injury if a collision occurs. Presenters stressed that system owners and operators need to be open-minded about new techniques in order to facilitate a successful transition to a Safe System.

The Safe Systems Work Group designed and administered a survey in September 2019 to gauge knowledge and attitudes about Safe Systems among safety professionals in the USA. The survey instrument was sent to about 500 Road to Zero Coalition members who, in a prior survey, had expressed interest in the section of the Road to Zero vision that addresses Safe Systems and Safety Culture. Responses were received from 88 individuals.

- More than 80% of respondents report being somewhat or very familiar with Safe Systems. This proportion is likely to overestimate knowledge of Safe Systems among all US road safety professionals since the sample frame consisted of individuals who had expressed interest in the Safe Systems portion of the Road to Zero vision.
- Of those working for a public agency, just 11% indicated that Safe Systems was widely practiced in their jurisdiction. Fourteen percent reported that their agency used Safe Systems on a targeted basis, and 35% indicated that their agency sometimes practiced Safe Systems.
- About 85% report that the biggest obstacle to Safe Systems implementation is either knowledge, funding, or leadership. Lack of knowledge was the most frequently reported obstacle at 34%, despite the fact that lack of training was reported by just 10%.

Fig. 3 Safe System concept diagram. (Source: Institute of Transportation Engineers)

One interpretation of these findings is that the lack of interest by public agency leadership, as reported by respondents, may be discouraging technical professionals from taking advantage of available training resources and preventing further investment of public funds in Safe Systems solutions.

To provide further clarity and direction for Safe Systems development, the Safe Systems Working Group developed a concept diagram and is formulating an action plan. The concept diagram presented in Fig. 3 illustrates the central role of Safe System principles, depicts the use of familiar elements of safety programs, *Safe Roads*, *Safe Speeds*, *Safe Road Users*, *Safe Vehicles* and *Post-Crash Care*, as means for implementing these principles, and shows how these activities define and reflect the ambient Safety Culture.

The pending action plan being developed by the Safe System Working Group will provide additional detail on activities that can be pursued in a 5-year time frame to increase awareness and build support for Safe Systems, develop and disseminate resources and tools for implementation, and institutionalize Safe Systems principles in the practices of road safety professionals.

Safe Systems Academic Center

Concurrent with the development of the Road to Zero Vision, the US Department of Transportation established a University Transportation Center at the University of North Carolina with the purpose of advancing transportation safety through a multidisciplinary systems-based approach. Working with four other universities, the

Collaborative Sciences Center for Road Safety (CSCRS) is conducting research and developing guidance that combines the principles of Safe Systems with the discipline of systems science.

The CSCRS was established in 2016 with a 6-year project period. The Collaboration has generated a range of research and educational products, including an important report on implementing Safe Systems in the USA (Dumbaugh et al. 2019), and an analysis of Vision Zero plans developed by cities across the USA (Collaborative Sciences Center for Road Safety 2020a). The CSCRS convened a Safe Systems Summit in April 2019 that was attended by more than 340 safety professionals from 29 states (Collaborative Sciences Center for Road Safety 2020b).

Federal Leadership and Support

The US Constitution preserves broad authority for state governments, including the design and construction of roads and regulation of road users. Vehicle regulation is among the powers given to the federal government since variations among state requirements for vehicle design or performance would be inefficient for vehicle production and hamper both interstate and international commerce. Decentralization of road authority has many advantages with regard to meeting local needs across states that vary significantly in terrain, climate and population. However, this lack of central road authority also has implications for achieving widespread change of the scale necessary for nationwide adoption of the Safe Systems approach.

A federal-aid highway program provides funding each year to states for construction, maintenance and improvement of certain roads and for safety programs targeting road design and road user behavior. Under this program, funds are available for specific purposes and with prescribed eligibility and spending constraints designed to encourage state investment in evidence-based methods.

For 2019, the federal-aid highway program provided more than $40 billion to states (Congressional Research Service 2019). Although these funds do not make up the largest share of road construction and maintenance costs, the program is nonetheless influential in establishing and reinforcing roadway design, maintenance and safety priorities. Investment areas, methods or specific interventions that are emphasized in the federal-aid program are seen as federal priorities or endorsements reflecting the will of the nation's highest-level transportation policymakers, thus influencing state activities.

The federal-aid highway program is revised or renewed on a 6-year cycle as part of the Congressional authorization of the functions and powers of the US Department of Transportation. As the end of a cycle approaches, Congressional offices formulate plans for the upcoming authorization period, and organizations with interests in roadway funding often make recommendations to these offices regarding emphasis areas consistent with their particular needs.

Authorization of the federal-aid highway program is a key opportunity to endorse the Safe Systems approach in the USA. As of 2020, this federal program has yet to address the concept of Safe Systems or provide an incentive for state or local roadway agencies to invest in this direction. Beyond explicit endorsement of the approach, Congressional authorization of the federal-aid highway could also facilitate Safe Systems implementation by incentivizing speed management activities at the state and local levels and removing the specific prohibition against spending program resources on automated traffic enforcement systems. This prohibition discourages adoption of automated speed enforcement, a strategy that has been an important element of Safe Systems implementation in other countries.

Focus on Children

With support from the FIA Foundation and others, the National Center for Safe Routes to School at the Highway Safety Research Center at the University of North Carolina is promoting adoption of Vision Zero for Youth programs both in the USA and internationally (National Center for Safe Routes to School 2020). These programs are designed first for the benefit of child and youth safety, with a focus on pedestrian and bicycle safety near schools, and have a secondary benefit of introducing Vision Zero and Safe Systems principles to communities. Child-focused safety activities are often easier to start than other road safety programs and frequently develop into larger community-wide efforts (National Center for Safe Routes to School 2013). Vision Zero for Youth programs often begin with a walking assessment following routes that children use to walk or bicycle to school. School officials, city officials and parents are engaged in identifying safety problems and applying Safe Systems principles to reduce risk.

New Approach: New Expectations

There are challenges to developing and implementing the Safe Systems approach in the U.S., particularly involving community expectations and political leadership, as well as openness to change. Because Safe Systems implementation tends to involve changes to the design of roadways, policies and vehicles, significant change can be slower than with behavioral interventions such as law enforcement programs. While the benefits of a Safe Systems approach are likely greater and more sustainable in terms of lives saved, compared to compliance-based programs, its implementation is slower and results are cumulative rather than sudden.

Political leadership is key to effective implementation of Safe Systems, both by committing the public funds necessary for improvements to roads and by gaining public support for policy and design changes, such as lower speed limits. Support from political leaders can also help gain acceptance for unfamiliar road features such traffic calming, roundabouts, and design changes, such as road diets, which reduce motor vehicle travel lanes to better accommodate space for walking, biking, and transit.

However, political leadership also brings certain challenges. For instance, the Vision Zero, or Safe Systems, approach is not a quick-fix but rather a long-term investment in change. This means that it is likely that a political champion may not see benefits during her or his leadership tenure and could even see negative trends in road safety resulting from a host of other factors (possibly out of their control), making it a riskier political calculation. Also, a close public association between a Vision Zero program and a specific political leader who champions the cause may lessen the subsequent leader's desire to visibly associate with it, as they may want to show their own priorities or brand.

US experience with Safe Systems implementation differs from that of Sweden and other nations in that the movement has been led largely from the local and advocacy levels, as well as by national professional organizations, and less so by the national government. This grassroots approach is perhaps less efficient than strong national leadership in securing resources and direction for local implementation. But considering political realities and the size of the nation and its federal structure, the US strategy of relying on the support of many local leaders may provide more stability in the long term.

Achieving widespread implementation of Safe System techniques in the USA will require a concentrated effort to raise awareness of the potential value of these practices at both the political and practitioner level across the many jurisdictions with responsibility for planning, operating and maintaining the US roadway system. Identifying pathways to implementation for urban, suburban and rural areas will be necessary to illustrate how the Safe System concepts can be adopted in a variety of settings. Tools, case studies and evaluations will help Safe System practices be deployed and support the concept of accomplishing change through many small decisions. The Road to Zero Coalition and its members, with support from the USDOT, can play an important continuing role in supporting the advancement of Safe Systems and movement toward the ultimate goal of Vision Zero.

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Establishing Vision Zero in New York City: The Story of a Pioneer

18

Ann-Catrin Kristianssen

Contents

Abstract

Vision Zero was established in 2014 as the foundation of the New York City road safety policy. The purpose of this chapter is to understand why and how Vision Zero was introduced as well as by whom and with what tools. The chapter focuses on understanding this policy change in New York City and is based on a document study and 18 semi-structured interview with 19 respondents city

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K. Edvardsson Björnberg et al. (eds.), *The Vision Zero Handbook*,
https://doi.org/10.1007/978-3-030-76505-7_20

administration staff, researchers, media, and NGOs. The analysis is made by looking closer at the state of four aspects by the time of the establishment of Vision Zero – problem framing, policy formulation, political actors, and proposed solutions. This theoretical framework is mainly based on the work of John Kingdon (Agenda, Alternatives, and Public Policies. Little, Brown, Boston, 1984) and Michael Howlett (Public Policy Adm 34(4):405–430, 2019). The chapter states that there were several factors leading to the adoption of Vision Zero. First, the road safety problems were not as serious as in many other regions of the USA, but compared to other major cities in the western world, the fatalities and serious injuries in New York City were deemed unacceptable by politicians, NGOs, and the public. The imminent problem on the ground was further emphasized by several high-profile cases of child fatalities in traffic crashes. Second, the Vision Zero policy or philosophy was a coherent and above all a successfully tested policy based on a scientific foundation. The credit for introducing Vision Zero in the New York City context is given to non-governmental organizations such as Transportation Alternatives and Families for Safe Streets and specific public administrators in key positions. These actors were all searching for new solutions, and as the politicians placed road safety high on the agenda, a window of opportunity was opened to Vision Zero. In addition, politicians, with the support and pressure from NGOs, established a policy program based on Vision Zero, and this program further established a belief in Vision Zero as a credible way forward. There was and is criticism directed towards the policy based on equity and that Vision Zero risks strengthening discriminatory structures. The basic idea of adapting the physical infrastructure to accommodate human mistakes is challenging in many American contexts, but in a diverse city such as New York, this approach may be able to address equity, according to several respondents, if based on solid crash data. The Vision Zero in New York City differs from the original Swedish version in mainly two ways: the focus in New York on law enforcement and on the behavior of the individual road user.

Keywords

Vision Zero · Road safety policy · Policy change · Problem formulation · Policy formulation · Program formulation

Introduction

> I do think that it was through our advocacy work that Vision Zero was brought to New York. (NGO 2)

> It really was their advocacy that brought the urgency to this issue. [. . .] they came together and said enough is enough, so I think it has come from this urgency of wanting to change and then for New York, it really was just good timing. (NGO 3)

> Mayor Bloomberg and his Transportation Commissioner Janette Sadik-Khan they had really laid a lot of the groundwork for pedestrian and bike projects that would become key parts of Vision Zero. (City Administration 1)

In 2014, New York City adopted Vision Zero as a foundation for its road safety policies. The purpose of this chapter is to describe and analyze this policy change. Vision Zero, as shown in this handbook, is both a road safety philosophy and a policy program. When a philosophy or a policy program like Vision Zero diffuses from context to context, translations inevitably take place to fit the political, administrative, cultural, and infrastructural preconditions. Therefore, we can expect both unique and similar features in the New York City Vision Zero when compared to other Vision Zero programs. It is easy to assume that a policy change is made because the previous policies were bad or even absent, but the New York City Vision Zero was not introduced in a vacuum, as there were plenty of road safety initiatives and measures prior to the introduction. Various city departments worked according to specific road safety strategies in the city, but these measures had not delivered the safety that New Yorkers wanted. Besides recognizing the problem and identifying a possible policy, it is necessary to have the support of as many actors as possible in order to achieve change. This support can also provide legitimacy and resources. One way to gather support for a policy change is to set up a reliable policy program focusing on structures of implementation. Theories of social science show that a window of opportunity for policy change is opened when several factors align such as (1) an urgent problem discussed in broad layers of the society, (2) the emergence of a new policy addressing that problem seemingly better than the old solutions, (3) a political will and support, and (4) the development of a policy program showing convincing paths to success.

These aspects can also be referred to as process streams. John Kingdon (1984) presented his multiple streams framework (MSF) in his study on agenda setting in the USA, and the framework has been a frequent tool to study policy change. In his model, the problem stream, policy stream, and political stream must converge for change to happen. For instance, if you do not have political will, you will not have change. If you do not present a convincing solution, there will be no change and so on. The model was built on previous research (c.f. Cohen et al. 1972) and has since been modified by many researchers by adding, for example, an implementation or program stream (Howlett 2019). The analysis of the road safety policy change in New York City in this chapter is based on a model adding this fourth stream, the program stream, as there is often a need for a credible program of implementation in order to open the window of opportunity.

The overall purpose of this chapter is therefore to describe and analyze the development of Vision Zero in New York City by using a streams perspective. The following research questions are applied:

- What road safety problems are to be solved through the adoption of Vision Zero?
- What is the main content of Vision Zero in New York?

- What did the political process look like, and who were the political entrepreneurs contributing to the adoption of Vision Zero?
- With what program will the Vision Zero policy be implemented?

In addition, these empirical issues will be briefly compared to the Swedish original vision as well as discussing what can be learnt from the establishment process of the New York City Vision Zero. After this introduction, the chapter contains a theoretical discussion focusing on policy change and a multiple streams approach, and thereafter the New York City Vision Zero policy is analyzed by applying these streams. The chapter proceeds with conclusions and a discussion.

Policy Change

Changes in policies, political priorities, and organizational structures are common and a natural part of societal development. Some of these changes are smaller adjustments to already existing policies, while other changes are more profound and require both a longer period of implementation and more resources, as well as additional personnel. Some changes are made due to external shocks such as disasters or other serious events (c.f Birkland 1997), and other changes occur without too much notice. When making policy changes in areas where you find particularly complicated issues, so-called wicked problems (Rittel and Webber 1973), the changes are sometimes inevitable but also multifaceted. It would not be wrong to refer to the number of people killed or seriously injured in traffic crashes each year as a wicked problem in terms of the complexity of the systems involved. That includes the difficulties of assessing how and when to reach the goal of solving the problem. But, at the same time, road safety initiatives all over the world aim to create a more systematic approach to the problem, to make it solvable. Related to this discussion, Vision Zero provides a new problem description, solutions directly related to the problem, and a vision on how to reach the stated goal (Belin et al. 2012; Kristianssen et al. 2018).

Levels of Policy Change

Policy changes are generally pursued to solve specific problems, and as problems differ, there are also different forms of policy change. Studies on policy change have focused on everything from incremental changes (Lindblom 1959) to more profound paradigm shifts (Kuhn 1962; Hall 1993), which has resulted in the identification of various taxonomies or levels of policy change. One commonly used description is based on four levels of change (Durant and Diehl 1989; Howlett and Cashore 2009). The first and second levels relate to incremental changes in "ordinary" policy development. One example of a first-level change is an adjustment in existing policies such as tax levels. A second level of change can be the introduction of a new policy for an old problem, for instance, a new policy for addressing problems of segregation without changing the overall problem frame. The third and fourth levels of change focus on more structural or paradigmatic shifts but in different forms and speed. An example of a third-level change is a policy changing the direction of climate change policy and movement towards sustainability. A fourth level change is a paradigm shift, for instance, a completely new economic system. The diffusion of Vision Zero all over the world is described by some researchers and practitioners as a paradigm shift (Belin et al. 2012, Swedish Transport Administration 2018) because it is more or less a complete overhaul of traditional road safety measures and has the potential to lead to a decisively novel outcome. Based on what we already know about Vision Zero and its implementation in various contexts, it is more than an incremental change as it is directly aimed to change the way road safety policy and measures are perceived. Time will tell if Vision Zero constitutes a complete paradigm shift on all levels.

Multiple Streams

There are naturally many ways to study policy change, and the purpose of this chapter is not to make a full recount of all theories. The temporal focus of this chapter is on the Vision Zero adoption process in New York City. Who promoted Vision Zero, how was it presented, who brought it on to the agenda, and how was it received by both administrative personnel and the public? These questions raised in the chapter relate to Harold Lasswell's (1958) influential model of communication "Who (says) What (to) Whom (in) What Channel (with) What Effect." This model has been influential not only with regard to how policy processes are studied but also in relation to research on agenda setting. As the chapter is based on the adoption process, a focus on multiple streams can provide a fruitful framework for studying this policy change. The streams approach concerns how an agenda is set, the factors leading to changing the agenda, and the actors providing support and leadership. John Kingdon's well-known study from 1984 on agenda setting in the US federal system treated the three streams – problem, policy, and politics – as separate but at the same time interrelated channels. Kingdon's model was inspired, for instance, by the work of Cohen et al. (1972, 1979) who presented what has come to be known as the garbage can perspective. Their model is a break from rationalist models on decision-making, pointing to different flows where there is no way to know exactly how a process will perform. Cohen, March, and Olsen described four flows: problem, solution, participants, and choice opportunities. The model portrays the number of problems, solutions, and participants involved in everyday public decision-making but also that they are only connected when a certain choice opportunity arises. In Kingdon's model, the three streams are also seen as separate arenas, and this highlights the role of policy entrepreneurs connecting the streams. When the streams align, we find a window of opportunity where change can happen quite rapidly. This is a way to explain why, out of an abundance of existing problems and solutions, only some problems and a specific set of solutions end up on the agenda.

Kingdon's streams related to policy change and agenda setting have been used by many scholars through the years and further discussed and developed particularly in the last couple of years (c.f. Cairney and Zahariadis 2017; Howlett 2019). One of these discussions has focused on the gaps in the streams model and the role of implementing specific solutions. According to Michael Howlett, a program stream based on implementation adds new potential to the streams model and will provide an opportunity in this chapter to separate policy design from a policy program perspective.

In this chapter, a four streams model, adding a program stream to the Kingdon model, will thus be used to analyze the empirical material. There are two main reasons for this adjustment. First, Vision Zero as a policy and road safety philosophy is connected both to solutions and to a broader policy program. Without a program perspective, there is risk of losing sight of one possibly important aspect of why Vision Zero became an acceptable policy solution. Having a clear program of implementation could enhance the chances of adoption. Second, the program stream adds other actors, particularly actors within the public administration, to the analysis of why and where a policy change takes place.

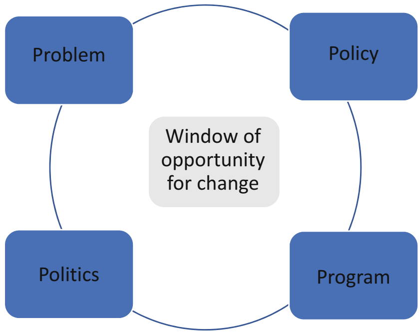
The Problem Stream

In Kingdon's study there are several routes for a problem to reach the agenda, and it is not necessarily the most urgent problem that ends of up being prioritized. The potential for a problem to reach the agenda depends on the support and will of both actors with influence and citizens who experience the problem. A problem can arise as mentioned earlier due to serious events, but it can also be related to earlier known problems that many people can relate to. Whether a problem gets attention is often determined by the existence of convincing narratives that speak to emotions and sometimes the existence of prejudice (Kingdon 1984). Using the words of Carol Lee Bacchi (2009), it is a question of what the problem is represented to be. But a problem given plenty of attention does not necessarily stay in focus, leaving the window of opportunity open for a very short period. In the streams theory, a problem is more likely to receive attention if the problem is related to a convincing policy.

The Policy Stream

This stream in Kingdon's framework is based on solutions that solve specific problems, and there are often differences in opinion as to what solution is the best, among people with varying expertise, professional viewpoints, or political points of view. Another key aspect is that solutions are developed over time, often in lengthy processes of discussion, translation, transformation, and compromise. A policy thus needs multiple types of support and is ultimately evaluated based on its cost-effectiveness; its technical qualities; its acceptance among politicians, the public, and experts; and of course its ability to solve the problem. The question is how the sometimes fast-moving problem stream connects to the slower policy stream. According to Kingdon (1984), policy entrepreneurs play a crucial role in preparing and perfecting the policy to match the problem. Research on policy entrepreneurs has been further developed by many scholars (c.f. Mintrom and Norman 2009). In this chapter, the focus of the policy stream will be on policy formulation with policy solutions being dealt with in the program stream.

Fig. 1 A revised multiple stream framework



The Political Stream

This stream focuses on the phase where ideas are turned into political opinion and where policymakers turn policy options and solutions into actual policies and legal frameworks. This is where political maneuvering takes place, and for a problem to be addressed at a certain point in time, there must be a political will. Sometimes this process coincides with elections which may enhance the chances for certain problems to end up on the agenda (Cairney and Jones 2016). Sometimes this process is predicable, such as in the case of a big crisis, but it could also be related to other factors. Politicians can also actively collaborate with other actors such as NGOs in order to push for a certain idea, problem, or solution, forming so-called advocacy coalitions (Sabatier and Weible 2007). At times competing coalitions arise leading to political conflicts in relation to various policy choices.

The Program Stream

The earlier mentioned modification of the multiple streams framework (MSF) focuses on adding an implementation or program perspective to the stream. Implementation is more commonly included as one of the policy stages in theories used to study the policy process. The program stream includes actors involved in the implementation process, such as civil servants and administrative officials, as they "...apply their knowledge, experience, expertise and values to shaping the launch and evolution of programs implementing policy decisions" (Howlett 2019, p. 420). Other actors can be active in this stream, such as private entrepreneurs and NGOs, through different form of co-production and collaboration. This stream will not be used in this chapter as a process perspective, but rather to study how the policy program of Vision Zero was presented by the time of the adoption of the vision (Fig. 1).

Research Design

This chapter focuses on the process of establishing the Vision Zero policy in New York City. It is part of a larger project also targeting policy process perspectives and equity issues. The purpose of the larger project is to map the development of Vision Zero in the city from a historical, political, and administrative perspective. All these topics do not fit into one single chapter, hence the focus on policy change and mainly the period of the adoption of the vision. This chapter more specifically focuses on the main events leading up the adoption of the vision and the actors involved in this process as well as the policy and organizational developments in the immediate period after the adoption. This means that historical developments concerning road safety as well as current developments of the Vision Zero program are mentioned, but not included in a systematic analysis. One specific purpose has also been to briefly compare the Vision Zero program in New York City to other Vision Zero programs adopted in other contexts, such as the original Swedish version.

The chapter is based primarily on a content analysis studying policy documents related to Vision Zero in New York City using the theoretical framework as a sorting mechanism. The documents selected for the study are action plans, guidelines, reports, statements, and newspaper articles, and they represent the period when Vision Zero was established. This qualitative content analysis shows how the problem is framed, the contents of the Vision Zero policy, and what actors play key roles in the adoption process, as well as the proposed program in relation to the vision. Documents from the New York City administration and particularly the lead agency Department of Transportation (DOT) are selected for analysis, and documents from the NGO Transportation Alternatives have been particularly targeted as this organization is identified as the key and leading NGO in relation to road safety.

To fully grasp the role of various actors in the process of promoting Vision Zero and finally adopting this policy, an interview study has been performed. The purpose of the interview study is to add layers and explanations to the process of introducing Vision Zero. In 2019–2020, 18 semi-structured interviews were performed with 19 respondents. The respondents belong to four main categories working with road safety issues in different ways: (1) local public servants representing several departments within the New York City administration that play a key role in the development and work with Vision Zero, (2) representatives from various non-governmental organizations (NGOs) both in the city and on the national level, (3) researchers, and (4) media. The views of politicians have been included in the form of public statements, interviews in the media, and other announcements. The interviews have been transcribed word by word and analyzed using the same theoretical framework but as stated with a particular focus on the process of introducing and establishing Vision Zero. The respondents are anonymous in the study and will be referred to as City Administration 1, 2, 3, etc.; NGO 1, 2, 3, etc.; Researcher 1, 2, 3, etc.; and Media 1, 2, 3, etc.

The questions focused on road safety work prior to Vision Zero; key actors in the process of promoting and establishing Vision Zero; policy documents and legal frameworks; the content of NYC Vision Zero; reactions from the public, administration, and politics; implementation process; organizational structure: Vision Zero task force; concrete measures; and challenges and opportunities.

This chapter is also designed to use the Swedish Vision Zero policy in a comparative perspective in order to describe the similarities and differences in the structure and content of the policy. A full description of the Swedish Vision Zero can be found earlier in this handbook.

Vision Zero in New York City

As many chapters in this handbook have shown, road traffic injuries and deaths are a global public health problem, and the statistics in the USA display a worrisome trend with a growing number of casualties, particularly among vulnerable road users such as pedestrians (US Department of Transport 2020). In 2018, there were 16 fatalities per 100,000 licensed drivers in the USA leaving 34,654 people dead. The typical fatality is a male motorist in the age group of 25–34 (NHTSA FARS database, accessed March 7, 2021). There are many actors who recognize the problem and work towards finding solutions, but the federal system imposes a number of challenges for the introduction of new policies on all societal levels, new legislation, and other types of innovations, such as vehicle improvement. Vision Zero and safe system approaches are fairly new policy directions for road safety in the USA, but the ambition to work with this approach has been introduced on the federal level, particularly through the Road to Zero strategy from 2014 and the successive campaign (National Safety Council 2014, 2021; NHTSA 2021; Vision Zero Network 2017; see also chapter on safe system in the USA for a comprehensive description and analysis).

Over 40 US states have joined the Road to Zero campaign (Vision Zero Network 2017) together with a large number of coalition partners on the local, state, and federal level (National Safety Council 2021, NSC, list of coalition partners, accessed March 12, 2021). There is a growing interest among states to discuss and incorporate the Vision Zero approach particularly as there is a Vision Zero movement also on the city level. The State of Washington pioneered the Vision Zero approach in the USA, launching their "Target Zero" in 2000, a decade prior to the adoption of Vision Zero in New York City. On the Washington State Department of Transportation website, we can read a well-known argument: "We have to ask ourselves: How many deaths and serious injuries are 'acceptable' on Washington's roadways? How many of your family members would it be 'acceptable' to lose to traffic crashes each year? Ten? Five? Of course, the answer is none. Zero" (Washington State Department of Transportation 2021). The state of Minnesota was another early adopter as it introduced its Towards Zero Deaths program in 2003, focusing on a data-driven approach to road safety work (Minnesota Towards Zero Deaths website 2021).

There has also been a growing diffusion of Vision Zero on a city level, where New York City led the way in 2014, followed by San Francisco the same year. There was a flow of cities adopting Vision Zero in 2015 such as San Antonio, Fort Lauderdale, and Austin. Since then, more cities have followed at a rapid pace (see Vision Zero Network for updated map of Vision Zero communities; see also Gonzalez 2018; Reynolds and Gale 2016; Shahum 2016; Territo 2016). This process has also inspired cities around the world to consider introducing Vision Zero. When looking closer at the development of Vision Zero in New York City, it is important to remember that although it is part of a national policy diffusion process, it is also a big city, larger than smaller countries, at least in population, and therefore it is also a unique city. It is comparable to other large cities in a global high-income perspective but also an inspiration for road safety measures in large cities all over the world.

The Road Safety Problem in New York City

New York City was and is considered one of the safest bigger cities in the USA when it comes to road traffic safety (DOT 2010), and there were existing road safety measures well before the introduction of Vision Zero – most notably the ambitious goal set in 2008 to reduce the number of traffic fatalities in the city by half by the year 2030. Even though road safety measures had been in place prior to Michael Bloomberg becoming the Mayor in 2002, the Bloomberg Administration that lasted until 2013 is credited with placing road safety high on the agenda.

> And it wasn't until Mayor Bloomberg started really focusing on sustainability and developing PlaNYC, the long-term sustainability plan which was released in 2007 that things started to change dramatically. [. . .] His innovation as a Mayor was the data-driven governance. (NGO 5)

PlaNYC was a strategic plan launched in 2007 to promote a broad agenda for a sustainable New York City (New York City 2007). It has been updated regularly and includes specific policies for road safety, particularly regarding pedestrians and bicycles. The Mayor brought Janette Sadik-Khan in as the Commissioner of the New York City Department of Transport (DOT) where she remained until 2013. She is credited by the respondents as the one who made innovative changes within the DOT and introduced a new perspective concerning urban design and engineering. Another groundbreaking plan was the New York City Pedestrian Safety Study and Action Plan (2010). The Department of Transportation is, together with City Hall, the central actor in the establishment and implementation of road safety policies in New York City, limited by the jurisdiction of the state and federal level which we will return to later on in the chapter. For a more detailed account of the departments within New York City administration and DOT working with road safety, see the following comparative report from The Swedish Transport Administration (2018). These are just examples of the many initiatives taken during the Bloomberg Administration with regard to road safety. So if a progressive road safety policy was already on the agenda, what was the problem that was going to be solved by introducing Vision Zero?

According to the non-governmental organization Transportation Alternatives, the road safety problem in New York City should not be compared to the situation in other US cities, but rather to other large cities in high-income countries, such as Paris or London (Transportation Alternatives 2011). When doing that, New York City falls short, and the organization points to several specific problems. First, the many fatalities are a huge cost for the society particularly since the crashes are preventable. At the time of the introduction of Vision Zero, the overall problem was that too many people died or were seriously injured in traffic crashes, and the first Vision Zero Action Plan described it further:

> . . .approximately 4,000 New Yorkers are seriously injured and more than 250 are killed each year in traffic crashes. Being struck by a vehicle is the leading cause of injury-related death for children under 14, and the second leading cause for seniors. On average, vehicles seriously injure or kill a New Yorker every 2 hours. (City of New York 2014)

Second, the city streets are not designed to prevent crashes. Third, speeding is a major problem, and the poor design does not help. Fourth, there is a widespread "culture of acceptance" when it comes to the number of deaths but also to behavior in the road traffic system. Fifth, the city organization working with road safety was not considered sufficient before the introduction of Vision Zero. Sixth, the same was said about law enforcement, particularly targeting speeding. Seventh, another problem was distracted drivers and driving under the influence of various substances. Eight, all the problems above tend to disproportionally affect vulnerable road users (Transportation Alternatives 2011).

These and many more specific problems are mentioned and discussed in the first Vision Zero Action Plan from 2014. In the foreword, Mayor Bill de Blasio calls for change:

> Drunk driving and failure to use seatbelts, once commonplace, are now socially unacceptable. Today, we must bring the same concerted effort against dangerous and careless driving on our streets. Better designs and regulations are already making our streets safer, and we will expand these efforts. We will bring more resources to enforcement and public outreach. In Albany, we will seek control over the City's speed limits and use of enforcement cameras. (NYC 2014)

The first road safety action plan from the new political administration under Bill de Blasio came in 2014 and, like the following action plans in the Vision Zero program, focused largely on upcoming measures and solutions. The document is a pledge to act, building on years of road safety work. The action plan is based on data provided by the Department of Transportation, and one key conclusion is that "dangerous drivers choices" (NYC 2014, p. 14) is a major cause of traffic crashes. There is furthermore a focus on problems with both physical and automated enforcement as well as insufficient legislation. Unsafe vehicles, both private and public, are also a problem, and the city administration also recognizes the need for improving street design.

If briefly comparing the problem descriptions at the time of the establishment of Vision Zero to the wording today, the problems are described using more or less the same language. Families for Safe Streets, which is a not-for-profit organization based on the engagement of relatives of people who have lost loved ones in traffic crashes, points to road safety problems such as reckless driving, problems of holding these reckless drivers accountable, and failure to construct safe streets (Families for Safe Streets website 2020). Their sister organization, Transportation Alternatives, recognizes the progress made based on the decrease in the number of fatalities from 2013 but argues that the city administration needs a much more holistic approach to the remaining problems and that many key problems are still not addressed (Transportation Alternatives 2018). The latest Vision Zero report from the city administration states that the number of fatalities decreased by 26% from 2013 to 2019 (City of New York 2020). If putting the problem into concrete numbers, in 2014, 259 people were killed in traffic crashes in New York City. In 2016 the number decreased to 231, and in 2018 it was 202 deaths (New York City 2020). In 2020, 244 people lost their lives in the New York City road traffic system (New York City 2021).

One problem that was not included in the overall agenda in 2014 was transportation equity, and this has become a major discussion, especially in relation to the

Black Lives Matter movement. It has become clear that transportation safety is increasingly discussed as a class issue. Several social movements are therefore calling on the city administration to adopt an equity perspective in relation to the transportation system (Transportation Alternatives 2017). The basic problem of inequity concerning road safety can be related also to areas such as environmental justice as some of the largest streets and boulevard with many serious crashes are located in poorer neighborhoods. These arteries have not yet been "engineered" properly which means that people in these neighborhoods have no choice but to use these roads, and, because their design encourages risk-taking and non-compliance with laws, these areas are also targeted by enforcement practices including both speed cameras and patrol interventions.

> This community hasn't received a safety project or a road-diet. So you need to make it safe, so there won't be the need for this inequitable enforcement. So that is kind of the state of it now. We are data-driven, and the data does not consider black, male, female, whatever. It does not always take into account where the infrastructure is. (City Administration 9)

It is also important to see the equity in relation to vulnerable road users. There have been many discussions in the last couple of years about the safety of, for instance, delivery workers (Research 1, 2019).

Problem Entrepreneurs

For a problem to reach the agenda, there is a need for dedicated actors who constantly remind policymakers and the broader public of a certain problem. Transportation Alternatives is viewed by several respondents in this study as one of the key actors in producing information and creating opinion about traffic safety problems in New York City (Administration 3, 2019). The organization produces reports evaluating the progress of the city administration, holds numerous seminars, and pushes for a more holistic approach to both problem framing and solutions. In addition, organizations such as Families for Safe Streets have worked hard to present the faces behind the statistics. The organization was established in 2014 by families of traffic crash victims. One way to change opinions about problem has been the publication of a list of names of people killed in traffic crashes since 2014:

> Since Mayor Bill de Blasio took office, more than 1,000 vulnerable road users – pedestrians, cyclists, e-bike and e-scooter riders – have been killed on New York City streets. These are their names. This is Mayor de Blasio's legacy. (Families for Safe Streets, https://www.transalt.org/vision-zero-fatalities, accessed December 8, 2020)

These powerful statements are emotional, but the organization has also worked over the years to point to various concrete problems, such as poor street design, drunk-driving, unsafe vehicles, and so on. In addition, the problems were also identified by political actors as well as key administrative units, such as the Department of Transportation, in the years prior to the adoption of Vision Zero. As there were road traffic safety programs in place, there was a consensus between various actors concerning many of the problems. The question at that time was whether road traffic safety would become prioritized in relation to other urgent problems. We know the answer by now, but we will return to a description of this process in the political stream section.

The Introduction and Development of the Vision Zero Policy

As mentioned earlier, Vision Zero was adopted in areas in the USA as early as 2000, and the policy or philosophy has diffused all over the world to cities, countries, and international organizations. The policy change in New York City was based on a worldwide search performed by NGOs, politicians, and administrators in New York City to find the best practices in relation to road safety. The Swedish Vision Zero has been recognized as a best practice based on its achievements related to the decrease in the number of fatalities and due to the construct of the policy.

> Sweden's Vision Zero – that ultimately no one will die or become seriously injured in traffic – has been recognized by the World Health Organization as a best practice that should be replicated by other cities and countries that wish to achieve ambitious street safety goals. (Transportation Alternatives 2011, p. 39)

Transportation Alternatives, in their report *Vision Zero* from 2011, highlighted the content of the Swedish Vision Zero as a key to progress and ultimate success. They pushed particularly for the ethical foundation of the vision that no one should die or be seriously injured in the traffic system and also that there is no such thing as accidents, as crashes are preventable. This is also part of the Vision Zero presented by the city administration:

> The fundamental message of Vision Zero is that death and injury on city streets is not acceptable, and that we will no longer regard serious crashes as inevitable. (NYC Action Plan, 2014:Foreword)

Another key part of the Vision Zero policy is that the construction of the transport system should be designed to manage the human factor that human beings – no matter how educated they are – will make mistakes. However, this human perspective is not part of the policy description of the city administration at that time. The report from Transportation Alternatives recognizes that this is a basic feature of Vision Zero, but states at the same time that: "...individuals often make a deliberate choice to engage in risky behavior on the roads, and too often this choice leads to death and serious injury" (Transportation Alternatives 2011, p. 21). Related to this perspective is the issue of responsibility, which is another key concept in the Swedish Vision Zero policy formulation. Road traffic safety is in Vision Zero a shared responsibility of all actors using the transport system. But the main responsibility ultimately falls on the system designer. This issue seems to be the most problematic to translate into a US context due in part to the notion of individual responsibility as interpreted in the US culture. Relaxing this responsibility is provocative for many US citizens. The description of responsibility follows another logic:

> Those who operate vehicles in a dense and vibrant city like New York have a special responsibility to take care when driving. Reckless or dangerous driving that puts New York families at risk should not be tolerated. In order to crack down on dangerous driving, the City proposes legislation.... (NYC Action Plan 2014, p. 22)

This quote also recognizes the shared responsibility of a broad number of road users, and we need to keep in mind the impact on road safety from the transportation industry such as taxis and other transports. On the other hand, according to the Vision Zero responsibility chain, the ultimate responsibility falls on the system designer. If using a Vision Zero approach, one could say that if it is possible to drive recklessly, it is because the roads are not designed to prevent that and/or that the vehicles are not designed to take human mistakes and errors into account.

The Swedish Vision Zero is based on a scientific foundation both concerning the tolerance of the human body to violence and how that should influence the construction of vehicles, management of speed, etc. and how the development of the policy should be based on good quality data and research. The first perspective is not highlighted in the key documents related to the establishment of the New York Vision Zero. However, it is clear that the policy is based on a data-driven approach. “Data analysis informs every aspect of the City’s response to the Vision Zero challenge. The introduction of tools to better identify problematic intersections, corridors and driving behaviors and target resources is essential to success” (NYC Action Plan 2014, p. 16).

One perspective that is prevalent in the city administration’s interpretation of Vision Zero is enforcement and the use of both physical and automated enforcement such as speed cameras. Enforcement, as described in road safety terms in the USA, is less related to how safety cameras are used in the Swedish Vision Zero policy. In New York City, they are more related to enforcement than prevention. This is another example of the local preconditions and administrative culture in New York City. According to several of the respondents, New Yorkers demand enforcement and would be very hesitant towards a policy that relied only on infrastructure and vehicle safety (City Administration 5, 2020). Another difference, compared to Sweden, is the aspect of outreach and education. This is not seen as a vital part of Vision Zero in Sweden, but in New York City it is an integral part of the policy. Outreach and communication are key issues in making people understand the notion of shared responsibility.

> Targeted outreach will complement enforcement and street design efforts and will spread the message that traffic deaths are preventable and that New Yorkers are responsible for safe behavior. (City of New York 2014)

If looking ahead to see what has happened to these aspects of Vision Zero, it is clear that the politicians and city administrators are dedicated to the ethical foundation of Vision Zero (NYC Vision Zero 5-year report 2019a). As New York has seen the number of fatalities rising at the end of the 2010 decade, it is also evident that the city administration recognizes the long-term commitment that is required to achieve the goals. As the process has moved along, the notion of shared responsibility can be seen, for example, in the work of the Vision Zero task force and other collaborative efforts which we will return to in the program section. It is important to state that this chapter is not judging what is the best Vision Zero program, but rather to identify differences and point to learning aspects when it comes to interpretations of Vision Zero.

Policy Entrepreneurs

Vision Zero was promoted by a group of dedicated non-profit organizations, led by Transportation Alternatives, pushing for the adoption of this road safety approach in New York City. They produced reports including Vision Zero policy formulations and suggestions on how to translate the vision into a New York City context. Vision Zero was also consistent with a growing focus on sustainability and a shift away from a car-focused society. Key staff members of the city administration joined in, eventually bringing Vision Zero, with the Swedish version as a role model, to the political table. Politicians, city administrators, and social movements had been looking for best practice models for years, and they found it in the Swedish road safety work.

> We found that Vision Zero had a very well-reputed brand and well-respected brand in policy circles. People knew what it was and believed in it. So we felt like that would be an advantage. (NGO, 5)

One explanation for various actors to come together to work with the same policy could be the circulation of staff, where it is not unusual for people to move from administration to organizations and vice versa. As Vision Zero was adopted, it was translated into a US and an urban context, and the contacts and exchanges with Swedish authorities were constant. This also led to a continued inspiration of specific Swedish Vision Zero policy solutions along the way.

The Political Process

As we have already concluded, the Vision Zero policy gained support among politicians, and one explanation is that the leading proponent of Vision Zero in New York City, Transportation Alternatives, began promoting and lobbying for change several years before the establishment of the policy. One way to convince the administration of such a change was to frame the city of New York in a global perspective:

> . . .when we compare New York with its peer cities in other developed nations it becomes clear that the city's current goal is not nearly as ambitious as it can and should be. For instance, while New York strives to cut its traffic fatality rate in half in 23 years, Paris did the same thing in just six. New York is already more than three years behind the principal cities of other developed countries. [. . .] This report recommends that New York City become the world leader in street safety and commit to a zero tolerance policy for traffic fatalities, establishing an ultimate goal of completely eliminating traffic deaths and serious injuries. (Transportation Alternatives 2011, p. 42)

It is interesting that the concept zero tolerance is used here as it is in many ways a total opposite to Vision Zero, as zero tolerance tends to be used in relation to enforcement, while Vision Zero is more related to preventability.

Another key to the policy change is that road traffic safety had been prioritized throughout many political administrations in New York City, and this administrative stability is described by the respondents in the study as a key factor in the adoption of Vision Zero (c.f. NGO, 3). From Rudy Giuliani through Michael Bloomberg to Bill de Blasio, the support for road safety measures has been evident. Another aspect of stability is that New York is a solid democratic city (as in the Democratic Party), and one respondent described the city as basically a "one-party city" (City Administration 2, 2020). Even republicans are portrayed as moderate democrats. This political stability is described as one important aspect of paving the way for a policy change related to road safety.

A fourth aspect and possibly the most important factor explaining the political support for Vision Zero is the mayoral election in 2013. In his political platform, mayoral candidate Bill de Blasio vowed to make road safety a prioritized policy area and Vision Zero the road safety policy. After taking office, his administration began working toward the adoption of Vision Zero and an action plan on how to organize and implement the new policy.

Although there was a consensus between organizations promoting Vision Zero, the city administration, and the political leadership, there was and is criticism towards Vision Zero as a policy. We have already touched upon the problems of equity that we will return to briefly in the program description, but there was also criticism from motorist organizations claiming that drivers of motor vehicles were described in unfair terms and that the rhetoric from Vision Zero proponents was offensive.

> We are not opposed to the goal, what we are opposed to is how the goal was enacted. One of the main tenets of Vision Zero is that no matter what, the motorist is always at fault. That is one of our biggest issues. Besides that, it also costs a lot of money. (NGO 4)

The respondents in this study claim that there is also a criticism based on ideology. Vision Zero was and is seen by some actors as a product of liberal European ideas, challenging the choice of the individual.

> There are two kinds of communities that tend to oppose what we are working on, they are either in opposition because they are just a lot more car-oriented than the rest of the city, right? So, in those communities, yes, we will get ideological pushback. And then, the other type of community where we tend to get pushback is more like [. . .] what you are doing is going to change my neighborhood for the worse. [. . .] Just a kind of general conservative idea. (City Administration 2, 2020)

Ultimately, there was a political will to change the road safety policy at that time, the policy had been introduced and marketed as a best practice from NGOs and from within the city administration, the political opposition was weak, and the Vision Zero spoke to interests already in play such as a growing bicycle and pedestrian movement. Although these actors did not necessarily see Vision Zero in the exact same way, it was enough to pave the way for change.

> . . .it was a combination of the media getting attention, the advocates mobilizing these victims. How can you look a mother in the face and tell her this is not important when she has lost her son. And then the political situation being ripe with that Mayors race. All of these things came together and that is honestly why I think it caught ground in New York. (NGO 3, 2020)

Political Entrepreneurs

The political entrepreneurs in this case were a coalition of actors from various NGOs, members of the city administration, and politicians willing to include Vision Zero in their political platforms. Many of the respondents in this study give credit to a few hard-working people at the social movements, and, in their opinion, Vision Zero would have looked different without the input of these key organizations. At the same time, the respondents also point to specific staff members within the administration who quickly saw the potential of Vision Zero and who accumulated more knowledge about the road to zero. These actors all used different tools to convince others of the opportunities of Vision Zero, and these tools consisted of everything from emotional stories from the families of victims to organizational benefits – all taking the city down the road towards zero. It is also worth mentioning that although many of the political, administrative, and advocacy voices aligned in support of Vision Zero, there are still institutions, such as the community boards, who were seen by many of the respondents as almost an obstruction to progress.

> Having to go through each community board and who the community board is comprised of may or may not be representative of the population that is actually living there, which is, you know, often the case. (NGO 2)

The Vision Zero Program

We will now explore the program perspective of Vision Zero mainly as the plan was presented at the time of the adoption of the vision in the first action plan. When arguing for a new policy and in this case a new goal, you need to convince others that it can be done, and one of the tools for convincing others is a program on how to get there. The program includes solutions in the form of concrete measures; goals, both short and long term; and an organization to manage the implementation.

When Bill De Blasio ran for Mayor in 2013, he promoted Vision Zero as a road safety policy for New York City. His campaign promise was to work according to the ambitious new target to reach zero by 2023 (c.f. Gelinas 2014, 2020), and when taking office de Blasio maintained his support for the vision, although the time frame of the target changed when faced with the challenges of reality. By adopting Vision Zero, new frameworks were introduced regarding both organization and solutions.

Looking first at the organizational changes, the New York City administration had a road safety program in place for many years prior to Vision Zero. That also meant that vital institutions were already in place, which is an advantage when making a policy change and adopting a new program. Several units, such as the Department of Transportation, had been working systematically for years collecting and analyzing data. The DOT is still the lead agency for systematically monitoring road safety and for implementing measures in the streets. One of the main new organizational features presented in the action plan of 2014 was the establishment of a Vision Zero task force.

> The Mayor's Office of Operations will convene and coordinate a permanent Vision Zero task force, comprised of the key agencies and partners needed to implement and extend this plan. The Vision Zero task force will work to meet the goals set forth in this action plan, establish additional benchmarks, and report progress to the Mayor's Office of Operations. (NYC Vision Zero Action Plan 2014, p. 8)

Placing the leadership of the task force at the City Hall is a sign of both political priority and political control. This kind of governance structure relates well to the original Vision Zero perspective of shared responsibility. The composition of the task force, with its 15 members, is based on the involvement and interest in Vision Zero, and its broad representation showed that Vision Zero was expected to permeate many different policy areas. The Vision Zero task force consists of the Business Integrity Commission, City Hall, Department of Transportation, New York Police Department, Department of Citywide Administration Services, Taxi and Limousine Commission, Sheriff's Office, Department of Health and Mental Hygiene, Law Department, District Attorney's Offices, Mayor's Office Community Affairs Unit, Mayor's Office of Data Analytics, Mayor's Office of Operations, MTA, and the Office of Management and Budget (New York City, Vision Zero task force website 2020b). The task force has also developed a number of working groups developing issues further. The task force is described as a key in the Vision Zero program.

> Getting the right people around the table is key. [. . .] They are very committed, they are very passionate, and they are very creative in terms of how they are thinking about traffic safety and how they are working together to come up with you know, ideas that are outside the box. (City Administration 6)

The Vision Zero Action Plan from 2014 furthermore laid out the Vision Zero program, where every department was ascribed a set of more or less detailed solutions. There seemed to be a clear image of what a Vision Zero program should contain, and references are made to some of the pioneers in the world and in the USA. Nonetheless, the program still rests on quite traditional road safety aspects such as the three Es (enforcement, education, and engineering).

> Vision Zero programs combine strong enforcement and better roadway engineering with improved emergency response and high visibility behavior campaigns to discourage dangerous behavior on roads and streets. In addition, Vision Zero-style policies raise the profile of traffic safety problems and help transform cultural attitudes toward traffic death and injury. Rather than accepting traffic fatalities as accidents, Vision Zero allows us – government agencies, industry groups, key transportation stakeholders and the public alike – to understand traffic crashes as the result of a series of actions that can be changed or prevented through enforcement, education, and design. (New York City, Vision Zero Action Plan 2014, p. 9)

The program presented in the action plan concentrated on law enforcement, legislation, street design, city government practices, and dialogue and outreach. The program contained 64 specific measures related to each department working with road safety. It is an ambitious program, and all the measures were to be followed up by the Vision Zero task force (City of New York 2014).

Looking at the recommendations from Transportation Alternatives prior to the adoption of Vision Zero, the solutions and measures suggested are fairly similar to those in the action plan. The focus of the solutions suggested by the Transportation Alternatives is on the ethical aspects of Vision Zero, involving the public in various forms, partnering with the private sector, redesigning streets, speeding, and speed cameras, as well as reaffirming the key role of the Department of Transportation. Another key part of their suggestion for a Vision Zero program was the formation of stakeholder groups and coordination between all relevant city administration units. Transportation Alternatives called for an establishment of:

> a hierarchy of new executive committees and working groups within city government to coordinate street safety initiatives across departments and agencies. These groups should include all city departments that have a stake in eliminating traffic fatalities and injuries. (Transportation Alternatives 2011, p. 41)

What differs is that the measures suggested by the Transportation Alternatives are less focused on the behavior of the road user.

When analyzing how the Vision Zero program is described in more recent years by the city administration, the difference is quite striking. The description of the Vision Zero program is more focused, as many of the earlier measures and reforms are in place. The focus is on collaboration through the Vision Zero task force, data-driven solutions, community outreach, and action plans directed at specific groups of road users (New York City, Year 5 report 2019a).

As mentioned earlier, one significant difference of the New York City Vision Zero as compared to the Swedish Vision Zero is the focus in the program on community outreach, education, and campaigns, although there are shifting opinions also in Sweden about the usefulness of campaigns. It is interesting to note that several of the respondents did not see this perspective as something that will directly correlate with lowering the number of deaths and serious injuries at least not in the short run, but that this kind of measure will hopefully create a common interest and a common safety culture which is important in a long-term perspective.

The current situation in New York has naturally been affected by the Corona pandemic, which has left an unwanted mark on communication patterns and on road traffic safety, as cars are more frequent in the current situation (Transportation Alternatives 2020; Gelinas 2020). The Vision Zero program has not come to a halt, but the respondents interviewed during the pandemic state that the financial situation is problematic and that planned measures will have to wait (City Administration 4 & 5). As the Vision Zero program depends on constant systematic improvements, the road ahead is quite bumpy. In addition, the Vision Zero program has been criticized for not taking equity issues into account, and as social inequality is a major political issue right now, this is a growing discussion in relation to road safety measures (see chapter on criticism of Vision Zero). The city administration has been accused of allowing discriminatory structures of police enforcement to find their way into the Vision Zero policy and of targeting specific groups with manual enforcement through racial profiling. The city administration is also accused of not taking appropriate road safety measures in poorer neighborhoods (Research 1, 2019). The response from the city administration to these concerns is that they are cautious not to reproduce structural discrimination, and that the data-driven approach is neutral in this respect, and lead road safety work to the locations where crashes take place. This creates an opportunity to switch from manual enforcement to automatic enforcement (City Administration 6, 2020).

It is also important to mention that the progress in the Vision Zero policy program is also dependent on good cooperation with the state legislature which controls important statewide policies such as the permissibility of speed cameras. It is also vital to have a good cooperation with the federal government regarding national priorities and norms.

> It is difficult because sometimes we rely on the data that is captured by New York State. And if we do not have access to that or we do not have a representative from the state, that makes our lives a lot more difficult. Policy-wise, speed cameras are very reliant on what legislators pass at the state level and if we do not have that understanding, then basically the whole speed camera program dies. (City Administration 8)

There are of course many more current programs and measures in place that could and should get more attention, but these fall outside the frame of this chapter and will be addressed by the project in other publications. The purpose of this chapter is to summarize the adoption process. To sum up, there are many measures frequently mentioned in both text and in the interviews, and we have already mentioned the safety camera program which is seen as a both cost-efficient measure and a more equitable solution than physical enforcement. The New York City administration has been working intensively with updating the safety of its own fleet (New York City, Citywide Administrative Services 2021) often entailing quite complicated negotiations with the vehicle industry. One respondent used the following example to describe the challenge: “When Volvo sells a truck in England or Sweden it has a sideguard. When they sell that same truck in the United States, the take it off” (City Administration, 4). Other often mentioned measures include prioritized bus lanes especially on major arteries in Manhattan and protected bike lanes.

Program Entrepreneurs

The Vision Zero program presented by the city administration in its action plan from 2014 shows great similarities with reports and statements from NGOs advocating for the adoption of Vision Zero. Creating a convincing and full program is one way for the city to gather support for Vision Zero. The main actor, working with the first action plan, was City Hall in collaboration with other city departments. The Department of Transportation was and is still a central actor in transforming policy into implementable measures and solutions. The respondents in the study also specifically highlighted the role of the former Transportation Commissioners Janette Sadik-Khan and Polly Trottenberg. The action plan from 2014 was related to the political platform of the new political administration, and looking at the yearly reports from city, it is evident that the Vision Zero program is constantly evolving. Collaboration and coordination among the large number of stakeholders, especially through the Vision Zero task force, have become a key feature. This organizational structure has also been exported to several other Vision Zero cities in the USA. We must not forget the role of NGOs such as Transportation Alternatives, Families for Safe Streets, organizations working with sustainability and research, and others, constantly challenging the city administration to do better as they ask for more Vision Zero, not less.

Analysis and Conclusions

As New York City already had road safety policies in place at the time of the adoption of Vision Zero in 2014, the question is what kind of policy change did we witness here? Was it an incremental change or something more profound, even paradigmatic? The change from a more traditional view of blaming the reckless driver to focusing more on street design and vehicle safety can be seen as a substantial change, at least in road safety philosophy. At the same time, there is still quite a lot of attention given to the recklessness of individual road users.

Problem Stream

Analyzing the framing and the construction of the road safety problem in New York City prior to the introduction of Vision Zero, it is evident that no actors found the number of fatalities and seriously injured acceptable. This was further strengthened by the deaths of several children in traffic crashes in conjunction with the period of the mayoral election. There was an opportunity to put the problem onto the agenda by both NGOs, politicians, and private citizens, and particularly by organizations such as Transportation Alternatives, who made sure that the issue was not forgotten. At the same time, there was public awareness of road safety problems, which made it easier to gain acceptance for prioritizing road safety.

Policy Stream

The Vision Zero policy had been promoted for many years by various NGOs, including bicyclist organizations, organizations working with sustainability, and organizations working towards a car-free society, and as road safety was already on the agenda, there was an opportunity to bring a new policy onto the table. Vision Zero was described as a best practice with an ethical profile matching the description of the problem. As the policy was picked up by politicians, a translation took place to fit into the context. The initial focus on enforcement and drivers' behavior is a deviation from the Swedish Vision Zero but could be interpreted as a way to get acceptance for a shift to a new road safety philosophy. The process of formulating the policy was not connected to conflict, although there were critical voices.

Political Stream

The mayoral election in 2013 turned out to be a game changer for road traffic safety and an opportunity to promote an urgent problem as well as the solution. In more theoretical terms, the "political mood" was right, and there was an opportunity to make a strong emotional appeal. Being the mayor who would push the numbers down to zero is naturally appealing. In a progressive and liberal city, it did not hurt to partner with strong NGOs with a lot of expertise, not only about road traffic safety but also how to connect road safety to other aspects such as sustainability. To sum up, the political opportunity was there to promote the problem framing and the solution, as well as a broad coalition favoring Vision Zero.

Program Stream

The final question is whether Vision Zero was also accompanied by a convincing policy program. The Vision Zero Action Plan from 2014 presented a comprehensive program based on shared responsibility. A Vision Zero task force was to be created involving a large number of city administration departments and units. Every department received their list of responsibilities, and the program was more or less guided by the three Es – engineering, education, and enforcement. This rather traditional road safety program was combined with the ethical perspective of zero. The program presented was not aligned completely with suggestions from NGOs, but some of the key aspects, such as collaborative governance structures and redesigning the streets, were similar. The differences in program approach did not cause major disagreements, and perhaps one explanation is that programs can be changed, adapted, and modified as the process advances. We have seen that the program has changed over the years to adjust to new insights and work modes (New York City 2017, 2018, 2019b, 2020a). The question here is whether we needed to add a program stream to understand the policy change. The answer is yes. In order to credibly promote a certain problem framing and a solution to that problem, there is a need for concretization. Inclusion of a program stream in this analysis reveals that the program presented by the city was convincing enough for that window to remain open.

Discussion

As New York City was considered a quite safe city in a US perspective in terms of traffic crashes, why was it necessary to change its road safety policy? This chapter has concluded that the number of fatalities and seriously injured was not acceptable to any of the actors working with road safety. NGOs focusing on transportation issues provided a platform for emotional stories of grief that had an impact on the view of the problem. Another explanation is that New York City, despite its low number of fatalities in a national perspective, was far behind other similar big cities in the developed world. This was possibly a motivation.

What Kind of Vision Zero?

Various NGOs and city administrative units had been searching for new methods, programs, and innovative ideas on how to make progress. Vision Zero was promoted mainly by NGOs such as Transportation Alternatives and was backed by considerable knowledge and a policy formulation. The impressive record of the Swedish Vision Zero policy program was used as an argument for change. The Vision Zero policy in New York City was and is not exactly the same as the Swedish version, but was translated to fit the New York context, and there is a growing convergence as well as constant exchange.

> Vision Zero originated in Sweden in the 1990s, and the country remains a model for progress in traffic safety and the administration of Vision Zero initiatives. Over the years, Sweden has evaluated its progress in a way that serves to guide other nations and cities pursuing the goal of zero traffic deaths and serious injuries. (City of New York 2020, p. 22)

Politicians, particularly the Democratic majority, joined with NGOs and administrative units to adopt Vision Zero. The NGOs are today constantly working to promote more road safety measures, and they continue to call for more Vision Zero, not less. But they argue that Vision Zero has to be based on principles of equity, which is a growing concern among many NGOs. The link between the NGOs and the administration is facilitated by a movement of personnel between the two and reinforces mutual understanding.

The New York City Vision Zero policy program, based on a new road safety organizational approach, along with new goal-setting strategies and solutions, adds clarity to how the policy is to be implemented. The structure of the efforts has been praised by many NGOs, but at the same time, the measures are constantly scrutinized and evaluated. For instance, Transportation Alternatives publishes on a regular basis a report card where the key organizations are evaluated based on their performance and on how they work with the Vision Zero program.

Learning from a Big City Experience

What can we learn from the case of policy change in the New York City road safety program? One apparent aspect is the role of the civil society in promoting new ideas, in creating knowledge and expertise, and persistently holding public authorities accountable. This strategy can lead to both productive collaborations and constant improvements. Another interesting aspect is the construction of a constantly developing collaborative structure within the administration – the Vision Zero task force. Its organization and work modes are undoubtedly something to learn from when aspiring to adopt Vision Zero or other long-term policy commitments. This is one key aspect in the discussions among Vision Zero cities (c.f. Vision Zero Network 2020).

New York City is unique, and the Vision Zero journey of this big city has just begun, particularly in relation to the long-term ambition of reaching zero. This will not be done quickly, and reaching zero by 2023, as was an aspiration in the beginning of the process, is quite impossible. Vision Zero, like other road safety measures, demands patience and can be regarded as a wicked problem in several aspects. Vision Zero also requires a robust system of dedicated actors as well as a comprehensive program. The cultural differences between the various contexts where Vision Zero is adopted are necessary to take into account. The question is whether the New York City Vision Zero will be less effective by focusing more on law enforcement, outreach, and education than the original Swedish version. Time will tell what will be deemed the most efficient ways to work with Vision Zero, and the diffusion process will provide more and more cases to study. Maybe these new cases will provide new ideas and solutions further developing the original policy.

Cross-References

► Adoption of Safe Systems in the United States
► Arguments Against Vision Zero: A Literature Review

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Traffic Safety in India and Vision Zero

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Abstract

This chapter presents the current state of traffic safety in India and a brief overview of history of traffic safety policies in India. The road safety policy adopted by the Government of India does not have any specific targets; however, the government has accepted the UN sustainable development goals (SDG) and targets in 2016. SDG 3.6 is related to road traffic injuries, and it requires that the fatalities due to road traffic crashes must be reduced by 50% by 2030. The last section of the chapter presents a roadmap for selected cities in India for achieving SDG target 3.6 by 2030 and discusses the results in the context of "Vision Zero" for India.

Introduction

"Vision Zero" is a landmark safety policy. It was introduced in Sweden at a time when Swedish roads and transport system were considered one of the safest systems in the world. Most countries have traditionally accepted that health losses due to accidents are a major, but to some extent acceptable, consequences of mobility. Contrary to this, the Swedish parliament in October 1997 opined that the long-term target for the road transport system should be that no one should be killed or receive long-term disablement by the system (Claes Tingvall 1998; Claes Tingvall and Haworth 1999). The Vision is an expression of ethical imperative that "It can never be ethically acceptable that people are killed or seriously injured when moving within the road transport system" (Claes Tingvall and Haworth 1999).

Vision Zero demands that the loss of human life in the road transport system is unacceptable, and therefore the transport system should be designed in a way that such events do not occur. This means that safety is a more important issue than other issues in the road transport system (except for health-related environmental issues). Mobility, therefore, should follow from safety and cannot be obtained at the expense of safety. Prior to the introduction of the Swedish Vision Zero concept, Dr. William Haddon in the USA had proposed that road traffic injuries be considered a serious public health problem and provided a structured method of analyzing and developing targeted interventions for safety (Haddon 1970, 1980). Charles Perrow introduced a structural analysis of complex systems, highlighting the notion of systemic error rather than an individual's error in high-risk systems (Perrow 1984). Vision Zero brought in the "Ethical Imperative" in the traffic safety debate.

That road traffic injuries (RTI) should be considered a public health problem has been accepted for decades (Gibson 1961; Haddon 1963, 1968). In 1962, L.G. Norman, who was the Chief Technical Officer of the London Transport Executive, prepared a report for the WHO in which he stated that "It has even been suggested that the limit of human performance is being reached in this respect and that the consequent accidents are the inevitable price of motorization. This view should not be accepted" and that "As a public health problem, road accidents are amenable to treatment by the methodology applied to epidemic disease, including the detailed investigation of individual incidents and the application of epidemiological techniques" (Norman 1962). However, RTI is the only public health problem where society and decision-makers still accept death and disability on such a large scale as inevitable (Mohan 2003). This human sacrifice is deemed necessary to maintain high levels of mobility and is seen as a necessary "externality" of doing business. Discussion only revolves around the number of deaths and injuries we are willing to accept. This is made clear in the opening paragraph of the US *Highway Safety Manual*: "There is no such thing as absolute safety. There is risk in all highway transportation. A universal objective is to reduce the number and severity of crashes within the limits of available resources, science, and technology, while meeting legislatively mandated priorities" (AASHTO 2010). A complete departure from this mode of thinking is "Vision Zero" that originated in Sweden. In October 1997, the Road Traffic Safety Bill founded on Vision Zero was passed by a large majority in the Swedish parliament (Tingvall1997; ""Vision Zero" in perspective of global generalization," 1998).

This chapter presents the current state of traffic safety in India and the issues surrounding the possibility of moving toward Vision Zero. A brief overview of history of traffic safety policies in India is presented to set the context. The road safety policy adopted by the Government of India (https://morth.nic.in/national-road-safety-policy-1) does not have any specific targets; however, the government has accepted the UN sustainable development goals (SDG) and targets in 2016. (https://niti.gov.in/index.php/verticals/sustainable-dev-goals) SDG 3.6 is related to road traffic injuries.

National Road Traffic Injury Fatality Rate

According to official statistics, 151,417 persons were killed and 469,418 injured in road traffic crashes in India in 2018 (Transport Research Wing 2019). However, this is probably an underestimate, as not all injuries are reported to the police (Bhalla et al. 2017, Mohan et al. 2009, Gururaj 2006). The actual number of injuries requiring hospital visits may be 2,000,000–3,000,000. In GBD 2010, it was estimated that there were 2.2 million injuries in India that warranted hospital admission, and 18 million injuries warranted an emergency room visit (Bhalla et al. 2014). Road traffic injuries (RTI) in India have been increasing over the past 50 years (Fig. 1). This may be partly due to the increase in the number of vehicles on the road but mainly due to the absence of coordinated evidence-based policy to control the problem. These data show that the number of fatalities has continued to increase at about 70% a year over 2000–2010, a slight lower rate over the past decade.

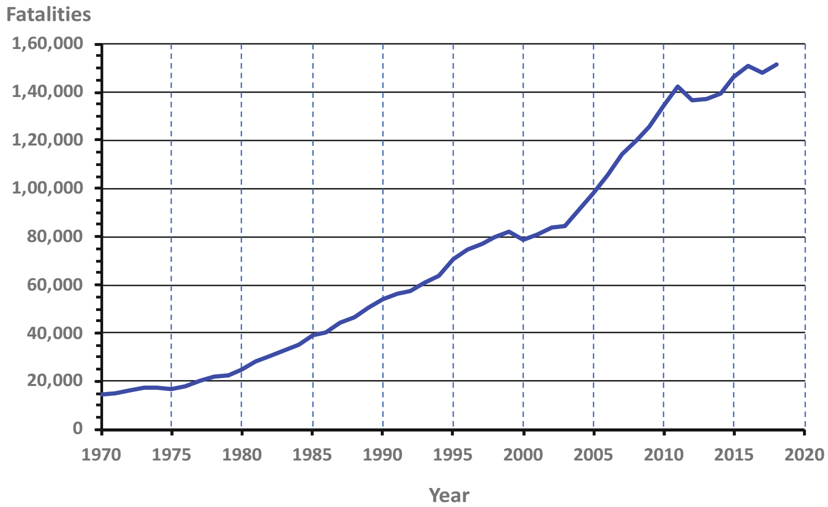


Fig. 1 Road traffic deaths in India from 1970 through 2018. (Source: NCRB 2015 and Transport Research Wing 2019)

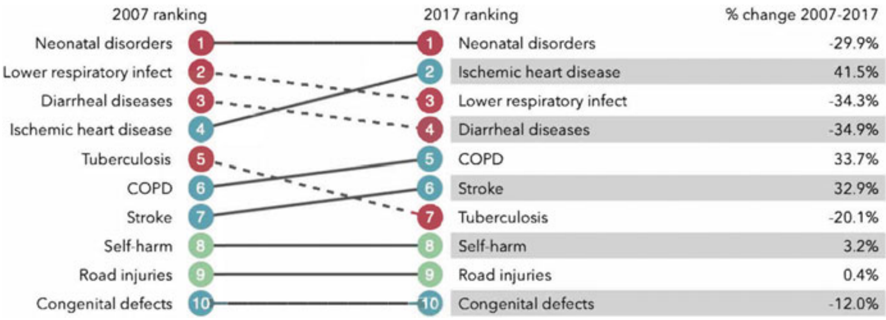


Fig. 2 Top ten causes of years of life lost (YLLs) in India in 2017 and percent change between 2007 and 2017 for all ages. (Source: Institute for Health Metrics and Evaluation (IHME 2018))

Ranking in Causes of Death and Population Health

Figure 2 shows the top ten causes of years of life lost (YLLs) in India in 2017 and percent change between 2007 and 2017 for all ages (Institute for Health Metrics and Evaluation (IHME) 2018). This figure shows that injuries resulting from road traffic crashes impose a substantial burden on the health of the population in India. Road traffic injuries are the ninth leading cause of premature death in India, and this exceeds the number of those who succumb to many diseases like malaria and HIV that are acknowledged to be important health issues in the country.

Figure 3 shows that over the last two and a half decades, the burden of road traffic injuries in India has increased, while that due to many infectious diseases has

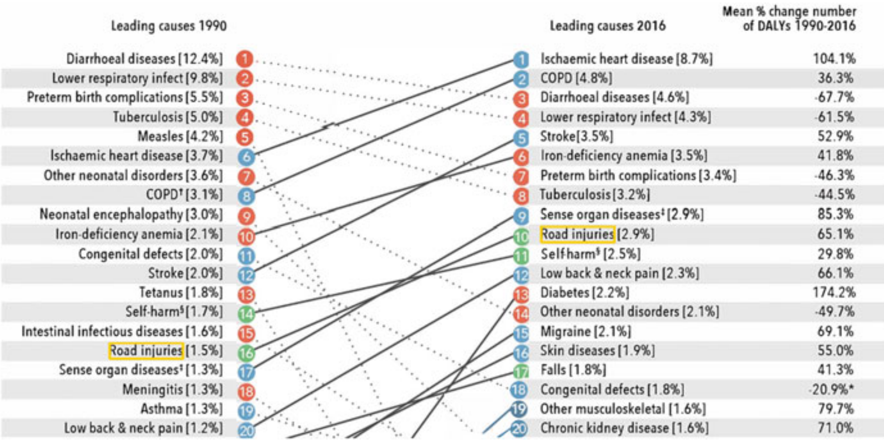


Fig. 3 Change in DALYs number and rate for the leading individual causes in India from 1990 to 2016. (Source: Indian Council of Medical Research, Public Health Foundation of India, & Institute for Health Metrics and Evaluation (IHME) 2017)

declined. In 1990, road traffic injuries were the 16th leading cause of health loss. However, in 2016 they were ranked tenth due to an increase of 65% in disability adjusted life years (DALYs) attributed to road traffic injuries (Indian Council of Medical Research, Public Health Foundation of India, & Institute for Health Metrics and Evaluation (IHME) 2017).

International Comparison

The 2018 WHO *Global Status Report on Road Safety* provides two sets of road traffic death statistics for every country (WHO 2018). These are the official government statistics (usually based on police data) reported by each country to the WHO and statistical estimates produced by the WHO by analysis of national health data (including vital registration) for each country. Figure 4 shows the official RTI fatality rates for different countries plotted against per capita income of the countries, and Fig. 5 shows the rates for the same countries as estimated by the WHO (WHO 2018). These figures show that for 43% of the countries, the WHO estimates are 1.5 times greater, and for 26% more than 3 times greater than the official rates are reported by the countries.

The ratio of the WHO estimate and the official rate for different countries is shown in Fig. 6. The ratio for India is 2.0 as the official reported rate is 11.4 deaths per 100,000 persons and the WHO estimate is 22.6. These data indicate that some countries with similar incomes have lower levels of underreporting and some with higher income levels have also have higher levels of underreporting. This suggests that lower national income levels cannot be taken as an excuse for inefficient data collection systems and it is possible for countries like India to set up professionally

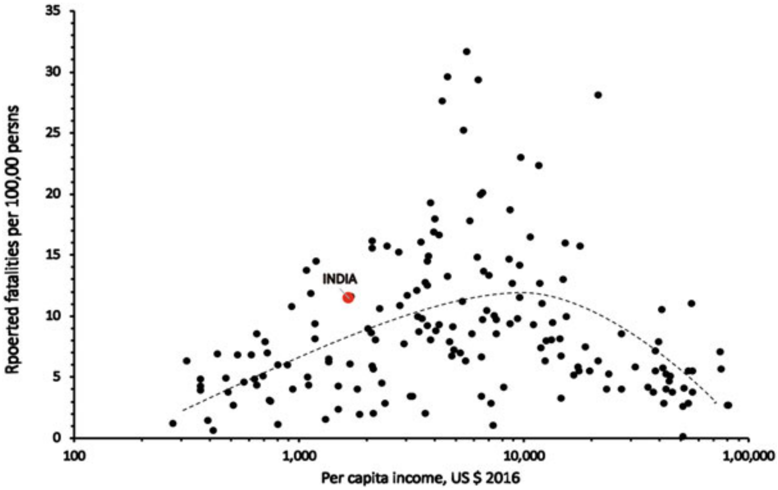


Fig. 4 RTI fatality rate per 100,000 persons reported by different countries vs per capita income. (Source: WHO 2018)

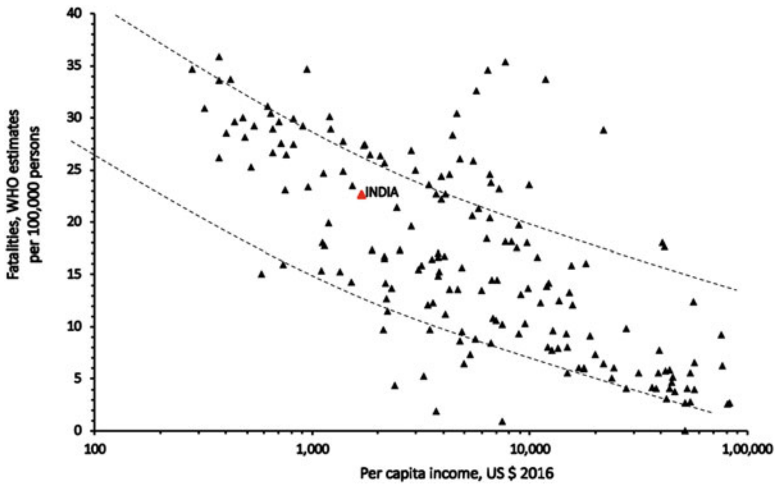


Fig. 5 RTI fatality rate per 100,000 persons as estimated by WHO for different countries vs per capita income. (Source: WHO 2018)

managed data collection systems that give a reasonably accurate estimate of RTI fatalities. Systematic collection requires streamlining police data at State level, establishing a system like FARS (Fatal Accident Recording System) in the USA.

Both the official country data and the WHO estimates (Figs. 4 and 5) show that there are countries with incomes similar to India that have RTI fatality rates lower than India. Again, demonstrating that lack of finances does not necessarily mean that a society has to have absence of safety on the roads. Of course there are many factors

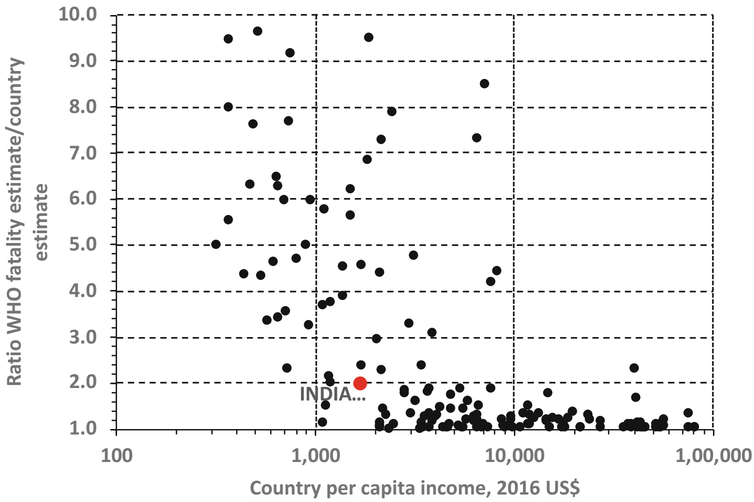


Fig. 6 Ratio of the WHO estimates and official RTI fatality rate per 100,000 persons for different countries vs per capita income. (Source: WHO 2018)

other than income that affect crash fatality rates. However, income is considered an important factor. At the same time, many countries much richer than India have much higher fatality rates. Therefore, we cannot depend on growth in national income alone to promote road safety. It will be necessary to put in place evidence-based national safety policies to ensure improvements in traffic safety.

Analysis of Data at the National Level

National Fatality Rates

Figure 7 shows the official estimates for the total number of RTI fatalities and fatalities per 100,000 persons in India from 1970 to 2018 (Transport Research Wing 2019). The total number of deaths in 2018 was 10 times greater than in 1970 with an average annual compound growth rate (AACGR) of 6%, and the fatality rate in 2018 was 4.3 times greater than in 1970 with an AACGR of 4%. There are indications that the rate of growth of fatalities in India decreased after 2010. There have been a few periods when the absolute growth in RTI fatalities decreased briefly, but the causes for the same are not known. However, it is known that motor vehicle crash rates have a tendency of decreasing along with a downturn in the national economy (International Traffic Safety Data and Analysis Group 2015):

> Economic downturns are associated with less growth in traffic or a decline in traffic volumes. They are associated with a disproportionate reduction in the exposure of high-risk groups in

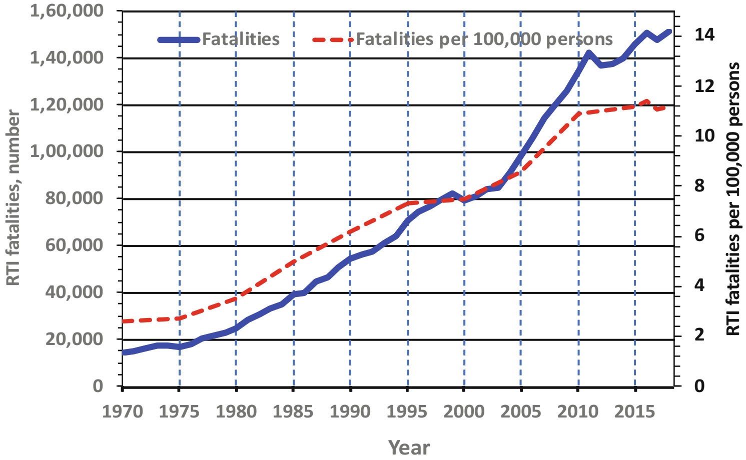


Fig. 7 Total number of RTI fatalities and fatalities per 100,000 persons in India. (Source: Transport Research Wing 2019)

> traffic; in particular unemployment tends to be higher among young people than people in other age groups. Reductions in disposable income may be associated with more cautious road user behaviour, such as less drinking and driving, lower speed to save fuel, fewer holiday trips.

This may explain the reason why the rate of growth in fatalities slowed down in India in the late 1990s and in the period 2010–2014 as these were also periods of low economic growth. Two modelling exercises have attempted to predict the time period over which we might expect fatality rates to decline in different countries (Koornstra 2007, Kopits and Cropper 2005).

Kopits and Cropper used the past experience of 88 countries to model the dependence of the total number of fatalities on fatality rates per unit vehicle, vehicles per unit population, and per capita income of the society. Thus, based on projections of future income growth, they predicted that fatalities in India will continue to rise until 2042 before reaching a total of about 198,000 deaths and then begin to decline. Koornstra used a cyclically modulated risk decay function model, which in a way incorporates the cyclically varying nature of a society's concerns for safety and predicts an earlier date of 2030 for the start of decline in RTI fatalities in India. If we assume the average growth rate of 6% per year declines to nil by 2030, then we can expect about 200,000 fatalities in 2030 before we see a reduction in fatalities.

The above models use the experience of high-income countries (HIC) over the past decades in calculating relationships between vehicle ownership levels and risk of death per vehicle. Therefore, the models presuppose the onset of decline at specific per capita income levels if the past road safety policies of HICs are followed in the future in countries like India. These predictions are based on the assumption that the relationship between fatality rates and income follows a pattern as shown in Fig. 4. However, if the pattern is more like the one shown in Fig. 5, then these predictions would not be reliable. The relationship between national income and RTI fatality rates (initial increase in deaths with increasing incomes and a subsequent decrease) may not be entirely correct. Therefore, it is possible that the earlier claims that fatality rates will continue to increase until societies reach income levels between US$ 10,000 and 20,000 (2013 international prices) before decreasing are probably not correct.

Based on an analysis of RTI fatality trends in Europe and the USA, Brüde and Elvik (2015) suggest that:

> A country does not at any time have an 'optimal' or 'acceptable' number of traffic fatalities. In countries with a growing number of traffic fatalities, one cannot count on this trend to turn by itself; active policy interventions are needed to turn the trend.

The trend shown in Fig. 4 is often used to justify that RTIs will increase until the per-capita income reaches 10 K USD. Elvik (2015) conclude that active policy interventions are required to turn the trend". If this is true, then the only way the decline of RTI fatalities can be brought forward at time is to institute evidence-based India-specific road safety policies that are more effective.

Estimates of Modal Share of RTI Fatalities in India

Figure 8 shows estimates of the share of different road user fatalities as reported by MoRTH (Transport Research Wing 2019) and estimates made by Hsiao et al. (2013), the present authors (IIT Delhi estimate), and Dandona et al. (2020). Hsiao et al.'s estimates are based on a nationally representative mortality survey of 1.1 million homes in India which reported 122,000 RTI deaths, IIT Delhi estimate is based on an analysis of police records obtained from 8 cities (Delhi Traffic Police 2014, Mani and Tagat, 2013, Mohan et al. 2013) and a number of locations on rural roads around the country (Gururaj et al. 2014, Tiwari 2015, Tiwari et al. 2000, and Dandona et al.'s (2020) estimate is based on several verbal autopsy data sources.

The MoRTH estimates suggest that pedestrian fatalities constitute only 15% of total RTI fatalities in the country. The Hsiao et al. (2013), IIT Delhi, and Dandona et al. (2020) estimates for share of pedestrian fatalities are 37%, 33%, and 35%, respectively. This is a very large gap between the official and researchers' estimates. Since Hsiao et al. and Dandona et al. have estimated the fatalities from verbal autopsies with a statistically representative sample of households in India (a part of the sample registration system of the Registrar General of India), it is likely that their numbers are closer to the truth. The IIT Delhi estimate is made from detailed analysis of police reports from various parts of the country and, therefore, may be considered as being based on official data, though from a smaller sample in the country. Since these latter estimates for pedestrian fatalities are similar, it is quite certain that these estimates are more reliable than those in MoRTH reports. The error in the official reports probably arises from wrong coding of the victims' status, and the procedure needs to be reviewed carefully and revised. A detailed analysis of

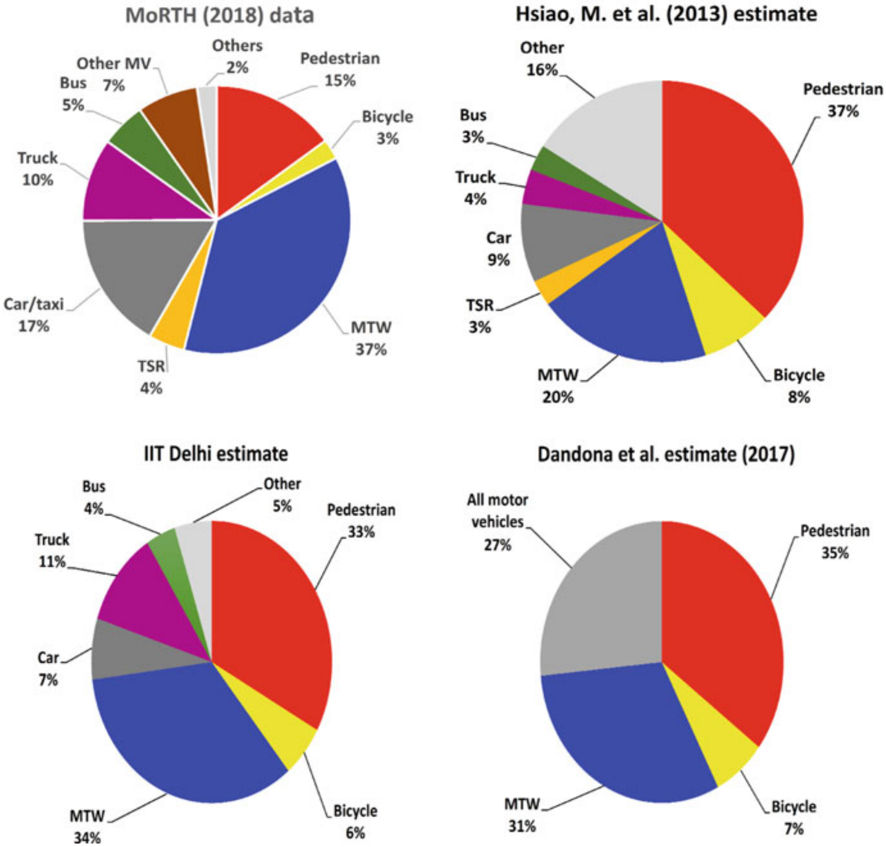


Fig. 8 Estimates of the share of different road user fatalities in India. Note: MTW, motorized two-wheeler; TSR, three-wheeled scooter ricksha. (Source: Transport Research Wing 2019, Hsiao et al. 2013, GBD: Institute for Health Metrics and Evaluation (IHME), IIT Delhi estimate – authors of the present report)

police records shows that the cases are registered, however, error occurs at the time of coding. Non recording may also be there, however, bigger problem at the moment is wrong coding. The Indian official estimates of pedestrian fatalities are extremely low compared to independent researchers' estimates (~15% vs ~35%); therefore, official estimates for all other modes will also be wrong. MoRTH data is based on police coding. The data is collected from the police station, compiled at State level and then at the National level. We have explained the coding problem of data earlier. IITD data source is also police data, however, coding is done in the lab after reading the description of the crash. The difference in the two data sets point to the erroneous coding. Hsia et al. (2013) and Dandona et al. (2017) is based on a different methodology (oral autopsy of one million deaths in the country). MoRTH is erroneous for coding the victims, when a bigger vehicle is involved. MTW and bus collision in which MTW is the victim may get recorded as bus victim if the bus

Table 1 Modal share of road traffic fatalities in selected high-income countries. (IRTAD Road Safety Annual Report 2019, https://www.itf-oecd.org/road-safety-annual-report-2019)

Country	Car	MTW	Bicycle	Pedestrian	Other
France	51	23	5	14	7
Germany	48	19	12	15	6
Japan	21	16	15	37	11
The Netherlands	41	7	30	8	7
Canada	50	11	2	18	19
Sweden	56	17	7	10	10
USA	36	14	2	16	32[a]

MTW Motorised two-wheeler
[a]Includes SUV, van, pickup truck

has been recorded as vehicle at fault. For the time being, we will have to use research estimates for modal share of road traffic fatalities and not the official number.

The modal share estimates for India are significantly different from those in most high-income countries (Table 1). What is most important to note here is that the proportion of car occupant deaths for countries included in Table 1 (except Japan) is greater than 40% and motorized two-wheelers (MTW) less than 23%. Estimates in Fig. 8 suggest that car and motorized two-wheeler occupant fatality proportions are <10% and >30%, respectively. These proportions in India are unlikely to change dramatically over the next decade. Because of these differences, road safety priorities may have to be very different in India, and some new safety interventions would have to be developed to move toward Vision Zero.

RTI in Urban Areas

According to the MoRTH report, 51,379 (34%) fatalities took place in urban areas and 100,038 (66%) in rural areas (Transport Research Wing 2019). These data suggest that the urban RTI fatality share is about the same as the estimated urban population share (34%) in 2018. (Rural population (% of total population) – India. The World Bank. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=IN) The latest report includes details for 50 million-plus (population) cities recording a total of 17,709 fatalities (34% of all urban RTI deaths). Figure 9 shows deaths reported in these cities for 2015 and 2018. Figure 10 shows the RTI death rates per 100,000 population in million-plus cities for 2015 and 2018. Population numbers for these cities are not available for 2015 and 2018 from the Office of the Registrar General and Census Commissioner, India. Population for each city in 2015 and 2018 was estimated using 2011 figures and official growth rates for the states they are located in (Technical Group on Population Projections 2006).

There were 10 cities with 50% lower rates than the average for all cities in 2018 with rates ranging from 2 to 7 fatalities per 100,000 population: Ahmedabad, Amritsar, Hyderabad, Kannur, Kochi, Kolkata, Mumbai, Pune, Srinagar, and Surat. It is not possible to explain the differences in city fatality rates per hundred

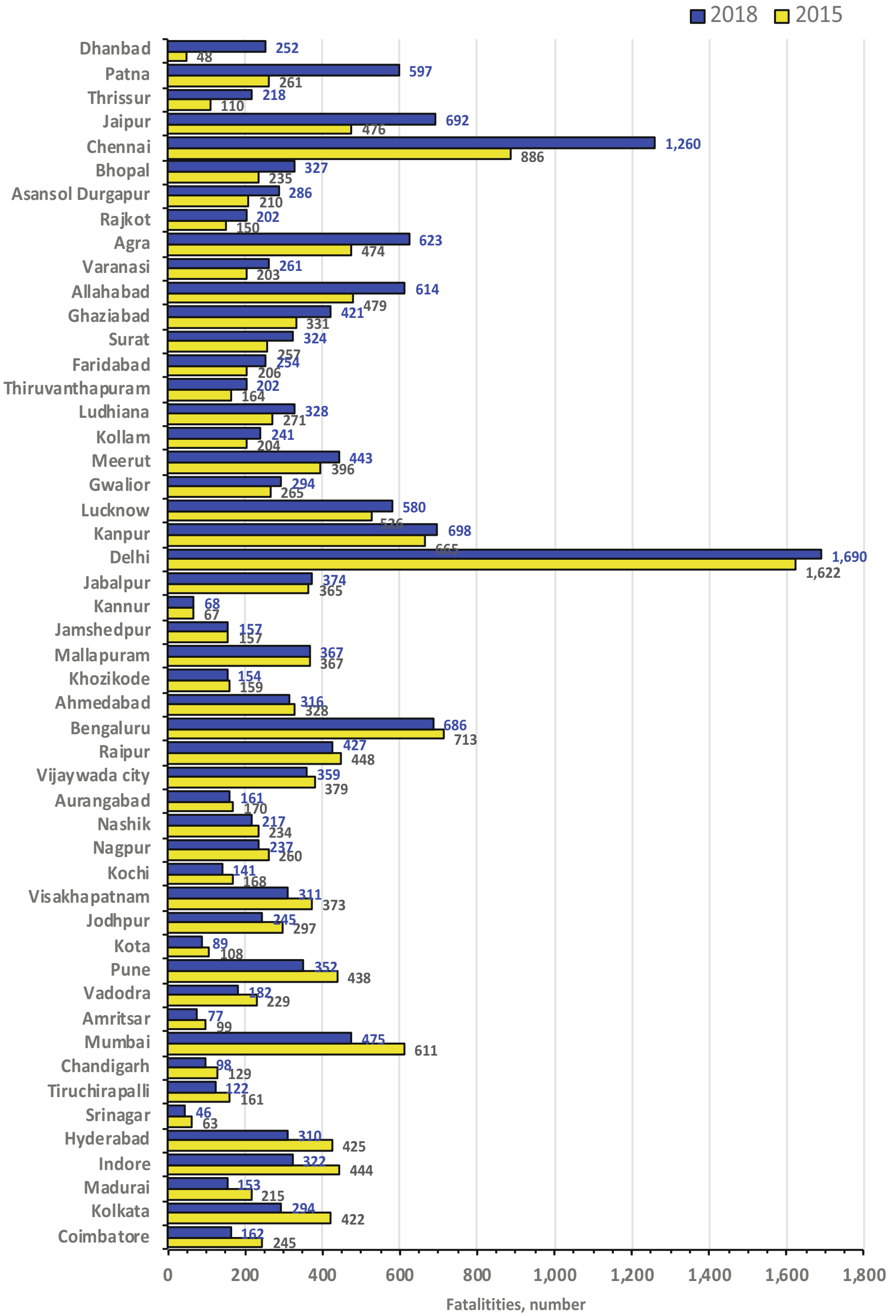


Fig. 9 Annual RTI deaths in million-plus (population) cities in 2015 and 2018. (Source: Transport Research Wing 2019)

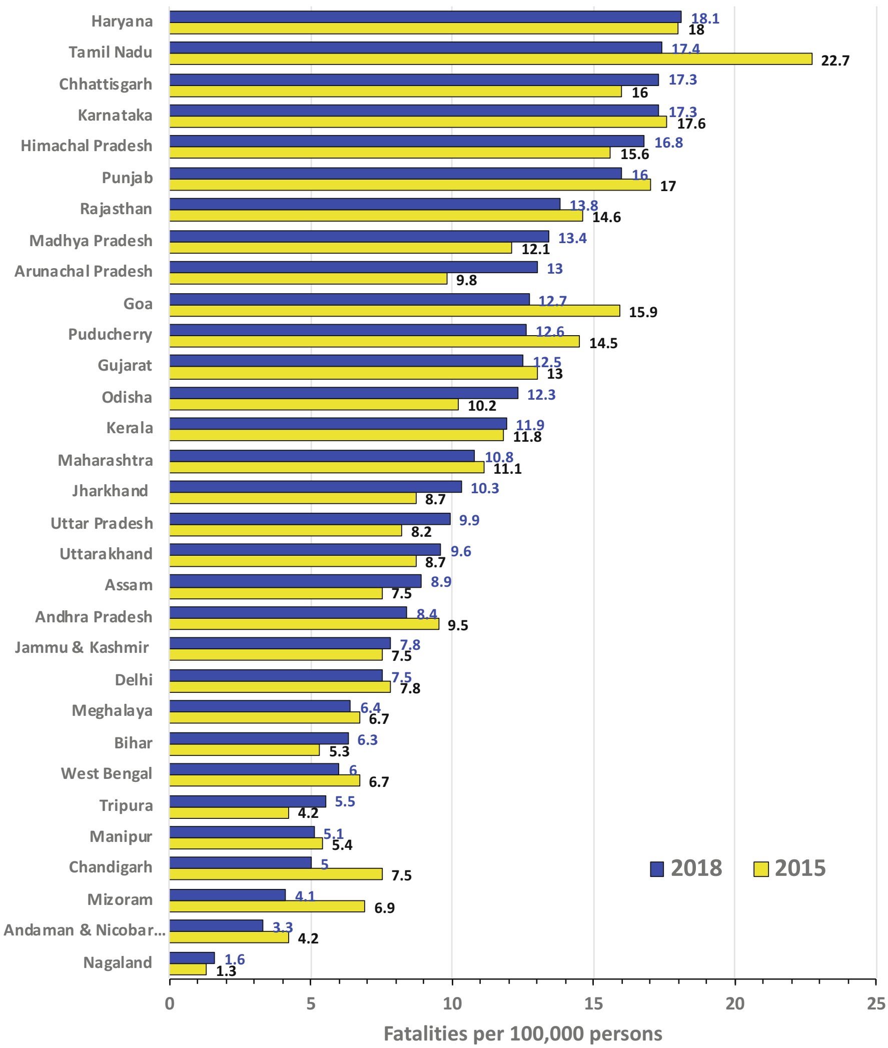


Fig. 10 RTI deaths per 100,000 persons in million-plus (population) cities in 2015 and 2018. (Source: Transport Research Wing 2019)

thousand persons as we do not have details of the implementation of safety policies in any of these cities. It is interesting to note that none of the high-rate cities include cities with populations greater than three million, whereas the low-rate cities include five with population greater than five million. The low-rate cities have rates that are similar to some of those in high-income countries. It would be important to investigate why rates are so different across cities in the same country. The findings might give us new clues on planning for Vision Zero in India. A study that examined the influence of road type and junction density on road traffic fatality rates in cities in the

USA suggests that a city with a higher proportion of wider roads and large city blocks will tend to have higher traffic fatality rates and therefore in turn require much more efforts in police enforcement and other road safety measures (Mohan et al. 2017a). We need to understand the influence of city form on road traffic crashes to make Vision Zero a reality. Since a vast majority of the victims in the cities are vulnerable road users, one possible cause of low death rates in low-rate cities (populations greater than five million) could be reduction of vehicle speeds due to congestion.

RTI Details for Selected Cities

Table 2 shows the proportion of road traffic fatalities by road user type in nine Indian cities. These cities vary in population from 280,000 to 20 million. The data for Delhi were obtained from the Delhi Police Department and for all other cities by analyzing First Information Reports (FIR) maintained by the police departments in the respective cities for a period of three years (Mohan, Tiwari, and Mukherjee 2013).

The proportion of vulnerable road user (pedestrians, bicyclists, and motorized two-wheelers) deaths in the nine cities range between 84% and 93%, car occupant fatalities between 2% and 7%, and occupants of three-wheeled scooter taxis (TSTs) less than 5% per cent, except in Vishakhapatnam where the proportion for the latter is 8%. The total of vulnerable road user deaths remains relatively stable across cities of different sizes, and the proportion of pedestrian deaths appears to be higher in cities with larger populations. VRUs are pedestrians, bicyclists and MTW victims. When these columns are added in Table 2, the range is 65–75%. Proportion of pedestrians in Delhi and Mumbai the large cities is higher than other cities.

RTI Victims and Impacting Vehicles

Figure 11 shows the data for distribution of road traffic fatalities by road user category versus the respective impacting vehicles/objects for two of the nine cities, Vishakhapatnam and Bhopal. These two cities are representative of the patterns in all the cities studied and have been selected as the fatality rates per 100,000 persons are different with Vishakhapatnam at 24 and Bhopal at 14 in 2011. In both cities, the largest proportion of fatalities for all road user categories (especially vulnerable road users) is associated with impacts with buses and trucks and then cars. This is true for the other cities also. The most interesting feature emerging from this analysis is the involvement of MTW as impacting vehicles for pedestrian, bicyclist, and MTW fatalities in the cities. The proportion of pedestrian fatalities associated with MTW impacts ranges from 8% to 25% of the total. The highest proportion was observed in Bhopal. The involvement of MTWs as impacting vehicles in vulnerable road user (VRU) fatalities may be due to the fact that pedestrians and bicyclists do not have adequate facilities on the arterial roads of these cities and that they have to share the road space (the curbside lane) with MTW riders.

Table 2 Proportion of road traffic fatalities by road user type in nine Indian cities. (Source: see text)

City	Population	Pedetrian	Bicycle	Motorised two-wheeler	Auto-ricksha	Car & taxi	Buus	Truck	Other
		Percent							
Delhi (2018)	1,99,58,118	46	3	34	–	4	1	0	12
Agra (2013–15)	15,74,542	41	10	37	4	2	4	2	0
Amritsar (2013–15)	11,32,761	27	20	40	5	3	1	3	1
Bhopal (2013–15)	17,95,648	41	5	44	3	2	2	3	0
Ludhiana (2013–15)	16,13,878	35	23	35	3	3	1	0	0
Vadodara (2013–15)	16,66,703	32	12	41	3	4	1	7	0
Visakhapatnam (2013–15)	17,30,320	43	6	35	9	3	1	3	0
Patiala (2015–2018)	4,80,000	22	14	51	3	7	3	0	0
Bulandshahr (2015–2018)	2,80,000	26	7	51	2	5	3	5	2

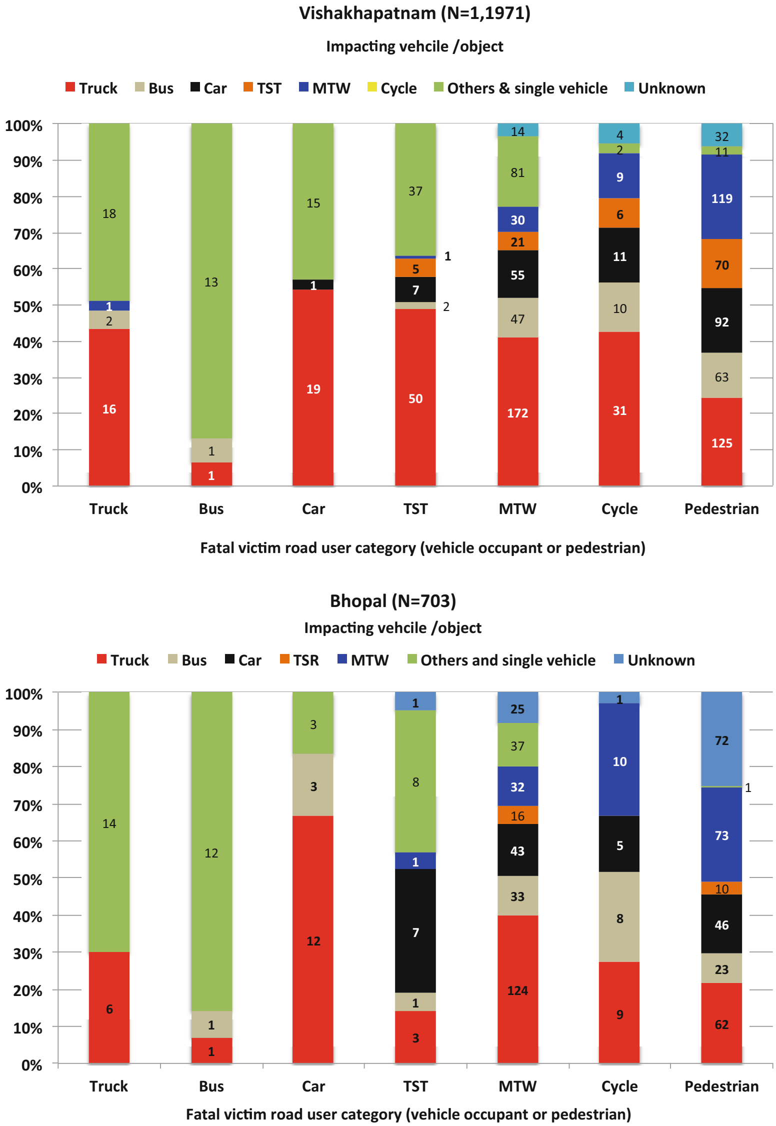


Fig. 11 Fatal RTI road user category and impacting vehicles/objects in Vishakhapatnam and Bhopal (numbers in bars represent number of cases; TST: three-wheeled scooter taxis)

The issue of serious injuries and fatalities among pedestrians hit by motorcycles has not received much attention internationally. Since the use of motorized two-wheeler for personal transport and deliveries is increasing in a large number of countries, it is necessary to give greater attention to safer motorcycle design and management of their movement on city roads.

RTI on Intercity Highways

Figure 12 shows the proportion of RTI fatalities on different categories of roads and the proportion of road length for each category (Transport Research Wing 2019). Fatality rate per km of road is the highest on national highways with 47.3 deaths per 100 km annually (Fig. 13). The relatively high death rate on NH could be because they carry a significant proportion of passenger and freight traffic. However, since details of vehicle km travelled on various categories of highways are not available, it is not possible to make a comparison based on exposure rates.

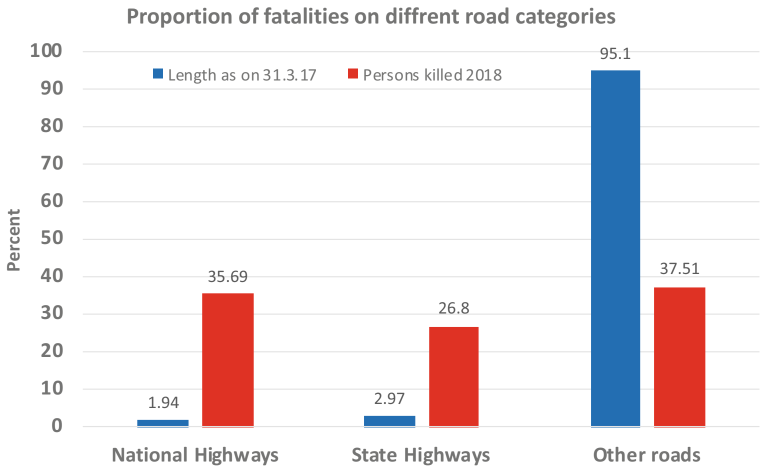


Fig. 12 The proportion of RTI fatalities on different categories of roads and the proportion of road length for each category. (Source: Transport Research Wing 2019)

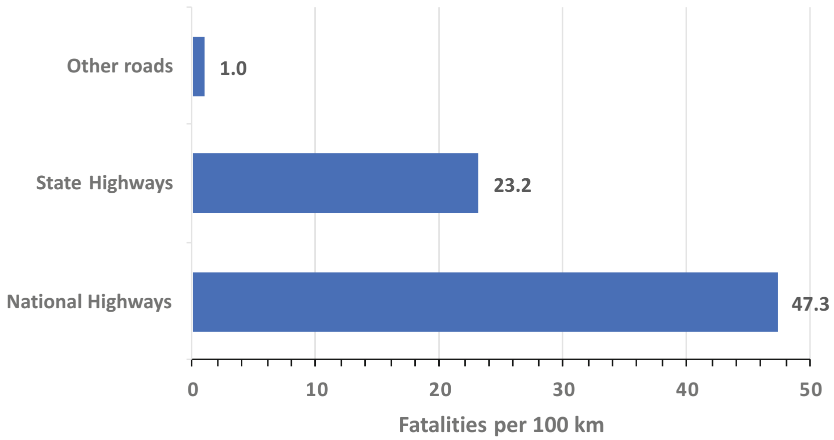


Fig. 13 Fatalities per 100 km on different categories of roads in India in 2018. (Source: Transport Research Wing 2019)

Recent research studies have reported fatal crash rates (fatalities per km) for three NH (NH-1, NH-8, and NH 2) as 3.08 crashes/km/year on six-lane NH-1, followed by 2.54 crashes/km/year on four-lane NH-24 bypass, and 0.72 crashes/km/year on two-lane NH-8 (Naqvi and Tiwari 2015).

RTI Patterns on Highways

A detailed study of 35 selected locations on highways showed that pedestrians and bicyclists constituted 43% of the fatalities (Tiwari, Mohan, and Gupta 2000) (Table 3). A more recent study (Tiwari 2015) investigated police reports of fatal crashes on selected locations on two-lane, four-lane, and six-lane highways and showed that the proportions of motor vehicle occupants and vulnerable road users were 32, 19 and 52% and 68% respectively, whereas the proportions for urban areas were 5%–10% vehicle occupants and the rest vulnerable road users. Though the motor vehicle occupant fatalities are higher on highways than in urban areas, as would be expected, the differences are not as high as in Western countries. A majority (68%) of those getting killed on highways in India comprise vulnerable road users, and this fact should be the guiding factor in future design considerations. Data from three highway segments from 2009 to 2013 show a similar pattern. Pedestrian and MTW proportions are very high except on the six-lane highway where the proportion of truck victims is higher.

Table 4 shows the involvement of different impacting vehicles in fatal crashes on highways. This shows that as far as vehicle involvement is concerned, the patterns are similar in urban and rural areas. Trucks and buses are involved in about 70% of fatal crashes in both rural and urban areas. This is again very different from Western countries where there are significant differences in rural and urban crash patterns.

It is possible that these high rates of vulnerable road deaths on rural highways are due to the fact that these roads pass through high-density population areas where local residents who do not possess motorized means of transport have to walk along these roads, cross them, or wait on the shoulders to access public transport. Some major design standards for rural highways and expressways have to be re-examined in the light of these findings.

Road Safety Policies and Enabling Legislation in India

When cars appeared on the street in the West and elsewhere, traffic engineering was established as a formal scientific and technical discipline. In the mid-nineteenth century, British colonial rulers in India established formal engineering training institutes to assist in the construction of railways, roads, and canals. The focus of this training was to impart knowledge about concrete, surveying, and construction techniques. The textbooks and the teaching resources came from the UK and the English language (Palit 1998). The Indian Roads Congress was established in 1934 to guide Indian engineers how to plan and build roads. The concrete roads were replaced with asphalt roads as was done in Europe, and the control of roads was given to provincial authorities – state public works departments – and local municipalities in some cases. The national trunk roads remained under the central control, and the Central Road Fund was created in 1930 to develop and maintain these roads. (Gijs Mom, India and the Tools of Empire: the emergence of the layeredness of modern mobility) Almost one hundred years later, the Indian Roads Congress continues to be an important professional body today. A large number of road planning and design guidelines have been issued to guide the field engineers involved in rural roads, state highways, and national highways.

The first Motor Vehicles Act in 1939 was introduced with the motivation to control vehicles plying on the road and protect the interests of the state-run railways. The number of cars, buses, and trucks grew from 1918 to 1930; however, there was a sharp decline in the number of cars from 1930 to 1940, and the number of buses and trucks remained constant. Buses were mostly for intercity movement. Buses provided a good option for third-class railway passengers, and cars competed with the first-class railway passengers. In cities three-wheeled "*rickshaw*" was first introduced for goods movement by Chinese traders and quickly spread in most major cites as passenger vehicles. A multilayered complex mobility evolved with the introduction of new technologies. Though there was some substitution of travel modes, it was not in a simple linear pattern which is easily predictable. The Census of India in 1936–1937 shows the dominance of pedestrian traffic followed by rickshaw motor cars and buses, not very different from the mix of traffic present on Indian roads a century later, with the exception of motorized two-wheeler.

While the road planning and construction is guided by various codes and guidelines issued by the Indian Roads Congress, the vehicle movement and vehicle specifications and penalties for violation of MVA rules are guided by the Motor Vehicles Act and Central Motor Vehicles Rules (CMVR). Until the mid-1980s, there was little discussion of traffic safety in these documents. The 1939 Act was primarily concerned about fixing liability based on driver error as "rash and negligent" behavior, enhancing penalties, and creating additional offenses. The existing law and policy debate on road safety in India have continued to focus on these three aspects. The 1987 urban transport plans expressed concern over vehicular pollution and traffic safety. There is also a discussion of planning urban areas in such a way that the need for travel is reduced – self-contained districts. "Efforts have been made to restrict the movement of slow moving vehicles like cycle rickshaws, hand carts and animal-drawn carts on congested roads within the CBD area in many cities. Priority for buses and other passenger vehicles, ban on heavy goods carriers and exclusive pedestrian streets are some of the regulatory measures suggested for the improvement of the traffic conditions in several cities" (Srinivasan, N.S. et al.Urban roads- India Report. in PIRAC World Road Congress, 1987).

Two important developments occurred in the late 1980s. One, the National Highways Authority of India was set up by an act of the Parliament, NHAI Act, 1988: "An Act to provide for the constitution of an Authority for the development, maintenance and management of national highways and for matter connected therewith or incidental thereto." (https://nhai.gov.in/about-nhai.htm) The second important development was the revision of the Motor Vehicles Act of 1939. The Motor Vehicles Act, 1988, came into force from 1 July 1989. It replaced Motor Vehicles Act, 1939, which earlier replaced the first such enactment Motor Vehicles Act, 1914. For exercising the legislative provisions of the Act, the Government of India made the Central Motor Vehicles Rules, 1989.

In 2005, the Ministry of Roads and Highways (MoRTH) that constituted an expert committee on Road Safety and Traffic Management was given two responsibilities (Committee 2007):

1. Study what new laws or amendments to existing laws would be required.
2. Recommend a structure for the proposed Directorate of Road Safety and Traffic Management, and advise on its role and functions.

Some of the key observations of the committee report were:

1. Existing institutions are not equipped to deal with increasing traffic on the roads.
2. Key ministries and the public sector play a peripheral role in improving road safety.
3. Road safety is not a priority in the development agenda of the state and central governments.
4. The existing Road Safety Council does not have adequate statutory backing, budgetary resources, or the mandate to be effective.
5. India must adopt the advancements made globally in road safety techniques and technology.

   The Committee also appended a draft of a law to its report, calling it the National Road Safety and Traffic Management Act. The Bill based on this draft was not accepted by the parliament.

In 2014, the Supreme Court of India established a committee of road safety experts headed by a retired justice of the Supreme Court of India. The committee's mandate is to (1) measure and monitor on behalf of the Supreme Court the implementation of various laws relating to road safety in the states and central ministries and (2) to identify the need for further legislation or changes in the existing laws.

The committee has been directing state governments to report progress made in implementing road safety laws since 2014. The 1988 Act was amended by The Motor Vehicles (Amendment) Act, 2019. The Act provides in detail the legislative provisions regarding licensing of drivers/conductors, registration of motor vehicles, control of motor vehicles through permits, special provisions relating to state transport undertakings, traffic regulation, insurance, liability, offenses and penalties, etc. The amended MVA has several provisions not included earlier: increased compensation for road accident victims, Motor Vehicle Accident fund to provide compulsory insurance cover to all road users, defining a good Samaritan, recall of defective motor vehicles, development of the National Transport Policy and National Road Safety Board, recognizing taxi aggregators, and increased penalties for several offenses.

Out of the many amendments proposed in the Act, increased penalties have been implemented in many states from 1 September 2019, and at the same time many states have decided to “dilute” the suggested increase in penalties. Most of the suggested amendments seem to be based on “common sense” as opposed to scientific evidence and therefore are not likely to have a serious impact on reducing road traffic crashes.

Many road safety concerns have not been addressed by the amended MVA. For example, the presence of villages and small towns along the highways has resulted in a mixed traffic patterns on highways in India. The density of small towns and villages along the highway and the presence of tractors, MTW, and three-wheelers on the highway along with cars, buses, trucks, and truck trailers present a very different traffic mix as compared to North America and Western Europe where most of the highway standards have been developed.

Traffic crash patterns in India are also substantially different as compared to North America and Western Europe. Pedestrian and motorcyclist involvement in fatal crashes on highways is greater than that of other road users. These highway crash patterns are similar to those observed in urban areas. In the past two decades, major investments have gone into expanding the national highway system in India. Yet the number of fatalities has continued to grow. This requires review of the current highway standards prevalent in India. Perhaps field experiments are required to develop appropriate road designs which meet the requirement of mixed traffic as is the practice in many European and North American countries.

Despite the efforts in the last few decades, the number of road traffic fatalities has continued to increase in India. The MoRTH report of 2018 has listed 1,51,430 fatalities. On the other hand, a study based on the sample registration system (verbal autopsies of a national sample) of the Government of India estimated that there were 275,000 road traffic fatalities in India in 2017 (Menon et al. 2019), and another recent modelling estimates 218,876 fatalities in the same year (Dandona et al. 2020). These estimates report higher share of pedestrian and motorized two-wheelers as RTC victims as compared to the MoRTH report. The states with better road infrastructure have higher rates of fatalities (Tamil Nadu, Karnataka, Kerala, Maharashtra, etc.). The MVA amendments do not address the reliability of crash estimates, which forms the basis of designing preventive strategies.

We have not yet created a system of producing scientific evidence for designing preventive strategies in India. A 2007 report from New South Wales in Australia evaluated the effectiveness of stricter penalties and found, “It is suggested that substantial increases in fines and licence disqualifications would have limited potential in deterring recidivist offenders. The present analysis, failed to find any evidence for a significant relationship between fine amount and the likelihood that an offender will return to court for a new driving offense. Nor was there any evidence from our analyses to suggest that longer license disqualification periods reduced the likelihood of an offender reappearing before the courts” (Briscoe 2004), and a meta-analysis suggests that “Increasing traffic fines was found to be associated with small changes in the rate of violations” (Elvik 2016). This suggests that increased fines as suggested in the amended MVA alone will not have the intended effect of reducing traffic crashes. The current traffic safety science suggests that if road users do not take their share of the responsibility, for example, due to a lack of knowledge or competence, or if personal injuries occur or for other reasons that lead to risk, the system designers (road designers) must take further measures to prevent people from being killed or seriously injured. This is consistent with the Vision Zero theory, which suggests that humans have limitations in perception, diligence, and other driving-related performance that are predictable and inevitable. These natural limitations are the primary reason for increased responsibility by system designers.

Therefore, reduction in the growing health burden due to traffic crashes requires establishing a system or institutional structure which enables generation of new knowledge – new road standards to ensure safe highways and urban roads in India, a highway design that can ensure safety of pedestrians, and a roundabout design that can control speeding two-wheelers. The newly amended Motor Vehicles Act provides for a National Road Safety Board to be created by the central government through a notification. The Board will advise the central and state governments on all aspects of road safety and traffic management including (i) standards of motor vehicles, (ii) registration and licensing of vehicles, (iii) standards for road safety, and (iv) promotion of new vehicle technology. The proposed board does not have any statutory powers; this may become another version of the current National Road Safety Council having representation from various ministries and other stakeholders with no statutory powers. The NRSC is expected to meet at least once a year. The presence of NRSC has not had any impact in reducing traffic crashes in the past. In the next section, we present case studies based on current safety knowledge.

Can Current Safety Knowledge Lead to Vision Zero in India?

In this section we present a scenario analysis for two small cities in India to estimate the effectiveness of implementing specific vehicle- and infrastructure-related strategies. In case of the smaller cities, this gives a unique opportunity since the number of fatalities is less compared to the larger cities in India. In addition to that, setting up countermeasures is easier if integrated early into the system.

The Approach to Reduction in Road Traffic Fatalities Estimation

In this exercise we attempt to evaluate the effect of the following road safety measures over time in the next 10 years. Three interventions are considered for assessing the impact on traffic safety. These are:

1. Vehicle safety devices with safety technology.
2. Enforcement of existing traffic laws with respect to the following specific aspects:
   (a) Speed control
   (b) Red light running
   (c) Seat belt use

   (d) Helmet use
   (e) Drinking and driving
3. Road infrastructure improvement for speed control.

Intervention 1: Vehicle Safety Regulations in India

Vehicle safety devices for cars (crashworthiness standards) and motorized two-wheelers (antilock-braking systems (ABS), combined braking systems (CBS), and daytime running lights (DRL)) have shown to reduce fatal crashes. The recent amendments to the Motor Vehicles Act have stipulated these devices along with crashworthiness to be mandatory for cars and MTW.

The Ministry of Road Transport and Highways, Government of India, prescribed that front seats of all motor vehicles must be equipped with lap and shoulder belts which took effect on 1 April 1994. Three-wheelers with engine capacity less than 500 cc were exempted. All vehicles sold in India after this date have been equipped with belts in front seats. Installation of seat belts on all rear seats in cars was mandated in September 2002. The government made crashworthiness norms mandatory for all new models of cars from October 2017 and for existing models from October 2019. The new minimum safety norms, including frontal and side crash tests, apply to all cars, and the cars are tested for offset frontal crash norms at 56 km/h and 50 km/h for the side crash test. In general, these crash test norms cannot be complied without the cars being equipped with airbags for front seat occupants.

The Ministry of Road Transport and Highways mandated that all new MTWs sold after 1 April 2017 be equipped with automatic headlamp on (AHO) feature (similar to the daytime running lamps (DRLs)). Antilock braking systems (ABS) were made mandatory for all new MTWs with engine capacity above 125 cc and combined braking system (CBS) mandatory for those below 125 cc which took effect on 1 April 2018.

The number of vehicles produced after 2019 and the proportion of the same in the fleet in subsequent years will determine the effectiveness in terms of the lives saved due to these devices. Since this intervention does not require any intervention from the city administration, it has been included as the first intervention.

Intervention 2: Regulations Regarding Use of Seat Belts and Helmets

The Motors Vehicles Act 1988 (India) made use of helmets mandatory for all MTW riders in the whole country in 1988. Use of seat belts by front seat occupants was made mandatory nationally five years later on 18 March 1999. But the use of seat belts by rear seat occupants was mandated by Motor Vehicles Amendment Act 2019. However, since enforcement of traffic regulations is a state subject in the federal structure of the Indian constitution, traffic regulations have to be notified and enforced by each state. The Delhi Traffic Police made use of seat belts by front seat passengers compulsory which took effect on 15 February 2002 and initiated enforcement of the same.

Even though the Motor Vehicles Act is a central government act, the enforcement of the law by the police authorities is in the purview of state and city law enforcement authorities. This has resulted in a paucity of the law being enforced. The use of seat belts and helmets is responsible for a sizeable decrease in fatalities in road traffic crashes. It is very important to note that since airbags are being installed in all cars produced post-2019, not using a seat belt in a car fitted with airbags can at times lead to an increase in injury to the occupants of the car. Enforcement being a local governance matter and something that can be easily achieved has been taken as the second intervention. Enforcement of seat belts and helmets is relatively easy and does not require any additional training or equipment for the traffic police; drinking and driving enforcement from global experience is not as easy. So we have taken the enforcement of alcohol and narcotic use by the driver as the last intervention.

Intervention 3: Reduction of vehicle speeds and preventing interaction between the vulnerable road users (VRUs) and motorized vehicle have shown great improvements in reduction of fatal road crashes. All these require changes in road infrastructure that have been scientifically designed. The main examples of these changes are conversion of junctions to roundabouts and installing speed controlling devices like speed breakers/rumble strips and speed cameras and pedestrian/bicycle centric infrastructure. These require both capital cost and time along with coordination between multiple local government agencies; because of these limitations, this has been taken as the third intervention. An improvement of 7% per year in installation of these infrastructural changes has been considered to achieve the SDG targets. This requires investment by the city governments; therefore, a low limit of 7% has been assumed.

Methodology of Estimation of Effectiveness of Intervention

The first step was to do a classification of the possible interventions followed by an exhaustive search of the literature to ascertain the effectiveness of the various interventions. Various systematic reviews and meta-analyses published were taken, and for every intervention, the average value of their respective effectiveness was taken for the analysis. Tables 3, 4, and 5 show the assumed effectiveness values and the corresponding sources.

Table 3 Effectiveness of vehicle safety technologies

Interventions	Effectiveness	References
Antilock Braking System (ABS) (MTW)	10.0%	Seiniger et al. (2012)
Antilock Braking System (ABS) (MTW)	12.5%	Seiniger et al. (2012)
Antilock Braking System (ABS) (MTW)	34.0%	Seiniger et al. (2012)
Antilock Braking System (ABS) (MTW)	37.0%	Seiniger et al. (2012)
Antilock Braking System (ABS)	13.0%	Bhalla et al. (2019)
Antilock Braking System (ABS) (car)	2.8%	Bhalla et al. (2019)
Antilock Braking System (ABS) (car + MTW)	9.6%	Bhalla et al. (2019)
Electronic Stability Control (ESC)	19.4%	Bhalla et al. (2019)
Airbags	3.2%	Bhalla et al. (2019)
Front pedestrian protection (car)	6.0%	Bhalla et al. (2019)
Crashworthiness (car)	28.1%	Bhalla et al. (2019)

Table 4 Effectiveness of enforcement

Interventions	Effectiveness	References
Seat belts (car)	12.1%	Bhalla et al. (2019)
Helmets (MTW)	42.0%	Liu et al. (2009)
Helmets (MTW)	37.3%	Peng et al. (2016)
Alcohol enforcement	8.70%	Staton., et al. (2016)

Table 5 Effectiveness of road infrastructure changes

Interventions	Effectiveness	References
Speed bumps	59.0%	Staton et al. (2016)
Speed limit enforcement	52.6%	Elvik. (2012)
Speed humps of trapeze shape	100.0%	Jateikiene et al. (2016)
Raised pedestrian crossings	83.0%	Jateikiene et al. (2016)
Speed bumps	73.0%	Jateikiene et al. (2016)
Red light camera	22.5%	Lee et al. (2016)
Section control	56.0%	Høye. (2014)
Section control	49.0%	Høye. (2015b)
Fixed speed camera	51.0%	Høye. (2014a)
Fixed speed camera	17.0%	Høye. (2015a)
Roundabout	73.0%	Elvik. (2017)

The second step was to estimate the population of Patiala City for the years 2019, 2025, and 2030. Simultaneously the vehicle population data was obtained from the Regional Transport Office (RTO) of Patiala City for the years 2012–2017. This was used to calculate the number of vehicles of various modes for the years 2019, 2025, and 2030.

Calculation of Scenarios to Achieve SDG 3.6

Based on the estimates illustrated in Tables 3–5, five scenarios were developed to localize the goals set by SDG 3.6 by the year 2030. The first scenario considers a case when no there are now new safety interventions is taken – business as usual (BAU). Subsequent scenarios take into account the listed interventions additively and showcase the percentage reduction in fatal crashes resulting from each interventions. The five scenarios are:

1. Business as usual (BAU).
2. Introduction of vehicle safety devices.
3. Introduction of vehicle safety devices + seat belt and helmet enforcement.
4. Introduction of vehicle safety devices + seat belt and helmet enforcement + road infrastructure changes.
5. Introduction of vehicle safety devices + seat belt and helmet enforcement + road infrastructure changes + driving under influence (DUI) enforcement.

Figures 14 and 15 show the reduction in fatalities for each scenario (for Patiala and Bulandshahr respectively). The results are based on the detailed methodology

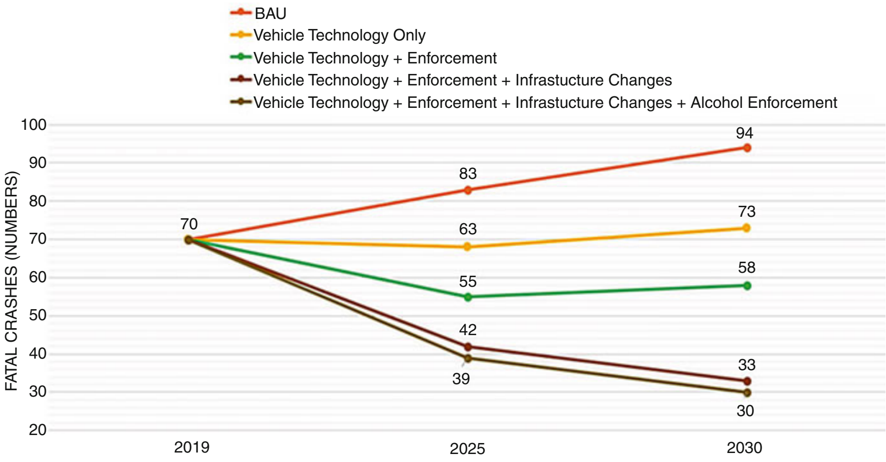


Fig. 14 Reduction in road fatalities by 2030 in Patiala

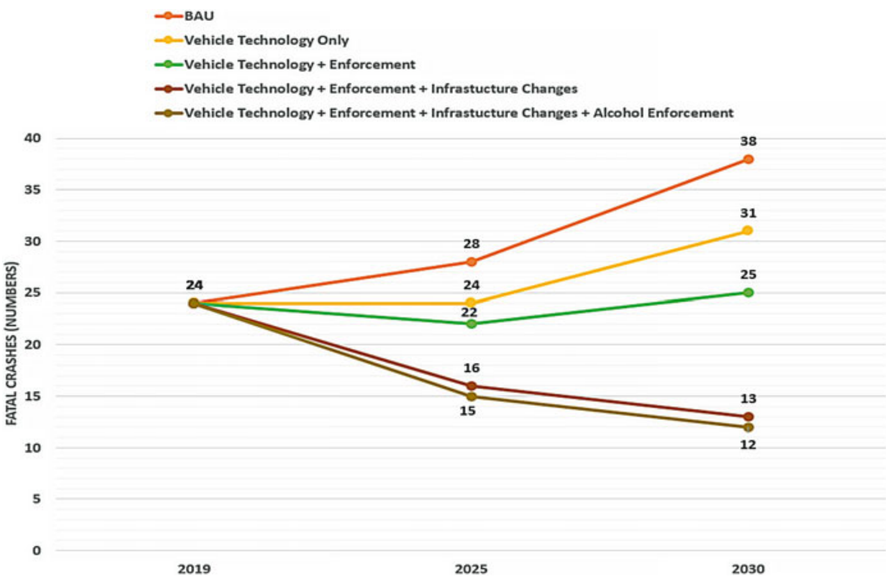


Fig. 15 Reduction in road fatalities by 2030 in Bulandshahr

presented by Mohan et al. (Mohan et al. 2021). As can be inferred from Figs. 14 and 15, the maximum impact in fatality reduction comes from the improvement in road infrastructure. Though this requires both time and monetary investment by the city administration, achieving SDG 3.6 is not possible without this intervention. The quickest and the easiest method to reduce fatal crashes is the enforcement of seat belts and helmets for cars and motorized two-wheelers respectively.

Vehicle Crashworthiness Standards (ECE and NCAP) for Promoting Road Safety Worldwide

In this section, we examine the role of automobile safety standards in decreasing RTI death rates around the world. An important stream in global intervention is in the promotion of universal motor vehicle safety standards. There are two approaches to improving car design: (1) legislation that prescribes requirements with which vehicle manufacturers need to comply and (2) information programs by organizations like NCAP (Global NCAP. http://www.globalncap.org/. Accessed 7 July 2019.) (New Car Assessment Program) around the world (ASEAN NCAP, Euro NCAP, Global NCAP, Latin NCAP, US NCAP, etc.) and the Insurance Institute for Highway Safety that provide safety ratings for cars and create a market for safer vehicles.

The WHO Status Report (WHO 2018) recommends that all countries should adopt the UNECE WP.29 motor vehicle safety standards and provides a list of eight to be prioritized for implementation by countries (Table 6). (WP.29 – Introduction. https://www.unece.org/trans/main/wp29/introduction.html. Accessed 7 July 2019) They also note that "New Car Assessment Programmes (NCAPs) have proved highly effective in raising the levels of vehicle safety significantly above the minimum regulatory requirements."

The regulatory aspects have the possibility of being applied across the board to vehicles (e.g., for pedestrian safety, including bus-pedestrian). Even though the

Table 6 Priority UN vehicle safety standards. (Source: WHO 2018)

No.	Standard
1&2	Frontal impact protection and side impact protection (R94 and R95):Ensure that cars withstand the impacts of a frontal and side impact crash when tested at certain speeds. These crashworthiness regulations help to protect occupants withstand the impact of front and side impact crashes.
3	Electronic stability control (R140): Prevents skidding and loss of control in cases of oversteering or understeering and is effective at reducing crashes and saving lives. It is effective in avoiding single car and roll over crashes, reducing both fatal and serious injuries.
4	Pedestrian front protection (R127): Provides softer bumpers and modifies the front ends of vehicles (e.g. removes unnecessarily rigid structures) that can reduce the severity of a pedestrian impact with a car.
5–6	Seat-belts and seat-belt anchorages (R14 – R16): Ensure that seat-belts are fitted in vehicles when they are manufactured and assembled and that the seat-belt anchor points can withstand the impact incurred during a crash, to minimize the risk of belt slippage and ensure that passengers can be safely removed from their seats if there is a crash.
7	Child restraints (R129): Ensure that the child seat is in place with the adult seat-belt and that ISOFIX child restraint anchorage points are fitted to secure the restraint.
8	Motorcycle antilock braking systems (R78): Help the rider maintain control during an emergency braking situation and reduce the likelihood of a road traffic crash and subsequent injury.

NCAP safety market applies primarily to occupants, pedestrian test results are a component of the Euro NCAP star rating system, but this is not the case in the USA.

Safer cars have had a major role in reducing RTI fatality rates in HIC over the past 40 years. Estimates for the USA suggest that the fatality risk in the average car or light transport vehicles in 2012 was 56% lower than in the average vehicle on the road in 1960(Kahane 2015). In the USA, there were 33,561 fatalities on roadways in 2012, which means an estimated 45% was prevented due to automobile safety standards. If in a country vehicle occupant deaths contribute only 20% instead of 64% of the total count, then it is possible that reduction in deaths due to automobile safety standards would be less than 15%.

Almost all our understanding of road safety issues derives from the experience of about a hundred years of motorization in the HIC of today. This experience is based on traffic systems where the safety of car occupants remained the central concern. In these countries cars have been the dominant part of traffic systems unlike in many of the LMICs where motorized two-wheeler and para-transit vehicles like three-wheeled taxis (TWT in this paper), *tuk-tuks*, and *jeepneys* constitute a significant proportion of traffic on roads. Since we do not have detailed epidemiological studies on the effect of these latter vehicles on traffic safety in LMIC, we do not have a good understanding of the risks faced by occupants of these vehicles where they are a dominant mode of transport.

Figure 16 shows the proportion of car and vulnerable road user (VRU – occupants of 2−/3-wheelers, cyclists, and pedestrians) fatalities in selected countries (for India only – Mohan et al. 2015; WHO 2015). In Cambodia, Colombia, India, Sri Lanka, and Thailand, car occupants comprise less than 20% of road traffic fatalities. Even in HICs like Japan, the Netherlands, Hungary, Poland, and Greece, VRUs constitute more than 50% of the fatalities. Figure 17 shows the total population of countries included in Fig. 16 with car occupant fatalities greater than 40% and VRU fatalities greater than 60%. We would probably get similar population ratios if we included all the countries in the world; however, it is not possible to make an accurate assessment as reliable figures for modal share of fatalities are not available for all countries.

The above analysis indicates that while it is important to establish the latest level of vehicle safety performance whether by government standards or NCAP-type testing worldwide, it should be noted that this alone will not reduce overall death rates in LMIC as the HIC experience indicates. However, it is important to understand that although improved automobile safety performance may not result in as dramatic a reduction in fatality rates in LMIC as in HIC, hundreds of thousands of people are maimed and killed in cars all over world, and they must have access to the best safety systems available as soon as possible. Another reason why implementation of the latest safety performance in LMIC would be beneficial for car occupants is that many of these countries have a much younger fleet than HIC (Fig. 18). While car sales have plateaued in HIC, sales are still increasing in most LMICs. Therefore, early implementation of the latest safety performance would result in a faster fleet replacement with the best safety features in LMIC than in HIC.

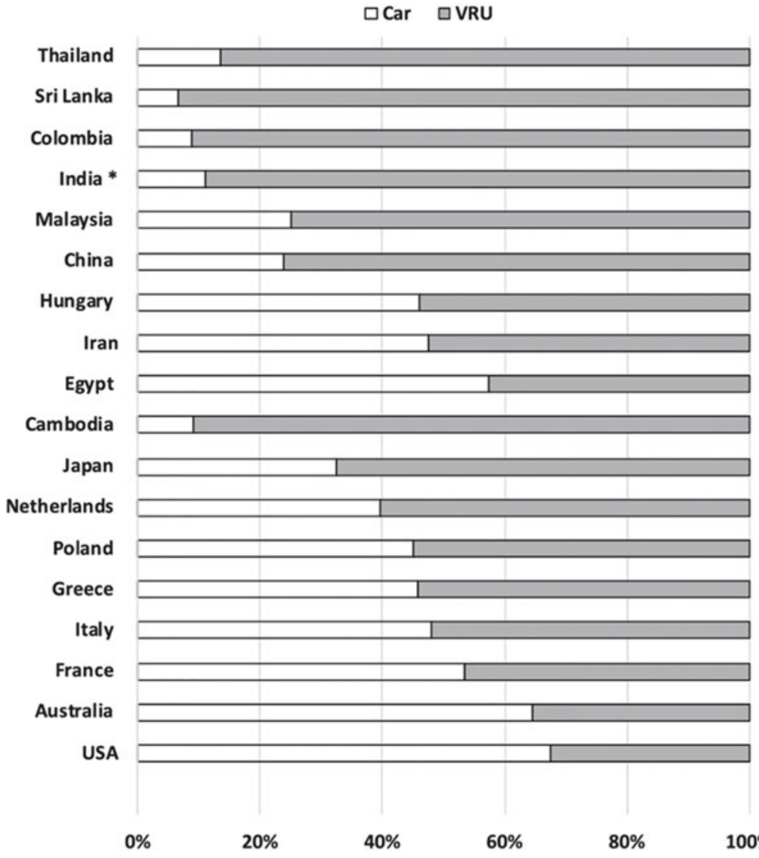
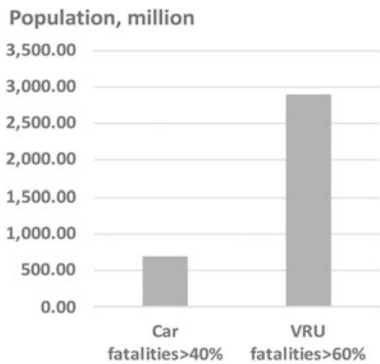


Fig. 16 Proportion of car and vulnerable road user (VRU: occupants of 2–3-wheelers, cyclists, and pedestrians) fatalities in selected countries. (Source: WHO 2015). Data for India from Mohan et al. (2015))

Fig. 17 Population of countries included in Fig. 16 according to proportion of car occupant and VRU fatalities



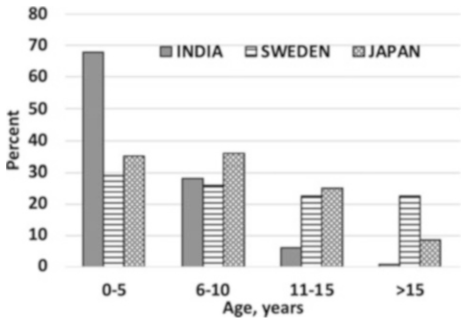


Fig. 18 Age of cars on the road in India, Sweden, and Japan in 2015

Relationship Between MTW Share in Vehicle Fleet, Pedestrian Exposure, and Fatalities

A thought experiment can be conducted to examine what would happen if the countries with very low fatality rates today had a much higher proportion of MTW in the fleet and a much higher exposure of pedestrians. Here we take the example of India, Japan, and Sweden. India, Japan, and Sweden had fatality rates of ~12, 4.7, and 2.8 per 100,000 persons, respectively, in 2013. If we keep the total number of vehicles constant in Sweden and Japan but change the fleet composition to 75% MTW and 25% cars, double the exposure of pedestrians, and then calculate overall fatality rates using risk of fatalities per unit vehicle and pedestrian per population constant for both countries, then we get the results as shown in Fig. 19. The estimated results show that the total number of deaths increases significantly in Japan and Sweden and the estimated fatality rates increase to 7 and 8.2, respectively. These estimates indicate that significant gains in traffic safety in HIC are partly due to the reduced exposure of VRU and not only due to the effect of safety policies. Since a large number of LMICs are not likely to reduce VRU exposure significantly in the next decade, exclusive focus on NCAP standards will not produce dramatic results in LMIC as they did in the HIC in the past. This thought experiment also suggests that it may not be possible for LMIC to reduce fatality rates below about 7 per 100,000 population along with high exposure of VRUs unless there are innovative developments in road design and vehicle safety standards including all indigenous intermediate transport vehicles with special emphasis on VRU protection.

Safety Standards for Vehicles Other than Cars (Not Covered by NCAP at Present)

Safety of Para-Transit Vehicles (Three-Wheeled Scooter Taxis)

Studies comparing the safety of large cars with small cars have consistently found that larger cars provide better protection than small cars (Broughton 2008; Buzeman

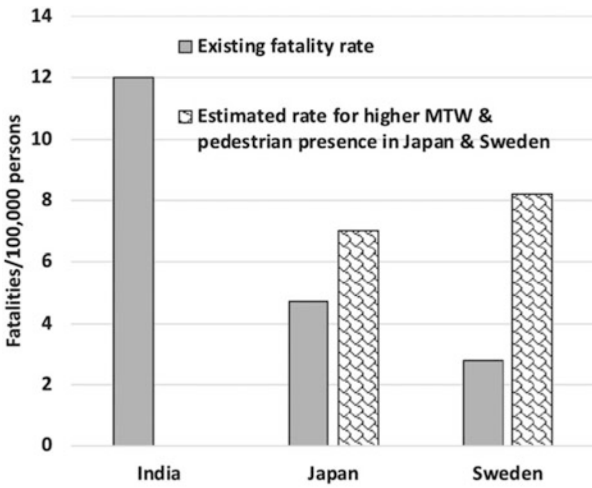


Fig. 19 Existing fatality rates in India, Japan, and Sweden and estimated rates in Japan and Sweden if they had 75% MTW in their fleet and 2 times the exposure of pedestrians. *Assumption: Occupant risk per vehicle and pedestrian risk per population remain constant

et al. 1998; Wood 1997). All these studies have been done in HIC where cars of all sizes are capable of the same driving speeds. Personal fatality risk for various vehicles in four Indian cities has been calculated by dividing vehicle-specific occupant fatality rates by estimates of the average daily occupancy of each vehicle. The occupancy rates for MTW, car, and TWT were estimated to be 4, 7, and 60 persons, respectively, per day (Chanchani and Rajkotia 2012; Mohan and Roy 2003; Wilbur Smith Associates 2008). The results of these calculations are shown in Fig. 20 (Mohan et al. 2016). Given the present trip lengths for each vehicle type, MTW riders are 3–6 times more at risk than car occupants. The MTW fatality rates per trip in Agra and Vishakhapatnam are much higher than those in the other three cities. The reasons for this are not known at present. At an individual level, risk per trip seems to be the lowest for TWT occupants in all the cities under the assumed occupancy rates and number of trips per day. This is a very surprising finding because average speed of TWT is much lower. TWTs weigh less than a third of cars, have no surrounding steel shell, and have to subscribe to only minimal safety standards.

Figure 21 shows all the fatalities associated with each vehicle type per 100,000 vehicle km per day. We assumed the following daily travel distance values for the different vehicle types: bus 150 km, car 50 km, TWT 150 km, and MTW 25 km. This is based on trip distances/lengths that each vehicle covers daily. The data include fatalities of occupants and road users other than vehicle occupants. For example, if a motorcycle hits a pedestrian and the pedestrian dies, the pedestrian death is also associated with the motorcycle. This index gives a rough idea of the total number of fatalities one might associate for each vehicle type given the present traffic conditions and mode shares. Essentially, the figures indicate that the low rate for TWT relative to cars is due to the higher number of passengers carried by TWT per day. These indices appear to suggest that, on a travel distance basis, TWT, MTW, and cars

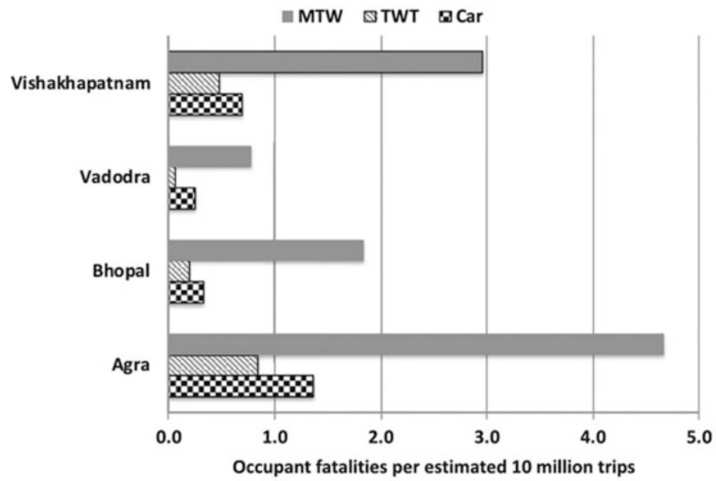


Fig. 20 Fig. 8. Personal fatality risk per 10 million trips for occupants of motorized two-wheelers, TWT, and cars in four Indian cities. (Source: Mohan et al. 2016)

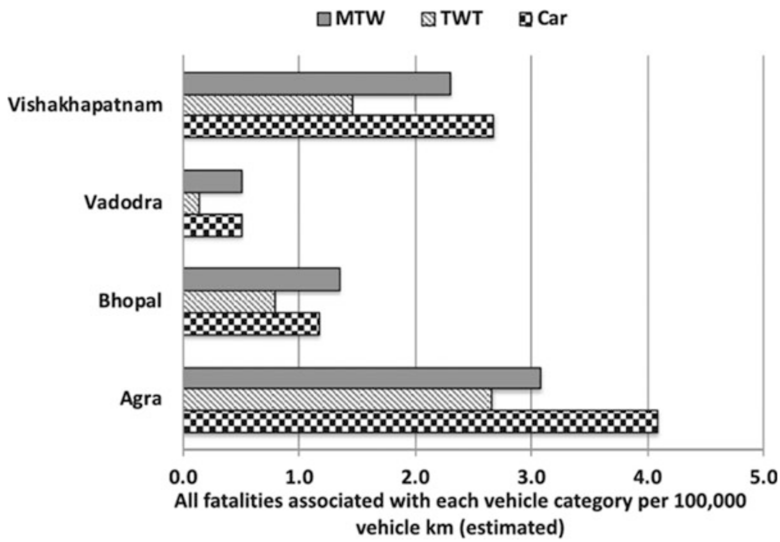


Fig. 21 All fatalities associated with each vehicle category per 100,000 vehicle km (estimated) in four Indian cities. (Source: Mohan et al. 2016)

may pose roughly similar level of danger to society under the present conditions. Safer design is a pressing concern for TWT, which are threats to both their occupants and the VRU that they impact.

No previous studies are available on safety records of motor vehicles that are not capable of high speeds operating in mixed traffic in urban areas. TWTs operating in

Indian cities have engines smaller in size than 175 cc and generally cannot exceed velocities greater than 50 km/h. The experience of TWT in Indian cities suggests that small lightweight vehicles with limited speed capabilities operating in the urban environment can result in low occupant fatality rates. The lower operating speed of TWT also implies that they pose a much lower risk to pedestrians, bicyclists, and other road users. This issue needs to be studied in greater detail, and if found true, it may be suggested that different crashworthiness standards or NCAP tests need to be developed for low-mass vehicles incapable of operating at speeds greater than 50 km/h. Such vehicles may be optimal for urban use and could be prohibited for roads with speed limits greater than 50 km/h.

It may not be possible for LMIC to reduce fatality rates below about 7 per 100,000 population along with high exposure of VRUs unless there are innovative developments in road design and vehicle safety standards including all indigenous intermediate transport vehicles with special emphasis on VRU protection.

Designs and Specifications

At the operational level, it is the state (public authority) that has the primary obligation for ensuring the people's right to road safety since the state is granted sovereign powers through the mutual transference of the powers of the citizens to the state by way of a social contract. At the implementation level, both roads and vehicle design, investments in research, and new knowledge generation are required.

Roads have become relatively safer in many high-income countries mostly due to improved geometric standards. Appropriate legislation regarding seat belt use, speed limits, and alcohol control has also contributed to improved safety. Often road standards (geometric design standards) in India have been based on either UK or USA design manuals. There are two important concerns in using or developing highway design standards mainly based on those in use in the USA or UK. The traffic mix for which these standards have been developed is very different from the traffic existing in India. The second concern is whether the design standards in HICs are based on traffic safety science (Hauer 1988).

Traffic crash patterns in India are substantially different compared to North America and Western Europe. Pedestrian and motorcyclist involvement in fatal crashes on rural highways is greater than that of other road users. These highway crash patterns are similar to those observed in urban areas. In North America, 10% of the fatal crashes on highways involve pedestrians. The presence of motorcycles is negligible, and long stretches of roads pass through wilderness. A large proportion of the highways is access controlled and designed for four-wheeled motorized traffic. Therefore, the road standards that have evolved to make access controlled highways safe for motorized vehicles may not ensure safety to other road users present on LMIC highways. However, in India standards similar to those in HICs have been adopted (IRC 2007; MoRTH 2010). In the past two decades, major investments have gone into expanding the national highway system in India. Yet the number of fatalities has continued to grow. The density of highways in a state and the number of fatalities seem to have a strong correlation. There is a strong reason to question the safety aspects of current standards in use.

Hauer (1988) has made important observations for North American roads: “No road in use is entirely crash-free, and therefore, in the interest of honest human communication no road can be called safe. The safety of a highway does not change abruptly when some highway dimension changes slightly. It follows that meeting or not meeting a dimension standard does not correspond to a road being ‘safe’ or ‘unsafe’. Also, highway design standards evolve with time. We used to build lanes 3.6m (12 feet) wide, now the standard calls for 3.75m wide lanes. This does not mean that the entire stock of old highways with 3.6m lanes is unsafe. It means only that the information, the judgements, and the economic considerations that go into the formulation of design standards change in time. In short, highway design standards are not the demarcation line between what is safe and unsafe. They are a reflection of what a committee of professionals of that time considers to be overall good practice.” These observations are valid for India too. Road standards set by Indian Roads Congress in India are based on committees where the membership includes practicing and retired professionals and academics. IRC does not have a rigorous process of synthesizing results of systematic reviews and scientific studies to propose or modify standards and monitor the impact of new standards.

Road infrastructure improvements (e.g., road upgrading and pavement) and roundabout design are found to be beneficial for safety. In the case of HICs, not only does better vehicle design but also improvements in road safety engineering reduce the severity of whiplash injuries when accidents occur, and this could be done by enhanced signal visibility or through complex intersection geometric upgrades (Navin et al. 2000; Perez 2006). In the case of countries like India, the safety benefit of roundabouts is clear; however, upgradation involving improved pavement surface, wider lanes, and wider shoulders may lead to higher speeds and increase opportunities for lane changing and conflicts. Pedestrians and slow vehicles on the curbside lane or shoulders will be exposed to motorized vehicles moving at much higher speeds. Safety benefit of road upgradation using the present standards is unclear for Indian highways.

Safe systems approach has three key principles (H. Y. Chen and Meuleners 2011; Transport Research Centre 2008):

- Principle 1 – Recognition of human frailty
- Principle 2 – Acceptance of human error
- Principle 3 – Creation of a forgiving environment and appropriate crash energy management

Current highway standards for geometric design of highways can be reviewed in the context of these three basic principles. Principles 1 and 2 must recognize that highways in India will have the presence of NMVs and pedestrians along with motorized traffic. Principle 3 becomes the operational principle for setting appropriate speed limits for ensuring a forgiving environment for all road users. Pedestrians will make mistakes in judging the possible risk in the system, whereas drivers can make mistakes in adopting an appropriate speed.

Design speed and design vehicle are the two most important elements which have been used to set highway standards in the past. Stopping distance of a modern car is very different from a tempo (three-wheeler) or two-axle trucks present on Indian highways. Therefore, selection of a design vehicle itself becomes important for setting the minimal standards for stopping distance, sight distance, and overtaking distances.

Design speed governs the design of horizontal curve, vertical curve, and the safe stopping distance. Conventional practice of keeping design speed higher than operational speed has been questioned by several researchers. Therefore, the design speed must be in line with the requirement of principle 3 “Creation of a forgiving environment and appropriate crash energy management.” This implies that for setting appropriate design speed, presence of NMVs, presence of activities along the highway, and density of built up area along the highway and frequency of towns and villages through which the highway passes must be taken into consideration. Design speed may vary from 30 km/h to 90 km/h with a road cross-section designed for appropriate crash energy management depending on the surrounding land use present along the highway.

Speed compliance by design: We started this paper quoting the success of legislation and enforcement; however, taking lessons from a number of studies in HICs, the most effective measure for speed compliance in India will be by design: active speed control measures. India has weak institutional capacity and weak enforcement of legislation; therefore, speed control by texture change, audible markers, rumble strips, change in geometric standards, median designs, lowering speeds at intersections by introducing roundabouts, raised stop lines, and speed humps on minor roads are expected to be more successful in speed compliance by all road users – good drivers, bad drivers, young drivers, knowledgeable drivers, drivers with poor driving education, etc. – ensuring compliance with the principle 2.

Many of the current standards for highway cross-section require revisions (Chen and Meuleners 2011; Mohan et al. 2017b) to comply with principle 3. Appropriate design of service roads, width of shoulders, and design of medians have to be reviewed to ensure safe designs for NMVs and different kinds of vehicles on the road.

Conclusions

The discussion above suggests that the previously assumed relationships between national incomes and RTI fatality rates (initial increase in deaths with increasing incomes and a subsequent decrease) may not be correct, and national income levels cannot be taken as an excuse for inefficient data collection systems or lack of safety on roads. Therefore, moving toward a target of zero deaths on the roads is a logical policy to be adopted by all countries.

However, we are likely to encounter many obstacles as we try to implement policies underlying Vision Zero:

- In most LMICs a large proportion (>60%) of RTI those getting killed in urban areas and on highways vulnerable road users. On the other hand, in the USA an estimated 45% fatalities were prevented due to automobile safety standards and NCAP-type testing. If in a country vehicle occupant deaths contribute only 20% instead of 64% of the total count, then it is possible that reduction in deaths due to automobile safety standards would be less than 15%. Since a large number of LMICs are not likely to reduce VRU exposure significantly in the next decade, exclusive focus on NCAP standards will not produce as dramatic results in LMIC as they did in the HIC in the past. There is a need for the development of suitable vehicle safety standards including all indigenous intermediate transport vehicles.
- Significant gains in traffic safety in HIC are partly due to the reduced exposure of VRU and not only due to the effect of safety policies. VRU trips have been reduced in many HICs for various reasons such as land use patterns requiring long commutes, easy access to cars, etc. It may not be possible for LMIC to reduce fatality rates below about 7 per 100,000 population along with high exposure of VRUs unless there are innovative developments in road design (including roundabouts, bicycle lanes, and expressways) with special emphasis on VRU protection.
- Fatality rates across cities and countries that have similar income levels can vary greatly. At present we do not know all the reasons behind these variations. It would be important to investigate why rates are so different across cities in the same country. These findings might give us new clues on planning for Vision Zero.
- The issue of serious injuries and fatalities among pedestrians hit by motorcycles has not received much attention internationally. Since the use of motorized two-wheeler for personal transport and deliveries is increasing in a large number of countries, it is necessary to give greater attention to safer motorcycle design and management of their movement on city roads.
- Very little effort has gone into the development of new knowledge, road designs, or vehicle safety specifications in most LMICs. Local research capabilities and resources for scientific research remain low.

Because of these reasons, road safety priorities may have to be very different in India and many other countries, and some new safety interventions would have to be developed to move toward Vision Zero. Translating Vision Zero requires efforts at several levels. At a very macro level, it involves the concept of "right to safety" enshrined in our constitution. A "right" to safety can exist only when there exists a relationship between individuals or groups using a product or services and the provider of those products or services. Constitutions of most countries ensure that their citizens have a right to life, and it is this right that gets translated into a right to live free from debilitating injury. Article 21 of the Constitution of India, 1950, provides that, "No person shall be deprived of his life or personal liberty except according to procedure established by law." "Life" in Article 21 of the Constitution is not merely the physical act of breathing. It does not connote mere animal existence or continued drudgery through life. It has a much wider meaning which includes right to live with human dignity, right to livelihood, right to health, right to pollution-free air, etc. Individuals and communities need to understand that a right to safety on the road is as valid as a right to clean air or a right to live free of small pox, polio, or malaria.

The first step forward would be for policy-makers in all countries to acknowledge that road users have a right to expect that state decisions affecting their safety should be based on fact-based expectation of the safety consequences of such decisions. This would require every policy, law, or safety standard (concerning roads, vehicles, or traffic management) established by the state to be accompanied by a justification for the same by including systematic reviews of the scientific evidence used for the decision and the expected safety benefits in numerical estimates. The document would have to include information on what effects that measure would have on all road users and non-road users on their daily lives. These documents would obviously have to be placed in the public domain.

The second step would be for manufacturers of vehicles and other road-based technologies to explicitly state the quality and limits of the safety features embedded in their technologies. For example, a car manufacturer would have to state that the car has been tested for frontal impacts at say 60 km/h, that its speed reduces fatality rates by approximately x%, and that it may not be as safe at speeds above that limit.

The third step would be for international agencies dealing with road safety (state and non-state) to examine all sources of systematic reviews of road safety interventions and use them to justify the policies they pursue. They should also make it explicit that they will fund road safety activity by non-government organizations only if they promote interventions justified by scientific evidence. If they diverge from available evidence, then they must provide justification for doing so.

The proposed measures should help us move in a path that leads us to a situation that actually establishes Vision Zero as a right enjoyed by all road users and the accompanying obligations of the state and the private sector that accompany that right. The exact modalities of implementing the suggestions successfully will only come with experience.

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20 Vision Zero in the United Nations

Meleckidzedeck Khayesi

Contents

Abstract

This chapter examines the development and use of Vision Zero policy and its related strategy, safe system approach, in the road safety programs of the United Nations and its specialized agencies. The chapter shows that progressively, Vision Zero moved from being cited in documents as an example of a transformative policy to being promoted as a way of thinking about or approaching road safety for countries to adopt. In addition, it has been used as a principle in the *Road safety strategy for the United Nations System and its personnel*. This strategy embraces the ethical imperative that "no road users, including pedestrians, should be killed or seriously injured in road crashes involving United Nations vehicles." It commits United Nations organizations to Vision Zero. It calls for a shift from a traditional road safety approach to a safe system approach.

Keywords

United Nations · World Health Organization · United Nations Road Safety Collaboration · Resolutions · Injury · Violence · Vision Zero · Safe system approach · World Health Assembly · United Nations General Assembly

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Introduction

Vision Zero is currently emphasized as an ideal principle or aspiration to pursue in the internal road safety strategy of the United Nations (United Nations 2019). This development shows how Vision Zero has traveled from Sweden and penetrated road safety policy discourse not only in countries and cities but also in international organizations. How did this development happen? How is Vision Zero reflected in the road safety policies and programs of the United Nations? These two questions constitute the focus of this chapter which examines the development and use of Vision Zero as an ideal principle or aspiration in the road safety programs of the United Nations and its specialized agencies. This chapter essentially examines turning points that led to Vision Zero becoming a key principle promoted or emphasized by the United Nations.

Vision Zero and its associated concepts are briefly clarified before moving to the rest of the analysis in this chapter. As already indicated, Vision Zero is a policy that advances the idea of no deaths and injuries on the roads (Belin 2012). Associated with this aspiration are three other concepts: safe system approach, sustainable safety, and Toward Zero. The safe system approach is a holistic and proactive strategy that seeks to realize the aspiration of Vision Zero through managing the elements of the road transport system to prevent crashes and reduce their impact when they occur (International Transport Forum 2016). Sustainable safety is the approach adopted by the Netherlands toward improving its road safety along the lines that Sweden pursued (Peden et al. 2004; Weijermars and Wegman 2011). While some scholars see sustainable safety as the Dutch version of Vision Zero, others perceive the two to be different. The concept of Towards Zero expresses the idea that the emphasis should be on the effort or process toward zero deaths. New Zealand uses the idea of "Road to Zero" in its 2020–2030 road safety strategy (New Zealand Government 2019). There is also an organization with the name "Towards Zero Foundation," seeking to realize the ideal of a world free from road traffic fatalities and serious injuries by promoting safe and sustainable mobility (Towards Zero Foundation 2020). Thus, Vision Zero was a new idea that has inspired other concepts.

Road Safety in the United Nations and Its Specialized Agencies Before Vision Zero

One of the chapters in this handbook discusses the development and adoption of Vision Zero by Sweden in 1997. This section examines road safety in the United Nations before Vision Zero was formulated or adopted. The United Nations and its specialized agencies such as the World Health Organization (WHO) and United Nations Economic Commission for Europe have been concerned about the prevention of road traffic injuries for several years., implying that the recent road safety efforts in the United Nations are part of an evolving policy. A paper on road traffic injury data mentions discussions on road safety at WHO in 1946, when WHO was formed and inherited the health functions of the health division of the League of Nations (World Health Organization 1972). One of the key roles that the League of Nations played was promoting the need for official road traffic injury statistics, different from general statistics on the causes of death.

Another United Nations agency that was established in 1947 was the United Nations Economic Commission for Europe (UNECE) (2017). UNECE established a transport division in 1947. This division has focused on road safety and other transport topics. It created a Working Party on Road Traffic Injury that has revised several road safety agreements and regulations as needed. The work of UNECE on road safety conventions and agreements is highlighted in different parts of this chapter. UN Economic Commissions in other regions also focus on road safety.

The Geneva Convention on Road traffic was signed on 19 September 1949 in Geneva, Switzerland (UNECE 2017). It entered into force on 26 March 1952, addressing minimum mechanical and safety equipment needed to be onboard, and defines an identification mark to identify the origin of the vehicle (Wikipedia 2020). This and other subsequent conventions became the core work of UNECE.

In 1961, World Health Day, observed every year on seventh April in honor of the date WHO was created, was dedicated to "Accidents and their Prevention." This was followed by a comprehensive report on the epidemiology, control, and prevention of road traffic accidents in 1962 (Norman 1962). This report discussed the nature and dynamics of the problem. It should be noted that WHO has played an important role in the epidemiological analysis of the magnitude and effects of road traffic injuries. For example, mortality from road traffic crashes, with special reference to motor vehicle collisions for the period 1950–1962, was the special subject in the Epidemiological and Vital Statistics Report of 1965.

In 1966, the World Health Assembly, the decision-making body of WHO, adopted resolution WHA19.36 which requested "the Director-General to consider the possibilities of WHO playing a more active role in the prevention of traffic accidents, with special emphasis on human and medical aspects of the problem and on the coordination of international research in this field" (WHO 1966). There was a discussion on road traffic injuries in the WHO Executive Board of 1969 that suggested that WHO should continue its close collaboration with the national, intergovernmental, and nongovernmental organizations working in this field (WHO 1969). These two examples indicate that road traffic injuries received attention from key decision-making bodies at WHO such as the World Health Assembly and Executive Board.

Another key development in the 1960s was the United Nations Conference on Road Traffic held from 7 October to 8 November 1968 in Vienna, Austria. The International Labour Organization, the World Health Organization, and the International Atomic Energy Agency were represented at the Conference in a consultative capacity. A major outcome of this Conference was the signing of the Convention on Road Traffic (UNECE 2017). This convention formed the basis for the work of UNECE, one of whose key activities "is the updating of the existing legal instruments in the field of road transport administered by ECE, such as the Vienna Convention on Road Signs and Signals and on Road Traffic of 1968, and the 1971 European Agreements supplementing them" (UNECE 2008). UNECE has carried on this work over the years and has regularly updated these legal instruments for road safety. There are currently six priority road safety conventions that UNECE and its member countries have produced for Europe and the rest of the world. These are:

- The 1968 Convention on Road Traffic
- The 1968 Convention on Road Signs and Signals
- The 1958 Agreement concerning the adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment, and Parts which are fitted and/or Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations
- The 1997 Agreement Concerning the Adoption of Uniform Conditions for Periodical Technical Inspections of Wheeled Vehicles
- The 1998 Agreement concerning the Establishment of Global Technical Resolutions for Wheeled Vehicles, Equipment, and Parts
- The 1957 Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)

These conventions provide the basis for states to develop national legal frameworks on road safety. In addition to these conventions, UNECE produced a consolidated resolution on road traffic in 2010, aimed at supplementing the 1968 Convention on Road Traffic and the 1971 European Agreement, covering subjects not considered in these conventions (UNECE 2010). Further, the International Transport Forum, EUROSTAT and UNECE produced the fourth edition of illustrated glossary for transport statistics, which includes key definitions on road traffic injuries (International Transport Forum, EUROSTAT and UNECE 2010).

In 1974, the World Health Assembly adopted Resolution WHA27.59, declaring road traffic accidents a major public health issue and calling for Member States to address the problem (WHO 1974). In the 1970s and 1980s, the World Health Organization adopted primary health care as a strategy to address health issues in member states. One of the elements of this strategy was community involved. It is therefore not surprising that a WHO road safety technical report on “New approaches to improve road safety” has an annex on the development of a community-based accident prevention program that emphasizes the role of local accident prevention groups and national accident prevention councils (WHO 1989). There were other road safety efforts going on in the world in the 1980s. For example, the safe community movement, which had origins in Sweden, was established toward the end of the 1980s, following the first World Conference on Accident and Injury Prevention, which was held in 1989 in Stockholm. The safe community movement creation was in line with a major premise of the conference that community-level programs for injury prevention are key to reducing injuries (Rahim 2005).

Administratively, within WHO, there was an effort to decentralize coordination of some global programs from headquarters to regional offices in the 1980s as part of institutional restructuring approach during the leadership of Director-General Halfdan Mahler. This is the context in which the global coordination of road safety work was conducted by the WHO office of the European region during this period.

There were other external developments in the 1980s and early 1990s that laid the groundwork and provided space for conversations on road safety research and policy. For example, the first conference Road Safety on Four Continents was held in 1987. Within a space of 2 years, as already noted, the first World Conference on Accident and Injury Prevention was held in 1989 in Stockholm. This conference was the mustard seed for a series of World Injury Conferences that are currently a key global forum for interaction and conversations on science, policy, and practice of injury prevention. A conference on vulnerable road users was held in 1991 in New Delhi, organized by the Indian Institute of Technology Delhi and World Health Organization. The conference issued a declaration on vulnerable road users, calling for better planning for these key road users (International Conference on Traffic Safety 1991).

In 1993, the World Health Day, with the theme "Handle life with care" (WHO 1993), was dedicated to violence and injury prevention. Road traffic injury prevention was one of the topics highlighted. The Global Burden of Disease in 1996 projected road traffic injuries to become the third contributor to global burden of disease by 2020 (Murray and Lopez 1996). This study, funded by the World Bank, drew the attention of WHO and its member states to a growing global health problem of road traffic injuries. UNECE continued with its work on road safety conventions and agreements. Other United Nations Economic Commissions also continued with their activities on road safety.

Road Safety in the United Nations and Its Specialized Agencies After Vision Zero

This section examines road safety in the United Nations after Vision Zero was adopted in Sweden. Given the growing attention to road traffic injuries, the World Health Organization established the Department of Injuries and Violence Prevention within the Cluster of Noncommunicable Diseases and Mental Health in March 2000 to facilitate a coordinated response to road traffic injuries and other injuries. For the 17 years prior to this, injuries and violence prevention had been housed as a unit within three consecutive departments: Department of Health Protection and Promotion, the Department of Emergency and Humanitarian Action, and the Department of Disabilities, Injuries Prevention, and Rehabilitation. Road traffic injuries prevention was identified as one of the focal activities for this department. The other was interpersonal violence.

The creation of a department devoted to injuries and violence prevention led to a major change in the focus and approach to road traffic injuries within WHO. In 2001, WHO produced a 5-Year Strategy for Road Traffic Injury Prevention (Peden et al. 2001). It emphasized a public health approach to road traffic injury prevention, consisting of problem definition, identifying and implementing interventions, and evaluating these interventions. The objectives of the strategy were:

- To build capacity at a national and local level to monitor the magnitude, severity, and burden of road traffic injuries
- To incorporate road traffic injury prevention and control into public health agendas around the world
- To promote action-oriented strategies and advocate for prevention and control of the health consequences of motor vehicle collisions

Several road safety activities were undertaken within the framework of this strategy: development of normative documents, implementation of country demonstration projects, and advocacy and revitalization of WHO Helmet Initiative. In 2001, WHO secured financial support from the Federation Internationale de l'Automobile Foundation, which enabled WHO to start supporting pilot road safety programs in five focal countries: Cambodia, Ethiopia, Mexico, Poland, and Vietnam. In addition to projects in the five countries, WHO developed a road safety report between 2002 and 2004. The year 2004 was a significant milestone in the road safety work of WHO since World Health Day 2004 was dedicated to road traffic injury prevention. The theme was "Road Safety," drawing the attention of the world community to the growing problem of road traffic injuries and the need to step up interventions. World Health Day is one of the major advocacy opportunities for public health. Activities were organized at the global, regional, national, and local levels, engaging millions of people worldwide and raising awareness effectively. On that same day, 7 April 2004, WHO launched the *World Report on Road Traffic Injury Prevention*. The report provided a global reference on the magnitude of the problem and pointed out directions for road traffic injury prevention. There were also regional reports like the one for the European Regional of the World Health Organization that tailored the content and recommendations to issues relevant to the regional settings. The report was used not only as a wake-up call but also as a tool to be used by governments, industry, and civil society in all countries to identify some of the actions they need to take to reduce this burden in their own country. Its six recommendations provided a basic framework of action that road safety stakeholders at national and international levels were expected to pursue (Peden et al. 2004):

- Identify a lead agency in government to guide the national road traffic safety effort.
- Assess the problem, policies, and institutional settings relating to road traffic injury and the capacity for road traffic injury prevention in each country.
- Prepare a national road safety strategy and plan of action.
- Allocate financial and human resources to address the problem.
- Implement specific actions to prevent road traffic crashes, minimize injuries and their consequences, and evaluate the impact of these actions.
- Support the development of national capacity and international cooperation.

The preceding overview highlights that there were several turning points or actions in the United Nations after 1997 that eventually led to Vision Zero being used or promoted as a viable road safety strategy:

- Creation of a department devoted to violence and injury prevention in WHO
- World Health Day 2004 that was dedicated to road safety, on which occasion WHO and the World Bank released the *World report on road traffic injury prevention* (Peden et al. 2004)
- The initiation of the United Nations Road Safety Collaboration in 2005, coordinated by WHO and UN regional economic commissions
- Organizing United Nations Road Safety Weeks
- Passing of resolutions on road safety by WHA and UNGA
- Increased focus on road safety by several UN agencies and other organizations
- Decade of Action for Road Safety 2011–2020
- Holding of two/three global ministerial conferences on road safety
- Implementation of road safety programs in countries
- Appointment of the United Nations Secretary-General's Special Envoy for Road Safety
- Inclusion of road safety in the 2030 Agenda for Sustainable Development (United Nations 2015)
- Development of the Voluntary global performance targets for road safety risk factors and service delivery mechanisms (WHO 2017)

Vision Zero in the United Nations Road Safety Documents and Programs

Vision Zero was cited as an example of a transformative policy in the *World report on road traffic injury prevention* (Peden et al.2004). It is described as a long-term strategy in which improvements are delivered in gradual increments, and where, over time, the responsibility for safety becomes shared by the designers and users of the road traffic system. The report argues that Vision Zero is relevant to any country that aims to create a sustainable road transport system, and not just for the excessively ambitious or wealthy ones. The report further posits that the basic principles of Vision Zero can be applied to any type of road transport system, at any stage of development. The report discusses Vision Zero within a framework of a paradigm shift in road safety policy. Other approaches discussed in the report are Haddon Matrix and public health approach.

The *Global Plan for the Decade of Action for Road Safety* (WHO 2011) indicated that its guiding principles are those included in the safe system approach. It emphasized that this approach aims to develop a road transport system that is better able to accommodate human error and take into consideration the vulnerability of the human body. The Plan reiterates the key principles of a safe system approach and advances a set of activities to be implemented under five pillars: road safety management, safer roads and mobility, safer vehicles, safer road users, and postcrash care.

In pursuit of the Decade of Action for Road Safety and the objectives of the United Nations Road Safety Collaboration, resolutions were passed by the United Nations General Assembly and World Health Assembly, calling for sustained action and spelling out key activities to be undertaken. Vision Zero is variously highlighted in these resolutions and other reports such as the United Nations Secretary General's reports on the global road safety crisis.

The safe system approach, a strategy related to Vision Zero, is described as an operational framework in several technical documents providing guidance on interventions. For example, a road safety package produced by WHO in 2017 reiterates that the Safe System Approach provides a viable framework to examine road traffic injury risk factors and interventions from a holistic perspective (WHO 2017). Like the *World report on road traffic injury prevention*, this document highlights the key principles of the Safe System Approach and presents 22 interventions that countries can implement. Examples of other documents that highlight the safe system approach or Vision Zero are pedestrian safety manual (WHO 2013) and powered two-and three-wheeler safety manual (WHO et al. 2017).

Another example of drawing on Vision Zero is in the *Road safety strategy for the United Nations System and its personnel* (UN 2019). This strategy makes explicit reference to Vision Zero, stating: "The strategy embraces the ethical imperative that 'no road users, including pedestrians, should be killed or seriously injured in road crashes involving United Nations vehicles.' The United Nations organizations hereby commit to 'Vision Zero.' The United Nations is engaged in developing a pro-active, forward-looking approach to road safety, which requires managing the interaction between speed, vehicles, road infrastructures and road user behaviours in a holistic manner" (UN 2019:8) It commits United Nations organizations to Vision Zero and calls for a shift from a traditional road safety approach to a safe system approach. It indicates it is based on a safe system approach and presents a set of activities under five pillars: road safety management, safer fleets, safer road users, postcrash response, and safer driving environment.

The trajectory presented in the preceding paragraph shows that, progressively, Vision Zero moved from being cited in documents as an example of a transformative policy to being promoted as a framework for countries to use. In addition, it has been used as a vision in the *Road safety strategy for the United Nations System and its personnel*. Vision Zero is promoted alongside other frameworks such as the public health approach. Vision Zero's emphasis on a system approach and evidence-based solutions is in line with effective solutions and integrated policy-planning perspective at the center of international health and development programs. Resolutions, documents, and strategies by UNRSC, UN, UNGA, and WHA have steadily referred to and used Vision Zero policy and its related strategy of safe system approach as an aspiration and a planning model to be used by organizations, countries, and cities in their road safety programs.

Conclusion

The development of the road safety policy and programs in the United Nations and its specialized agencies such as the United Nations Economic Commission for Europe and World Health Organization has a long history, embedded in both internal and external institutional processes. Policy and programs advance not only specific interventions to solve a problem but also strategies, visions, and tools for institutions and countries to use. This chapter has traced turning points in the United Nations and its specialized agencies that led to Vision Zero moving from being cited in documents as an example of a transformative approach to being promoted as an ideal for countries to use. In addition, the chapter has shown that Vision Zero has recently been used as a vision in the *Road safety strategy for the United Nations System and its personnel*. This strategy embraces the ethical imperative that "no road users, including pedestrians, should be killed or seriously injured in road crashes involving United Nations vehicles." It commits United Nations organizations to Vision Zero. It calls for a shift from a traditional road safety approach to a safe system approach. The contribution of this chapter is in examining processes and contexts that either favor or hinder the promotion of a strategy or framework in an international context, in this case Vision Zero in the United Nations.

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Towards a Potential Paradigm Shift: The Role of Vision Zero in Global Road Safety Policy Making

21

Ann-Catrin Kristianssen

Contents

Abstract

Vision Zero is a term mainly connected to road traffic safety and has its roots in the Swedish road safety policy, although similar concepts are used in other countries. It was adopted by the Swedish Parliament in 1997, and due to the success of lowering the number of deaths in traffic crashes significantly, it has become an inspiration to road safety strategies in countries and cities all over the world. An important factor as to why Vision Zero diffuses is the incorporation of the vision in reports and strategies from international intergovernmental organizations and through the work of nongovernmental organizations. The development of finding a common global

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strategy for road safety has been an ongoing process for many years, and the purpose of this chapter is to map the role of Vision Zero in this global development process. This is performed by studying the integration of Vision Zero in the road safety work and strategies of key international intergovernmental and non-governmental organizations. The chapter also contains an account of possible opportunities and advantages of working with Vision Zero as a tool on the global level as well as the criticism towards the approach. This chapter discusses the content of what is being diffused, why it is diffused, who is diffusing, and how it is diffusing. The material consists of key global policy documents and 29 semi-structured interviews with senior experts working with road safety on a global level. The main conclusions are that Vision Zero is a well-established global road safety policy program and a road safety philosophy integrated into both the work and texts of the major intergovernmental organizations working with road safety. There is a widespread opinion that Vision Zero and other safe system approaches constitute a paradigm shift in global road safety work. It is regarded as an innovative and inspiring policy based primarily on its ethical approach. It is also regarded as a coherent policy program and rests firmly upon years of progress and experience. Even though many of the respondents are positive towards the ethical base and the systematic approach, there are still those who argue that Vision Zero cannot be used as a policy tool, at least not in low- and middle-income countries. It is obvious that Vision Zero is not interpreted and reproduced in the same way in all contexts, but the question is if that is part of a natural transformation process leading to new interpretations or if it is a problem for the Vision Zero trademark.

Keywords

Vision Zero · Global road safety policy · Global governance · Policy diffusion

Introduction

Road injuries or road traffic crashes is one of the main health problems globally as 1.35 million people are killed in road traffic crashes yearly. It was the eighth cause of death in the world in 2018 and the leading cause of death for children and young adults aged 5–29. In comparison, deaths in road traffic crashes now supersede the number of deaths caused by HIV/AIDS (WHO 2018). In addition, it is estimated that 20–50 million people are injured in the road traffic every year. The burden of road traffic injuries is highly disproportionate hitting the populations in low- and middle-income countries particularly hard as 93% of the fatalities can be found in these countries (UNECE 2019). With projections of even higher numbers of road traffic deaths in upcoming years, particularly in low- and middle-income countries, international organizations, individual countries, and city administrations all over the world have acknowledged the need for action. Legal frameworks and guidelines have been in place for many decades, but the process of creating global policies, programs, and institutions has been significantly slower. Many of the conventions and legal provisions in place, such as the Geneva Convention for road traffic from 1949, have helped not only governments but also private companies to conform to global standards, and these legal guidelines have been a solid foundation for further progress. These conventions have mainly been under the supervision of the United Nations Economic Commission for Europe (UNECE). Despite a growing number of agreements, the progress concerning global policies, conventions, and resolutions for road safety was slow for a long period, and road safety was not a prioritized global policy area. This started to change, particularly during the late 1990s and early 2000s, and two important factors were the influx of resources leading to the collection of more data on traffic crashes and the publication of the World Report on road traffic injury prevention by the World Health Organization (WHO) in 2004. The same year, the WHO was invited by the United Nations to coordinate global road safety efforts, in close cooperation with the UN Regional Commissions, and one of the first actions related to that UN resolution was to establish the UN Road Safety Collaboration. After the adoption of the Decade of Action 2011–2020, the inclusion of road safety in several of the sustainable development goals in 2015 (road safety was not included in the millennium goals), and a number of ministerial conferences on road safety, it is fair to say that this policy area is established as one of the key development issues on the global agenda. On the other hand, millions of people still die every year in traffic crashes, and there is a growing demand for more concrete action.

Vision Zero, which is normally included into the family of safe system approaches, has received growing attention during the last two decades and is seen by many experts as a coherent policy program and even a policy innovation (Belin et al. 2012; Belin and Tillgren 2013; Kim et al. 2017). Vision Zero, as it will be described in this chapter, was developed in Sweden and adopted by the Swedish Parliament in 1997 (Swedish Government 1997; Swedish Parliament 1997a, b). The Swedish road safety work was already well established before the introduction of Vision Zero, but as the number of deaths in traffic crashes went down significantly after the introduction, many experts give credit to the systematic road safety work that Vision Zero enabled. In 2019, Sweden reported 2.1 deaths/100,000 population (Trafikanalys 2020) compared to approximately 18 deaths/100,000 population as a global average (WHO 2018). As the policy area of road safety grew increasingly global, actors within this field began to look at what was being done in countries like Sweden and the Netherlands but later on also in countries such as Australia and Norway who have all adopted similar, but also somewhat different, kinds of safe system approaches to road safety. Vision Zero is also inspiring and diffusing to other sectors in the society (Kristianssen et al. 2018). The progress made in these countries received global attention, and many organizations and individual experts were inspired by this approach, but there were also conflicts as the traditional views of road safety work differed quite considerably from that of the safe system approach (Salmon et al. 2012).

The purpose of this chapter is to map the role of Vision Zero in the development of global road safety policy. This is performed by studying the integration of Vision Zero in the road safety work and strategies of key international intergovernmental and nongovernmental organizations. The chapter also aims to account for possible opportunities and advantages of working with Vision Zero as a tool on the global level as well as the criticism towards the approach. A final purpose is to analyze whether Vision Zero has been transformed as a philosophy or policy program as it lands on the global level.

The main research questions are:

- What is the role of Vision Zero in global road safety policymaking?
- Do the key components of Vision Zero change when integrated in global policymaking?
- Why is Vision Zero seen as a promising approach and by whom?
- What are the challenges of working with Vision Zero on a global scale?

Why are these relevant questions to ask in relation to the development of global road safety policies? First, the global road safety policy process is an example of how global agenda-setting works and how actors in different capacities relate to a new idea. Second, it is important to scrutinize the strengths and weaknesses of new and inspiring ideas, particularly those who become role models for so many.

The chapter consists of six parts starting with this introduction. The second part addresses diffusion processes and how global agenda-setting is made. The methodological approaches are described in the third section followed by the presentation of the empirical material, i.e., the mapping of the role of Vision Zero in global road safety policy and the reflections on Vision Zero as a tool in practice. The fifth section contains an analysis, and the final part of the chapter is devoted to conclusions and a discussion about the significance of the diffusion of Vision Zero in conjunction with the global sustainable development goals as well as other implications for the future.

How Do New Ideas and Policy Choices Enter and Consolidate on a Global Level?

Every global policymaking and agenda-setting process is unique in the sense that all policy areas have their own settings and preconditions, but there are also general discussions about mechanisms and factors related to policy change on the global level. The purpose of this section is to provide a theoretical foundation to the aspects of policy diffusion, global policy change, and global agenda-setting processes. These perspectives will help us to understand why some ideas become the base of new global policies and why other ideas are discarded. The theories can also provide an insight into the motives and roles of actors in the policymaking and agenda-setting processes.

Global Policy Diffusion

Policy diffusion is a wide scientific field and relates to all societal levels, and research is performed with both quantitative large N studies as well as qualitative case studies. There are a number of empirical questions related to policy diffusion such as identifying actors, structures, methods, motives, timing, and content. Studies on how ideas travel between different contexts have been performed for decades, and we can, for instance, find inspiration in early research about imitation (Simmel 1904). Policy diffusion is a theoretical and empirical topic in many disciplines such as Political science, Public health, Technological disciplines, Human geography, Sociology, etc. Many researchers within this field depart from books such as Everett rogers' *diffusion of innovations* (1962). Rogers' theories, which have been developed in many revised editions, focus on the diffusion of new ideas and technological innovations and are based on four central dimensions: the innovation itself, how it is being communicated, temporal factors, and social system. According to Rogers, the innovation has to be adopted by a critical number of entities in order to be established and thus regarded as an innovation. The theories are based on an actor perspective and timeline, as the adopters are categorized as early adopters, early majority, late majority, and laggards (Rogers 1962). It is today more and more common to use new ideas, reforms, and innovations in the public sector, often seen as a part of the diffusion of new public Management, and these so-called policy innovations "*...offers a new definition of a political problem, provides a new political vision for the political community, and/or proposes a new set of political goals and strategies*" (Sørensen 2016:157). Inspired by the early research on diffusion, many influential studies have been published particularly within the field of political science (c.f. Berry and Berry 1990), and three subfields began to emerge: (1) policy diffusion, (2) policy transfer, and (3) policy learning. To learn from others is an intrinsic part of a lot of the policy development that is taking place, but it does not necessarily mean that policies are diffused or transferred. Research on policy diffusion have traditionally been more focused on structures, mechanisms, finding patterns, and explanations in predominantly quantitative studies (Gilardi 2016), while policy transfer relates more to actors, cases, and to follow processes rather than explaining them (Evans 2009). In attempts to create an overarching approach to both these subfields, various frameworks have been presented, such as the following model by Dolowitz and Marsh (1996, 2000) suggesting that there are seven ways to understand policy transfer: (1) Who is diffusing? (2) Why is a policy diffusing? (3) What is diffusing? (4) Are there degrees of diffusion? (5) What is the inspiration or original policy? (6) Are there factors limiting the diffusion? (7) Can the diffusion be connected to more successful policies? Several models such as this have mainly been used in a transnational or national setting. There are other examples of broader theories and models of explanation linked to global diffusion processes. These models often relate to mechanisms of diffusion, such as learning, imitation, coercion, and competition (Shipan and Volden 2008).

The international and global dimension is also prevalent in concepts such as bandwagoning (Ikenberry 1990), where states join other countries' policies for different reasons. It could be related to different kinds of alliances or that smaller countries adopt policies of bigger countries for political gains. In an international perspective, it is also relevant to talk about concepts such as policy translation or policy borrowing, as this is part of the ongoing process of creating global policies. Good examples are discussed and diffused in various circumstances, such as during international negotiations, conferences, and the like, and are at times incorporated into global policy documents. Finally, another key concept in the development of global policies is diffusion of ideas (c.f. Goldstein and Keohane 1993). This concept is often used in relation to specific arenas for diffusion, for instance, regional organizations such as the EU (Börzel and Risse 2009), and many studies have also focused on conscious strategies of diffusion (Stone 1999, 2012). The actors actively diffusing ideas are often called policy entrepreneurs and linked to global advocacy networks (Finnemore and Sikkink 1998; Keck and Sikkink 1999). They form knowledge-based groups often called epistemic communities (Haas 1992). We will return to these concepts later on, but we can already establish that Vision Zero is part of a diffusion process as countries and cities all over the world have adopted Vision Zero policy packages. In relation to these models mentioned above, the question is what kind of policy has diffused, why has it diffused, who diffuses, and under what circumstances?

Global Policymaking and Agenda-Setting

What ends up as a prioritized issue on the global agenda is as stated based on many aspects, and it is quite complicated to ascertain whether and when a problem has become a global issue (Neveu and Surdez 2020). Political scientist David Held argues that there are three different ways for promoting issues and for changes to happen on the international level. First, actors and organizations within the civil society link with progressive or powerful governments and make a case together. Second, international institutions can by themselves adapt to a new situation or push an issue forward regardless of opinions on the domestic level. Third, powerful networks of actors are formed in order to influence a policy area either from the top or from below (Held 2017). These factors can help us understand the direction of the development of a certain policy area. But there are also other important preconditions, such as the availability of resources, information, and data, and of course the political will to make changes. Agenda-setting is related to power, and such a process also involves risks and challenges. Klaus Dodds (2005), a geopolitics researcher, provides four critical aspects of global agenda-setting. First of all, how do we know that the key actors are focusing on a relevant problem? Second, by creating a global network for a certain policy area, there is always a risk that some geographic areas or views are not represented and that some perspectives get lost on the way from the national to the global level. A third concern is the incentives and motives of the actors involved in shaping the agenda. There is always a risk that powerful actors set the agenda in a way that creates division instead of global unity. Fourth, international relations are based on voluntary cooperation, and it is a dire task to argue with and convince skeptical actors to participate in certain governance structures such as international conventions and the like, which makes the jurisdiction of the decisions made a constant subject for discussion (Dodds 2005). Challenges apart, actors will not seize to promote issues on the global level that they find important, and it is particularly relevant to understand not only agenda-setting and policy change but rather the mechanisms related to deeper institutionalization processes, which require a more profound change of global structures.

Global Advocacy

To answer the questions raised in this chapter, we also need to understand the role of actors more specifically. Here, two perspectives will be used: transnational advocacy networks (TANs) (Keck and Sikkink 1998, 2014) and the advocacy coalition framework (ACF) (Sabatier 1998; Sabatier and Weible 2007). The seminal work by Keck and Sikkink from 1998 established the concept of transnational advocacy networks which has been used widely to describe both loose and more formal collaboration between various actors working on a global level on a specific issue sharing basic values. These networks are based on "the centrality of values or principled ideas, the belief that individuals can make a difference, the creative use of information, and the employment by nongovernmental actors of sophisticated political strategies in targeting their campaigns" (Keck and Sikkink 1998). The TAN concept is focusing mainly on the work of NGOs, and the network actively promoting road safety on the international level is broader. Therefore, we need to acknowledge that these global networks can also contain various actors from many institutions. The Advocacy Coalition Framework (ACF), as presented by Sabatier, views policy change as either caused by external shocks or a more long-term negotiation, that all participants in the coalition or network share a common belief system, and that there is a high degree of learning between the participants (Sabatier and Weible 2007). This can be related to the earlier mentioned epistemic communities. Although ACF has primarily been intended for contexts where there are competing coalitions, it will be an open empirical question in this chapter whether there are such constraints within the policy area of road safety. This brief introduction to theories on diffusion, global policymaking, and agenda-setting does not presume to be all-encompassing but helps us to understand what happens when new ideas are introduced on the global level. The focus is both on the content of the new idea and on the actors actively promoting or discarding this idea. Was Vision Zero actively promoted, or was it part of a more traditional policy borrowing process? Being a new idea, was the introduction of Vision Zero a conflictual process?

Global Road Safety Policymaking Research

Although there is plenty of road safety research with a global or transnational perspective specifically targeting different aspects such as road assessment, speed management, vehicle safety, traffic crashes, etc., not a lot has been written about global road safety policymaking. Research on road safety tends to focus more on the national level and local examples, although policy-related research about road safety is scarce also on those levels. The existing research on global road safety policymaking focuses mainly on two perspectives, concrete policies and/or measures often related to specific global commitments, and more actor-centered studies. As an example, there is research following the progress made in relation to the pillars of the Decade of Action. Hyder et al. (2017) conclude that a lot of progress has been made in terms of systematic efforts on all levels to decrease the number of deaths but that it is still difficult to measure progress. There is need for more data and above all better data. An example of policy-related research is the set of literature on road safety philosophy mainly those writing about safe system approaches (c.f. Larsson et al. 2010; Hughes et al. 2015). The existing literature on safe system approaches recognizes both the ability of this approach to be used in global and national road safety contexts and also that existing safe system models can be further modified. There is both a possibility to learn from other sectors and from within the road safety sector. Turning to studies with a focus on actors within the road safety sector, McIllroy et al. (2019) have performed an interesting mapping of the influence of road safety actors at various levels as well as their interaction. This is a particularly interesting study as it gives a vivid image of the system and clearly visualizes both the potentials and challenges. When actors are intertwined in a system, there are opportunities for single actions to have effect in the larger system under certain circumstances, but the study also makes it clear that it is more likely that actions directed only towards one topic will divert the attention from the broader picture. There is also literature offering a helicopter perspective on road safety looking both at the historical development of road safety thinking (Hakkert and Gitelman 2014) and forward-looking approaches (Wegman 2017). This brief summary of research on global road safety policymaking shows that we need to know more about the role of global road safety strategies and policies in the overall road safety system.

Research Design

The content of this chapter is based on a research project mapping global road safety policy and governance. The project is financed by the Swedish Transport Administration, and one part of the project relates to the role of Vision Zero in global road safety policymaking. The empirical material consists of policy documents, such as reports, resolutions, visions, and other kinds of statements from key intergovernmental organizations, such as the United Nations and its regional commissions, the WHO, the World Bank, and the OECD. The documents from intergovernmental organizations (IGOs) have been studied using a qualitative content analysis where sections on Vision Zero and the related concept safe system have been selected for deeper analysis. These texts are scrutinized in order to find key components of Vision Zero. These key components used for the analysis can be found under section "The Vision Zero Policy in Global Road Safety Policymaking." Other sections of the texts have also been read as a way to analyze whether Vision Zero components have been used while not using the terms Vision Zero and Safe system. Statements and reports from nongovernmental organizations (NGOs) have been analyzed in order to identify whether there are alternative perspectives on the role of Vision Zero.

In addition, the chapter is based on an interview study with 29 respondents from various IGOs, NGOs, and research organizations working with road safety. The interviews were performed in 2017–2018. The selection process is based on finding senior experts within the field of road safety, and the criteria are that they are or have been working for intergovernmental organizations or nongovernmental organizations. The respondents also include researchers with an expertise covering global road safety issues and experience in cooperating with various kinds of international organizations and institutes. The interviews are semi-structured and have all been transcribed word by word. The interviews were made equally on online platforms, face to face, and over telephone. The respondents are anonymous and coded according to the following: intergovernmental organizations (IGO 1, 2, 3, etc.), nongovernmental organizations (NGO 1, 2, 3, etc.), and researchers (research 1, 2, 3, etc.). The respondents have in almost all cases a broad background, often starting their careers on the national level, and a majority of them have been working for several kinds of international organizations. The respondents have been selected based on two parameters: their current affiliation where they are asked to talk about the discussion and work of their organization and the unique expertise in this field where they are also asked to reflect more personally on the development of global road safety policies. In order to find these senior experts, a snowballing approach has been used, where the respondents have been asked to name other experts who both agree and disagree with their position. This has been complemented by direct contacts with specific organization. The questions asked concerned the following topics:

- The role of Vision Zero in the global road safety policy documents
- The role of Vision Zero in the global formal and informal discussions concerning road safety
- The advantages of working with the Vision Zero policy
- The challenges of understanding as well as implementing Vision Zero
- The past and current road safety philosophies
- The implementation of Vision Zero in relation to the specific challenges of low- and middle-income countries

Vision Zero in Global Road Safety Policymaking

In order to understand the role of Vision Zero in global road safety policy, we will first identify the main events in this development process concentrating on the last two decades. As mentioned earlier, there have been existing guidelines and regulations for road traffic ever since transportation systems were established. These regulations, such as the Geneva Convention from 1949 (United Nations 1949) and the Vienna Convention from United Nations 1968, have mainly been supervised by the UN Economic Commission for Europe (UNECE) and are today under the supervising umbrella of a number of work packages. The temporal focus of this chapter is from the late 1990s up until 2020, mainly because of the establishment of Vision in the later part of the 1990s, but also due to the fact that we have during these last 20 years witnessed a consolidation of road safety as a global policy area. Before this period, many actors regarded this policy area as falling mainly within the national interest sphere. This was also a period where new organizations were established promoting road safety, such as the World Bank-sponsored Global Road Safety Partnerships (GRSP) established in 1999 and hosted by the International Federation of Red Cross and the Red Crescent Societies. The question is what made road safety a *global* problem besides being an evident national and local issue? Both the respondents in this study and the documents point to an increasing and more systematic collection of solid data as a key reason for the growing global interest in road safety. This began already in the 1990s, and one such process was a collaboration between the World Health Organization (WHO) and the World Bank. This process of data collection and bringing road safety to global attention was also backed by individual countries, aid organizations, and later on by other IGOs and NGOs. This data collection process led to the publication of the influential *World Report on Road Traffic Injury Prevention* (WHO 2004). Although this was not in any way the first attempt to frame and form global road safety as shown earlier in this handbook, this report was for many an important turning point for global road safety measures as it so clearly identified the basic problem; millions of people are dying each year in traffic crashes. The same year, the United Nations adopted a resolution (United Nations 2004 UNRES 58/289) inviting the WHO to be the coordinator for road safety within the UN system. The same resolution also called for the WHO to cooperate closely with the UN Regional Commissions in this capacity. As the resolution also named the World Bank as a key actor, it broadened the interpretation of how the coordination would be structured. When accepting this coordinating role, the WHO, in close cooperation with the UN Regional Commissions, established the UN Road Safety Collaboration (UNRSC) in 2004. The first high-level ministerial meeting on road safety took place in Moscow in 2009, and it was followed the same year by the UN declaration of the Decade of Action for Road Safety, 2011–2020. Specific programs were set up to monitor the progress related to the pillars of the Decade of Action (Hyder et al. 2017). During this decade, many NGOs established programs for road safety, and some of the most influential have been the FIA Foundation, the Bloomberg Philanthropies, the Global Alliance of NGOs for Road Safety, specific road assessment programs such as iRAP, car assessment programs such as Global NCAP, several victim's organizations, etc. The second global ministerial meeting took place in Brasilia in 2015, a global envoy for road safety was established at the UNECE the same year, and in 2015, the sustainable development goals (SDGs) were adopted, where road safety was explicitly included. From not being mentioned in the millennium goals to being included in the SDGs in relation to both health and transport has already made a big difference worldwide. The consolidation and institutionalization of road safety as a global issue has continued with the establishment of the UN Road Safety Trust Fund (United Nations 2018) placed at the UNECE and the third Global Ministerial Conference in Stockholm in 2020. The recommendations presented at the conference have since then been endorsed by the United Nations (United Nations 2020). The question asked in this chapter is if specific road safety philosophies can be discerned in this process and particularly Vision Zero.

The Vision Zero Policy in Global Road Safety Policymaking

Before identifying the role of Vision Zero in global road safety policy, it is important to create a common point of departure as to what Vision Zero is. This is naturally mentioned in many chapters in this handbook, so this is a brief recap based on Belin et al. (2012). First of all, the problem to be solved is that people die and are seriously injured in the road traffic system, not that accidents occur. The problem is also that the system is not built to handle human mistakes. Humans will always make mistakes, and if the system is adapted to this precondition, crashes are preventable. The ultimate responsibility thus falls on the system designer, not the individual road user. The assumption must also be that nobody wants to die, everyone wants safety. There is therefore no optimum number of deaths in relation to cost. Finally, the goal must consequently be to eliminate fatalities and serious injuries. In addition to this definition, the Swedish Vision Zero is based on a scientific foundation both in relation to human tolerance to violence and how policies and measures are adopted. Vision Zero furthermore adds a long-term perspective on road safety based on a management by objectives, and the vision is grounded in a system of actors where everybody is responsible for its part in the road safety system, ideally a kind of network governance with one clear lead agency.

After the adoption of safe system approaches in a number of countries, particularly Western European countries such as Sweden and the Netherlands (Larsson et al. 2010), the ideas quickly became part of the ongoing discussions in various intergovernmental organizations and collaborations mentioned partly above. The dominating approach to working with road safety up until then can be illustrated by the three Es: education, engineering, and enforcement (c.f. McIllroy et al. 2019). The Swedish Vision Zero has a different approach as already concluded in this handbook as to its ethical approach, scientific foundation, comprehensive or systemic perspective, long-term management by objectives, and its view on shared responsibility and shared safety interest. As the Swedish Vision Zero was adopted in 1997, it is important to remember that the policy has naturally gone through changes and updates over the years.

The pioneering report from the WHO and the World Bank in 2004 introduced the safe system approach to a larger global audience and labelled it as a requirement to work with safety in the complex transport system because there is a need for:

> ...understanding the system as a whole and the interaction between its elements [...] In particular, it requires recognition that the human body is highly vulnerable to injury and that humans make mistakes. A safe road traffic system is one that accommodates and compensates for human vulnerability and fallibility. (WHO 2004:157)

The description of the Swedish Vision Zero is given space in the report and described in the following terms:

> Vision Zero in Sweden and the sustainable safety programme in the Netherlands are examples of good practice in road safety. (WHO 2004:158)

The WHO has continued to produce Global Status reports on road safety, and Sweden is often used as a successful example. The WHO has followed the continued updates in measures and policies in the Swedish road safety strategies.

> Experience in Sweden illustrates how better results can be achieved through long-term, perennial planning of systematic, evidence-based approaches to intervention, supported by a strong institutional delivery including leadership, sustained investment and a focus on achieving ambitious road safety goals and targets across government, business and civil society. (WHO 2018:20)

Vision Zero and safe system approaches were also recognized by other organizations during the 2000s, such as in the report from OECD and the International Transport Forum, published in 2008, which is a collaboration with representatives from individual countries and NGOs. This report is mentioned by other organizations and by the respondents in this study as a key in both knowledge development and the diffusion of the approach. One of the key aspects of the report is that:

> It describes how a Safe System approach can re-frame the ways in which safety is viewed and managed. (OECD/ITF 2008)

The report argues that the safe system approach, and Vision Zero as an example of it, constitutes a groundbreaking shift in how to work with road safety. The OECD/ITF has contributed to produce reports containing country evaluations (OECD/ITF/IRTAD 2016) and other assessment reports focusing on the role of safe systems. A report from the OECD/ITF from 2016 refers specifically to the process of introducing the safe system approach as a paradigm shift (OECD/ITF 2016).

The Moscow Declaration, which came out of the first global ministerial meeting in Moscow on road safety, acknowledged both the 2004 report from the WHO and the 2008 report from OECD/ITF urging countries to adopt a safe system approach. More importantly perhaps from a global perspective was the call for a decade of action. The Decade of Action for road safety 2011–2020 was declared by the United Nations in March 2010 (United Nations 2010) and contains five pillars focusing on safe roads, safe mobility, safe vehicles, safe drivers, and post-crash response. The global plan for the Decade of Action is based on a safe system approach and provides guidelines as well as urging countries to prepare their own road safety plans in accordance with the pillars. The safe system approach related to the global plan includes the acceptance of human errors, the production of infrastructure and vehicles in direct relation to the limitations of the human body, and shared responsibility (WHO 2010). The UN Road Safety Collaboration, hosted by the WHO, is working actively with its members to find productive ways to work with the pillars, and one has been to promote safety targets and another to base the pillars on a safe system approach. A recent UNRSC report states that:

> Integrated with safe system action across all pillars will ensure the global fatality and serious injury reduction targets are met by 2030. (UNRSC 2020)

The United Nations works on various fronts when it comes to road safety. The Global Forum for Road Safety (formerly WP.1) hosted by the UNECE is overseeing the global regulatory work concerning road safety described in its own plan for the Decade of Action (UNECE 2010; UNECE 2012) its integration of a safe system approach into the legal instruments. The UNECE also gives space to introducing new ways to work with regulations and presents in several ways the Swedish long-term method of working with management by objectives. The UNECE also hosts the UN Special Envoy for Road Safety, currently Jean Todt, and the role of the special envoy is to mobilize political support, to raise awareness about the work of the UN, to do advocacy work and alleviate partnerships, and to showcase good practice (UNECE 2015, terms of reference). Working for the United Nations, the special envoy's role is to promote the UN agenda (which we can now conclude promote a safe system approach) but also to call for action, which he did in the foremath of the latest high-level ministerial meeting:

> Road crashes on the alarming scale we witness today are not accidents. They are the failure of a system which does not sufficiently value safety. This is why we need a new paradigm for road safety that focuses on building a safe system. (UNECE 2020)

Although Vision Zero and safe system approaches are diffusing to all continents of the world, the other UN regional economic commissions such as UNECA, UNECLAC, UNESCWA, and UNESCAP are particularly highlighting the challenges faced by low- and middle-income countries when it comes to road safety measures. For instance, the African Road Safety Action Plan linked to the Decade of Action states that:

> The Decade of Action will provide the opportunity for African countries to intensify or to develop activities towards building their institutional capacity. Countries that have made more progress in putting in place structures and processes to improve road safety can focus on more advanced targets, such as capacity building at local government level, and developing local research and road safety monitoring. (UNECA 2011)

It is a valid discussion as to whether certain institutional, political, and civic preconditions have to be met in order to fully apply a safe system approach. When studying documents also from other UN Regional Commissions, the focus in the information on road safety is generally on more specific road safety problems disproportionately bestowed upon low- and middle-income countries and not on global road safety philosophies, although there are exceptions such as in this report by the UN commission for Asia and the Pacific:

> Speed management measures should be consistent with the global "Safe System" approach to road safety: road designers, builders and managers must take into account the known limits of the human body. (UNESCAP 2019:14–15)

The World Bank has together with a number of actors, such as the Global Road Safety Partnership (GRSP) hosted by the Red Cross, worked with road safety in cooperation with low- and middle-income countries. The World Bank supports the safe system approach as stated in a report by the Global Road Safety Facility (GRSF) hosted by the World Bank:

> The globally accepted best-practice approach to addressing the road safety crisis is the Safe System approach. (World Bank/GRSF 2020:6)

There is an awareness of the specific problems in low- and middle-income countries, but in a report written in collaboration with the World Resources Institute (WRI) supported by the Bloomberg Philanthropies and the FIA Foundation, the safe system approach and Swedish Vision Zero (termed the best-known brand of the safe system approach) are described as universal approaches.

> With the policy concept spreading, caution needs to be taken to ensure that all the features of a Safe System approach are evident in each new context. Although the distinct needs and opportunities in each location require unique strategies for action; the principles, core elements, and key action areas of a Safe System remain conceptually universal and interrelated. (World Bank/WRI 2018:13)

The second global ministerial meeting on road safety, held in Brasilia in 2015, was focused on the inclusion of road safety in the global sustainable development goals (SDGs), and among other perspectives, the Brasilia Declaration (2015) encourages the use of road safety targets in order to reach the goals. In order to find tools to work with the SDGs, several actions were taken such as the establishment of the UN Trust Fund for road safety in 2018 following a UN resolution (UNECE 2018; UN 2016, resolution 70/260). The global strategies for the trust fund specifically mentioned the safe system approach in Sweden and the Netherlands.

> This approach takes into account human failings and requires that not only the users are responsible for complying with traffic rules but that joint responsibility is borne also by all actors involved in design, construction, maintenance and improvements of roads and vehicles as well as organisation of post-crash response so as to ensure highest road safety performance. (UNECE 2018)

The third global ministerial meeting on road safety took place in Stockholm in 2020, and the Stockholm Declaration (2020) emphasized the safe system and Vision Zero approach in several sections such as:

> Encourage Member States that have not yet done so to [. . .] ensure that legislation and standards for road design and construction, vehicles, and road use are consistent with safe system principles. (Stockholm Declaration 2020:3)

The declaration also encouraged the private sectors to use safe system principles in their whole value chain and furthermore highlighted “the need for an integrated approach to road safety such as safe system and Vision Zero” (Stockholm Declaration 2020:2). The Stockholm Declaration was endorsed by the United Nations in August 2020 (United Nations 2020).

We have seen through this presentation how the safe system approach and the Swedish Vision Zero as the key example have become part of the strategies and visions of the major intergovernmental organizations working with road safety. It is also clear that there is a partnership between many of these organizations and NGOs providing both resources and projects in line with the global strategies. The advocacy work of organizations such as the FIA, the FIA Foundation, Bloomberg Philanthropies, World Resources Institute, the Global Alliance of NGOs for Road Safety, the Global Road Safety Partnership, and many more has helped diffusing texts and projects promoting a safe system approach and Vision Zero although focusing primarily on “getting things done.” The challenge when using a safe system approach and Vision Zero is to get the right things done. The question is whether these commitments stated above to a safe system approach have been or can be transformed into workable tools on the global level. It would first of all require a common comprehension and knowledge on what a safe system approach is and Vision Zero in particular. The question is also whether these approaches can also be tools when working with road safety in a low- and middle-income context or are these perspectives made for countries with all the “right” institutions, political systems, and civil societies in place?

Safe System and Vision Zero in Practice

As in many other policy areas, strategies and visions have to be transformed into concrete projects and measures in practice. In this process, individuals and groups establishing these strategies as well as implementing them face all kinds of challenges. This section contains a description of how senior experts in the field of road safety analyze the role of Vision Zero and safe system approaches on the global level primarily, but they also address the link between the global and the national level. Why is it important to study what 29 senior experts have to say about Vision Zero? First of all, these experts are part in forming and framing the global agenda on road safety, and what they base their work on is relevant for the outcome. Second, the selected experts have a long experience working within this field, which makes their analyses grounded and insightful as to the role of various road safety philosophies and strategies, although they do not always agree with each other. Third, as the experts work with different instruments, in a variety of organizations, and with specific areas of expertise, they form a micro society for road safety issues.

A Paradigm Shift in Road Safety Philosophy?

Policymaking is often easier when there is a group of people sharing the same understanding of the world, so-called belief system (Sabatier and Weible 2007), the same problem definition, and similar sets of solutions to these problems. Many of the respondents in this study are saying that there is a need for a common understanding of road safety problems in order to find the right solutions, but not all agree that it is crucial that everyone shares a common road safety philosophy. The respondents paint a picture of two parallel road safety philosophies: the traditional view that the problem concerning road safety is primarily the behavior of the road user which causes serious injuries and deaths and the safe system approach where there is basic view that human beings make mistakes and that we have to construct a system that allows for these mistakes. The overall opinion among the respondents is that both these philosophies exist parallel to each other. There are many experts working with road safety that still believe that the behavior of the road user can be considerably altered leading to fewer deaths, but that deaths cannot be avoided completely. Others are convinced that deaths can be prevented and that the transport system can be constructed in a safe way. The study on which this chapter is based shows that there are three perspectives regarding road safety philosophy and a potential paradigm shift. First, a minority of the respondents claim that the traditional view still prevails as the leading global road safety philosophy and that the introduction of the safe system approach has led to interesting discussions but has not changed road safety work in practice. These respondents claim that this is evident when focusing on the national level.

> I'd say that the majority of the road safety community is still working to the old approach, and the safe system approach is becoming increasingly recognized, but it still hasn't made it beyond the sort of small group of enthusiasts into the wider community. (NGO 1)
>
> First, I am not sure that it is a package that is well understood by all so there are still in several countries [. . .] a kind of skepticism about safe systems. (IGO 3)

A second group of respondents argue that the safe system approach is the dominant global road safety philosophy today, but that it has not changed road safety work on the ground yet. They claim that the safe system approach is constantly gaining ground although it is a slow process and that the approach might be seen as a bit too complicated and theoretical.

> I think definitely that the safe system has taken a long time to manifest itself and grasp people. [. . .] I mean really, again, there is a lot of people who work on theoretical level. I mean if you look at the world and who are the thinkers and who are the implementers, there are many more people who have it in their head than actually doing it on the ground. (NGO 8)
>
> There is a growing consensus around Vision Zero kind of approaches and particularly if we talk about safe systems and the number of sort of landmark reports that have led to that [. . .]. It really embraced a lot of these things and so it is almost a consensus now. Not entirely, but it is almost consensus. (NGO 9)

Others also argue that there is a limit to the usefulness of more theoretical approaches as you need to understand each and every context in order to make a difference. The argument is that enough has been said on an abstract level, now is the time for action.

The third group of respondents is those who claim that there has been a significant shift and that the safe system approach is the leading road safety philosophy today. This is especially highlighted in relation to the global scale and in the work of intergovernmental organizations. These respondents argue that we are witnessing a paradigm shift, significantly altering the way road safety is viewed in terms of problem formulation as well as solutions.

> . . .overall there is a good understanding about the need for an integrated approach. So the philosophies or the ideas are more in tune than in conflict. (IGO 2)

Most respondents view the "conflict" between a traditional road safety approach and the safe system perspective as problematic in terms of hindering organizations to work effectively with road safety on a global scale, while others do not.

> Safe System is not that kind of prevailing philosophy, despite the fact that everyone is talking about it. I don't particularly see one paradigm in the world. But I think it is a good thing that there is no one paradigm, because one recipe would never ever work. (IGO 1)

The Role of Vision Zero in Global Road Safety Policymaking

All respondents in the study recognize that the Swedish Vision Zero is a leading safe system approach, and as such it is visible in all global road safety discussions. The question here is whether Vision Zero is portrayed in a similar way whenever used, and another question is whether the perspective is recognized on other levels than the global. First of all, the presentation of safe system approaches as portrayed in global policy documents shows that there is a quite coherent image of the approach, but we start seeing different ways of using the concept when looking at the material from some NGOs, specific implementation processes on a national level, and how the perspective is interpreted by cities ready to launch a Vision Zero, for example. This is where we start to see major differences in how key terms are interpreted. This is particularly clear when it comes to road user behavior and enforcement. Several respondents are praising the ambition of Vision Zero but argue that it is difficult for some actors to turn it into a workable tool.

> Vision Zero has a big role and we can't justify anything else, of course not. It is what it is all about and that is what it should all be but I think it is still coming across as a very sophisticated western idea and people don't understand why we need another role and it is yet another buzzword. (NGO 8)

Many of the respondents, convinced that the safe system approach is the way forward, are also aware of the difficulties of translating the philosophy to all levels as well as political and geographical preconditions. There is thus a significant difference in how Vision Zero is recognized on different levels.

> I would describe it as the leading light within the international community, but I'd also describe it as a policy that people don't understand or haven't traditionally understood well, but I still believe that it has great potential. (NGO 3)
>
> I think one of the problems though is that there is a gap between the countries and governments that really understand what it means and then some countries and governments and other stakeholders are still make a rather simplistic analysis. I find very often when you talk particularly to politicians who have lots of competing pressures on their lives and they have got a lot of demands that they need to satisfy. They will all reach for very simple solutions. (NGO 9)

The respondents are also to some extent reflecting upon whether it is actually the exact content of Vision Zero that is seen as a promising policy or if Vision Zero represents one way of having a systematic approach to road safety. Therefore, it is an interesting discussion whether countries in dire need of lowering the number of deaths should start working according to a safe system approach or if they should start by establishing systematic road safety strategy, perhaps with one specific area at a time, eventually adopting a full Vision Zero.

> . . .they [a systematic approach vs. Vision Zero specifically] work along each other. They are complementary to each other, but the plan is to having moved [. . .] your road safety capacity, move it to a higher level of operations. So that is the plan. That may mean concentrating on one or two specific areas first more than others. That doesn't mean you give up the idea of zero fatalities, but it is an operational plan and I always saw Vision Zero from a philosophical term. It is part philosophy, part operational and I think it is a hell of a great philosophy. We don't have a better kind of philosophy right now. (IGO 4)

The Advantages of Vision Zero

It is evident that many of the senior experts interviewed for this study acknowledge both the growing role of Vision Zero and also the challenges of introducing new ideas on a global scale. So what are the advantages of Vision Zero, or rather what are the features that make this policy diffuse all over the world? The study identifies at least five "attractive" features.

First of all, the zero approach is presenting something new and unusual, something inspirational going beyond what anyone thought would be possible. Once you start talking about zero, many of the experts argue that there is really no way back. This ethically based argument has, for instance, also been seen in campaigns for safe system approaches.

Second, it provides a whole comprehensive policy program, which makes it a more holistic and systematic approach. It involves all kinds of actors and organizations. Related to this is the notion of shared responsibility but also that the responsibility ultimately falls back on the system designer.

Third, the way Sweden managed to lower its number of deaths and serious injuries is seen as a great inspiration.

> . . .we can build on your experiences and see how safe system has been implemented in practice, what it means. So it starts to become something tangible, that you can observe, that you describe. . . (IGO 3)

But the inspiration also comes from the "story" of Sweden itself and how Vision Zero fits into the political and cultural dimension.

> I think Vision Zero has been the most marketable [. . .] in terms of having ambitious targets you know it is the Swedish model [. . .] it is not just the story of what Vision Zero is, it is a political story and how Sweden came to accept certain interventions such as the 2+1 roads [. . .] So I think the sort of cultural aspects of Vision Zero are very valuable. . . (IGO 4)

The fourth aspect pointed out as a positive feature is that Vision Zero is a long-term strategy and not a short-term slogan (even though it is a catchy phrase). This means that you are getting a full policy program but that you have to be patient and persistent. Therefore, you also need political support.

> Part of that dynamic is that is, I think it always makes you look forward. You always sort of think well what is coming next. What is the technology that I could use and you will always face new bottle-necks or new problems that come up on the horizon. (NGO 9)

The fifth view of Vision Zero is that it is perceived as based on facts, data, and science. This concerns both the way Sweden works with management by objectives based on a continuous data collection and traffic crash data.

The Challenges of Vision Zero

On the other hand, the respondents also point to a number of challenges concerning Vision Zero and its implementation in relation to the positive aspects mentioned above. First of all, the zero approach could be regarded as an unrealistic target and also naïve. This pertains in particular to a criticism that Vision Zero is a policy for high-income countries and is more challenging to implement in low- and middle-income countries. And it is at the same time in that context that improvement is mostly needed.

> I think the countries in our region, they are not there yet because we are so far from zero so it is very helpful to have this at the horizon saying that no loss of human lives is acceptable for you know in this area but at this point I think if we could just cut them by half, the road safety accidents in our region, that would have been a tremendous progress. That being said, I think, well I know that the idea of vision zero is very useful in a sense that it shows how road safety is something that can be overcome. (IGO 9)

Sweden and several other countries using a Vision Zero approach have seen considerable improvement over the years as we have discussed, but the respondents also point to the uniqueness of these countries. They are all wealthy countries with an opportunity to invest, not only in monetary terms but also in ethics. Not all countries have democratic regimes, and many face other problems.

> ...the usual argument is that Sweden is very wealthy and it's a small country when it comes to population and it's manageable, and there is a lot of law-abiding citizens and the issue of ethics, and not economics, is something that goes well with the Swedes, okay, part of your psyche, or part of your fabric, so the issue of how replicable the Safe System Approach is, not only for places in Europe, you know, Germany or Poland or Russia, but to Congo, or to South Africa, okay. This is when all of this, it breaks down. (IGO 1)

We have already concluded in an earlier section that although Vision Zero presents a full policy program, it is still difficult to understand. It is also complicated to identify what is part of a system. Therefore, there might be countries saying that they implement Vision Zero but they do not grasp the approach to the full.

> I think that there are some very good elements in the Safe System Approach, but the issue, you know, the evidence is that nobody else is doing it, despite the fact that many countries are actually saying that they are doing it. . . (IGO 1)

Finally, and in relation to the transparency of Vision Zero and the ability to understand its features, the approach is by some respondents seen as too academic and too theoretical but also that it takes energy and resources to translate the vision so that it both fits and can be accepted in all kinds of contexts. Some countries have less time to spend on being patient and wait for the long-term results and are more eager to find policies that can be implemented right away leading to positive short-term effects.

> I think the safe system and all these things are connected and we are definitely supporting the ideas, but I still think that our role is really the implementation and I think translating Vision Zero and the safe systems down to that, it would require some work that might, should might be better spent on implementation. (NGO 8)

Analysis

Looking at the development of global road safety policies, there is no doubt that the safe system approach and Vision Zero play a significant role, the very least as an inspiration. It is undoubtedly a new, inspiring, and for some actors a quite provocative way of thinking. Looking at the selection of the policy documents, there seems to be more or less a consensus that safe system approach is the way forward in road safety policy. The interviews, on the other hand, show that policy implementation is not that simple, nor is the complete change in safety culture that Vision Zero requires in many contexts. This section returns to the theoretical perspectives on diffusion presented earlier and presents a short analysis of the role of Vision Zero in global road safety policymaking.

What Vision Zero Is Diffusing?

The first question scrutinized in this analysis is if we are observing the diffusion of a coherent road safety policy program or philosophy or if there are several alternative interpretations. In other words *what* is being diffused? Looking at the various documents from intergovernmental organizations, there seem to be a consensus on what a Vision Zero is. The explanation, in some cases, is that the texts have been produced in close cooperation with Swedish authorities or Swedish experts, but the coherence is evident even in other documents. The conclusion is that there is an awareness of what Vision Zero is on a global policymaking scale. When looking at materials from NGOs and the arguments raised in the interviews, the understanding of the content of Vision Zero and safe system approaches is more varied. Some organizations are strong advocates for a safe system approach, but they are simultaneously writing about campaigns directed at educating the driver. These perspectives do not go well together. The respondents in this study point to complexities in understanding safe system approaches and that there are cases where Vision Zero in particular has been used as a catchy slogan but where the content is more related to a traditional road safety philosophy.

Why Is Vision Zero Diffusing?

The groundbreaking report from the WHO in 2004 was one of the first global road safety documents grounded in solid data. Together with other similar reports and documents, it helped identifying deaths in the road traffic system as one of the major causes of deaths, particularly in low- and middle-income countries. The fact that the WHO is the lead agency also framed road safety as a public health issue. All these development prompted intergovernmental organizations to adopt new ways of working with road safety, as we have discussed earlier in the chapter, and it opened a window of opportunity (Kingdon 1984) for Vision Zero and other safe system approaches to offer a new kind of policy but also a completely new way to assess the problem. Another explanation is related to the presentation in the last section on the "attractiveness" of Vision Zero. It is generally regarded as a new interesting policy program, which has also been tested successfully in various contexts.

Who Diffuses Vision Zero?

When analyzing the interview material, it becomes quite clear that the voices promoting the Vision Zero approach belong to a global or transnational advocacy network. It is not a formal network, but many of the experts in this study know each other or know of each other. Many of them share the same belief system and form a sort of epistemic community, where their philosophical point of departure is the safe system approach and particularly Vision Zero as the leading policy. Therefore, it has been important to broaden the number of respondents to make sure that alternative voices are included. Using solely the snowballing method of selection would have led to a more one-sided result. This network consists of experts from NGOs, from intergovernmental organizations, from research, and from national governments, and using Held's categorization, this network has helped pushing Vision Zero and safe system approaches onto the global road safety agenda. It has been a process where the NGOs have been particularly successful in forming alliances with key intergovernmental organizations to make sure that certain issues of road safety are emphasized. These actors can also be described as policy entrepreneurs (Mintrom and Norman 2009) using several arenas to promote their ideas.

How Is Vision Zero Diffusing?

The policy entrepreneurs are, in this case, actors deliberately diffusing Vision Zero as a policy program, but there are also more organic processes of policy learning and policy translation. When a country is making progress in a complicated policy area with many actors involved and with lives on the line, other countries naturally tend to look at this particular success story asking what can be learned from that process. If a country or city attempt to copy a policy, it is rarely without complications. Instead, you often find that there is a translation process to adapt the policy to the context. Vision Zero is definitely diffusing in that way as we speak, but as this chapter is focusing on the global level, we can see how Vision Zero is presented to a wide global audience in the global policy documents, and the inclusion of the vision into these policy documents is part of the diffusion process. Vision Zero is also diffused at global conferences and seminars of different kinds. Representatives from countries that have adopted Vision Zero or other safe system approaches are often invited to share their knowledge in other contexts.

Conclusions and Discussion

We can conclude that Vision Zero plays a significant role in global road safety policies and that the introduction of the vision has led to a shift in the work mode from a traditional behavioral approach towards a system's approach. But in order to conclude that shift, there are several steps to be taken. Although it is evident that Vision Zero has inspired many intergovernmental organizations as well as NGOs, there is still an ongoing process of implementing this approach in many different contexts. Evaluations of these attempts will determine whether Vision Zero is a vision for everyone or has to be transformed in order to fit various kinds of contexts. This is especially challenging in relation to low- and middle-income countries.

The material analyzed in this study shows that the key components of Vision Zero remain intact in the writings from the intergovernmental organizations. Interpretations and transformations take place on other arenas and other levels.

Vision Zero is seen as a promising approach for many reasons, and one obvious factor is the success of the policy in many countries. It is being regarded as best practice which is exemplified, for instance, in the chapter in this handbook. Another reason is that it can be interpreted as a policy program or package ready to be used, and a third is that the ethical core is viewed by many as the only way forward.

There are challenges when introducing new ideas onto the agenda, and one of those is that certain models or programs are viewed as miracle methods and are introduced too quickly and/or too disorganized. It is therefore essential to see this process going on in global road safety policy with a little bit of caution and as a process of continuous development and transformation. It is also important not to abandon what might be successful processes or policies already in place. The old is not necessarily all bad, and the new is not necessarily all good.

It is important to recognize that there is a huge difference concerning the point of departure for high-income countries and for low- and middle-income countries. Therefore, it is crucial to add a question to the analysis of the diffusion process – where is the diffusion taking place? The difference in preconditions is also relevant in relation to the direction in which countries can go.

> Countries with a mature road safety approach [. . .] are expected to move in the direction of a Safe System approach. [. . .] Many low- and middle-income countries (LMIC) face a different starting point. Reports indicate that there is a lack of almost everything: a lack of leadership, a lack of political priority, a lack of funding, a lack of expertise, etc. [. . .] . . .although LMIC could learn from HIC, they cannot simply copy successful HIC strategies. Local circumstances differ. . . [. . .] LMIC should invest in local capacity building to carry out these tasks and create effective road safety communities that involves all players. . . (Wegman 2017)

Although there are challenges, several interesting cases can be observed in low- and middle-income countries and not only related to the adoption of new road safety plans resting on safe system approaches but also how to work with the SDGs in an integrative way. The city of Bogotá in Colombia is one example of a city working with integrative approaches. Perhaps it is in these types of cases where we can find new approaches and methods in order to take the next step in road safety policymaking.

This chapter has focused on the diffusion of Vision Zero within the area of global road safety concluding that Vision Zero plays a role in the consolidation and development of road safety as a global policy issue. One interesting question that arises is if the establishment and consolidation process of road safety as a global policy area differs from other areas entering the global policy family. Every area is of course unique, containing an intricate web of actors, policy preferences, and problems (c.f. the issue of HIV/AIDS in Harman 2010), but we have also witnessed a more general growth in bilateral, multilateral, and transnational processes of collective policymaking since World War II. A comparison between global road safety policymaking and other policy areas would be an interesting and relevant continuation of this project, and in the area of global health, there is an interesting distinction to be made between the global policy development of communicable and noncommunicable diseases. Communicable diseases are often viewed as more acutely urgent, as we have seen in the case of COVID-19, and can therefore enter a global policy phase quicker than noncommunicable diseases that tend to linger longer on a national level or possibly regional level. One significant aspect of global governance today as compared to decades ago is that the international system now includes institutions to deal with both crisis situations and day-to-day management of global problems. In any case, it is fair to say that any future comparisons between global agenda-setting processes would have to include aspects such as urgency, problem framing, financial support for data collection, and the establishment of institutions.

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Part III

Management and Leadership for Vision Zero

ISO 39001 Road Traffic Safety Management System, Performance Recording, and Reporting

22

Anders Lie and Claes Tingvall

Contents

Abstract

Traffic safety has shifted from being a solely individual issue to also include responsibilities from those organizations that influences the use and quality of the road transport system. This chapter explores the background of this and presents how ISO 39001 has been introduced as a tool to manage traffic safety in organisations. Further it is setting organizational road traffic safety into context of the 3rd Global Ministerial Conference on Road Safety, the Stockholm declaration and the decision of the United Nations general Assembly. The chapter also discusses how a value chain analysis can help organisations in understanding and tackling their road safety footprint and part of their sustainability reporting.

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Vision Zero · Management systems · Traffic safety performance · Traffic safety footprint

Background

The development of traffic safety has in recent decades gradually moved from an individual road user approach to a more systems and stakeholder perspective (WHO 2004). One of the major steps was the strategies and classifications developed by Haddon (1970; WHO 2004) pointing at a more widespread set of countermeasures, many times towards organizations, technologies, and management. With the introduction of Vision Zero (Tingvall and Lie 2017; Lindberg and Håkansson 2017) in the mid-1990s, this development became even more pronounced. The "system designers and providers" were given a key role to develop and take responsibility for the provision of safety for the citizens. The methods they are supposed to use must be evidence-based and without compromising safety in return for other benefits. This was and still is a different and radical policy in comparison with earlier policies (Hauer 2016; Swedish Transport Administration 2019).

The gradually more pronounced importance of how organizations improve the safety for citizens, employed, and customers is becoming more explicit with the introduction of 2030 Agenda (or the United Nations Strategic Development Goals). Traffic safety is a global goal since 2015, and in 2020 the United Nations General Assembly (United Nations 2020) expressed that organizations, both public and private, should improve safety by "applying safe system principles to their entire value chain." This is no doubt an expression emphasizing that organizations should apply a systematic approach to road traffic safety including employed, third parties, and customers in their attempt to eliminate road traffic deaths and serious injuries (in crashes). In doing so, the management standard ISO 39001 (ISO 2012) could be a valuable tool for the organization seeking to base its actions on sound principles and evidence-based solutions.

As part of the preparations for the 3rd Global Ministerial Conference on Road Safety, held in Stockholm in February 2020, the Academic Expert Group was formed by the Swedish Transport Administration. The "Academic Expert Group" recommendations (Swedish Transport Administration 2019) leading up to the Stockholm Declaration (2019) and the United Nations General Assembly Resolution (United Nations 2020) in 2020 stressed the importance of sustainability reporting for organizations that wish or must demonstrate progress regarding road traffic safety. Such sustainability reporting should preferably be based on known and standardized expressions of road safety goals, targets, performance, and results.

A key component in Vision Zero is the concept of shared responsibility. Every organization generating or having activities in the road transport system has an obligation to care for road traffic safety. As one cannot expect all of these organizations to have deep or even fundamental knowledge in the field of road traffic safety, support tools are essential. ISO 39001, “Road traffic safety (RTS) management systems,” is such a tool (ISO 2012).

The International Organization for Standardization (ISO) has extensive experience in developing international standards. In 2008, Sweden initiated the work to develop a management system standard for road safety, what came to be ISO 39001. The development work was coordinated by the Swedish Institute for Standards, and the Swedish Road Administration sponsored with a chairperson and extensive work. The first version of ISO 39001 was released in 2012.

At the time the ISO 9000 family for quality management standards and the ISO 14000 family for environmental management standards were widely used. The road traffic system standard for road safety was developed in the same structure as these at the time existing standards. The approach was strengthened as ISO during the process developed harmonized guidelines for all ISO management system standards. Today management standards from ISO have significant similarities making the use of more than one standard in any organization more straightforward.

Today in the year 2020 ISO 39001 is to some degree used even if it hasn’t been picked up to the same extent as the ISO management system standards for quality or environmental management.

Below some of the key components of ISO 39001 are described. They are chosen to have high relevance to Vision Zero. The complete standard can be acquired from ISO.

In the following we use organization to indicate any form of company, public or private, or any official body on national, regional, or local. ISO 39001 is usable for all of these.

ISO 39001 is a management system standard, the basis for the development of a management system. Like any management system standard, the aim of ISO 39001 is to set up a management system containing requirements that are documented and can be controlled. In a certification process, the organization should be able to confirm that it is living up to the demands in the standard and the management system they have developed. The certification can be done internally, or, in the most ambitious cases, the certification is performed by an accredited third party certification body.

The general structure follows the high-level structure of ISO management system standards starting with scope and terms/definitions. That is followed by sections on the context of the organization, leadership, planning, support, operations, performance evaluation, and finally continual improvements.

Terms and Definitions

ISO 39001 uses some essential terms and definitions that emphasize the close links to Vision Zero. The most important definition aspect is how road traffic safety is defined.

In the management standard, road traffic safety is defined as "*conditions and factors related to road traffic crashes and other road traffic incidents that have an impact on, or have the potential to have an impact on death or serious injury of road users*."

Serious injury is defined as "i*njury with a long term health impact or non-minor harm caused to a person's body or its functions arising from a road traffic crash*."

These definitions point out a very clear direction in line with Vision Zero; it is the negative outcome in the shape of death or long-term health impact that road safety should focus on. Minor harm or harmless incidents have second priority.

It is also of importance that road users are defined as "*any person on the road*." Using this definition, organizations using ISO 39001 must take responsibility not only for their own staff and personnel but also for potential opponents in traffic that may be endangered by the operations of the organization. This responsibility includes the demand to follow up the effects on third party road users influenced by the operations of the organization.

Context of the Organization

There are not many organizations or companies that completely lack interaction with the road transport system. On the contrary, most organizations have many interfaces to road traffic safety. The understanding of these interfaces and interactions is essential when focusing road safety-related actions. Few organizations have a good understanding of their influence on road traffic safety in their entire value chain. This is why ISO 39001 demands a mapping of activities and actions the organization have in relation to the road transport system. It is also demanding a mapping of needs and exceptions on the organization that other actors may have. This includes the legal and other requirements related to road traffic safety to which the organization subscribes.

The context of the organizations should form the basis for the ways to focus traffic safety actions and how to define and measure the most traffic safety relevant progresses.

For all organizations it is essential to map how road traffic safety interacts with their complete value chain. It isn't only about the organizations' own use of the transport system; it is also about incoming and outgoing transports of goods and potentially passengers. Furthermore the commuting of personnel is an important element.

Understanding the extent of interaction with the road transport system is essential for all organizations that want to improve their performance in the field of road safety.

Leadership and Commitment

ISO 39001 is demanding a management system in which the top management (defined as: *person or group of people who directs and controls an organization at the highest level*) owns the highest responsibility. However, if the organization decides that the scope of the management system covers only a part of an organization, then the top management refers to those who direct and control that part of the organization.

There are high demands on the road traffic safety management system to be compatible with other strategies and actions in the organization. Further it should clearly state that elimination of death and serious injury in road traffic crashes is the long-term road traffic safety objective. Another fundamental basis is that the organization should develop strategic actions and select specific courses of action, building on the best available information.

It is the top management's responsibility that the road traffic safety actions have high priority and that these actions are result-oriented.

One important role of the top management is to develop and manage a road safety policy for the organization. The policy should be appropriate to the purpose of the organization, include a framework for setting road traffic safety objectives and targets, further include commitment to satisfy applicable road safety-related requirements, and finally include a commitment to continual improvement of the road traffic safety management system.

Planning

ISO 39001, as most management system standards, are based on a plan-do-check-act procedure. The planning should be based on the understanding of the organization's role in the road transport system and in line with the policy decided by the top management.

The organization shall follow a process that reviews its current road traffic safety performance, determines the risks and opportunities, and selects performance factors.

The road traffic safety performance factors are essential to ISO 39001. The safety performance factors are a set of predefined areas that are relevant to most organizations. It is not an all-inclusive list, but the purpose is to guide organizations into the most important factors for road safety. On these factors targets should be based and performance measured.

There are three types of performance factors in ISO 39001. The first kind is related to the exposure of the organization to road safety-related risks. They can be related to exposure factors such as travelled distance and road traffic volume, including vehicle and road user type, whether influenced or not directly influenced by the organization.

The second type of performance factors is outcome-oriented. They are called final safety outcome factors and relate to real outcome such as the number of deaths and serious injuries occurring in the complete sphere of influence of the organization.

As most organizations will have no or very few actual fatalities or even serious injuries, there are challenges in working only directly towards these final outcomes. ISO 39001 is therefore also containing "intermediate safety performance factors." They are based on well-known and commonly used factors related to road traffic safety (Gitelman et al. 2014).

The concept behind the safety performance factors is that they should contain a known link between the factor and safety performance. By working towards improvements in the performance in the areas of the factors, real performance benefits will be generated. As the safety performance indicators are closer to operations than the final outcome, action can be better focused and followed.

ISO 39001 is presenting a set of predefined safety performance factors that organizations should choose from when developing their safety management system. Not all are relevant for all organizations, and there are organizations that potentially have a need to develop other safety performance factors, guided to their specific needs. The management system standard contains this possibility; however, the potential additional safety performance factors must be based on "best available informations" that is proven to be efficient in achieving the final outcome goals (fatalities and serious injuries).

The road safety management system standard ISO 39001 is using this wording to describe the intermediate safety outcome factors: "*these safety outcome factors are related to the safe planning, design and use of the road network and of the products and services within it, the conditions for entry and exit of those products, services and users, as well as the recovery and rehabilitation of road traffic crash victims*."

The following factors are presented:

- Road design and safe speed
- Use of appropriate roads
- Use of personal safety equipment (i.e., seatbelts, child restraints, bicycle helmets, and motorcycle helmets)
- Safe driving speed
- Fitness of drivers (fatigue, distraction, alcohol, and drugs)
- Safe journey planning
- Safe vehicles (occupant protection, protection of other road users, road traffic crash avoidance and mitigation, roadworthiness, vehicle load capacity, and securing of loads)
- Appropriate authorization to drive/ride the vehicle
- Removal of unfit vehicles and drivers/riders from the road network
- Post-crash response and first aid, emergency preparedness, and post-crash recovery and rehabilitation

In the management system standard, the intermediate safety performance factors are described at a relatively high level of abstraction. Some of them have to be further developed by the organization using the standard. One typical example is vehicle safety. In Europe the most relevant way to measure that is by using Euro NCAP stars or points. However, that Europe-centered specific rating system has low or no coverage or validity in other parts of the world.

For any organization the selection of safety performance factors, and the specific definition used and the way to measure status and progress, is very important and should be explained in the management system.

There are substantial differences in how different safety performance factors can be influenced, measured, monitored, and reported. Using seatbelt use as an example, activities can range from policy decisions, via surveillance/measurements, to the application of seatbelt reminders or even ignition interlocks. Today's technologies can be extremely helpful in both monitoring and supporting proper behavior.

The safety performance factors, exposure-oriented, outcome-oriented, or indicative, are used to determine, monitor, and measure road traffic safety objectives and targets. There should be clarity in what should be done, what resources would be required, who in the organization holds responsibility, when will results be available, and how the results are to be evaluated.

Achieving results demands not only focus but also resources, competence, awareness in the full organization, and its value chain and communication, internally and externally.

ISO 39001 is demanding relevant documentation of the traffic safety management system being developed and used. However, the documentation demands should reflect the size of the organization and its type of activities, processes, products and services, the complexity of processes and their interactions, and the competence of persons in the organization.

Operations

The organization is expected to deliver towards the goals set up in the planning process – all in line with management system standards. However, ISO 39001 includes a demand concerning emergency preparedness and response when fatalities or serious injury happens.

Evaluating Performance

A key component in any management system is to evaluate performance in relation to the specified goals. In ISO 39001 the demand is worded as: "*The organization shall establish, implement and maintain a process to periodically evaluate compliance with applicable legal road traffic safety requirements and other road traffic safety requirements to which the organization subscribes*." It is essential to note the importance of legal requirements.

One additional way to evaluate performance and initiate further development of the management system is to investigate and understand relevant crashes and road traffic incidents. As this could be very effort-consuming, ISO 39001 is only demanding such investigation of "*road traffic crashes and other incidents in which it is involved that lead, or have the potential to lead, to death and serious injuries of road users*."

The organization should make audits to verify that it is conforming its own requirements and demands with ISO 39001. The audit can be internal or external. The results should be reported to relevant management levels.

Management Review

It is the top management that in the end holds responsibility for the delivery of improved road traffic safety. In the last phase of the plan-do-check-act cycle, they should consider if the traffic safety performance is in line with the plans and if needed take corrective action. This is done in the management review of management standards. The review should according to ISO 39001 contain:

- The status of actions from previous management reviews
- Changes in external and internal issues that are relevant to the road traffic safety management system
- Information on the road traffic safety performance, including trends in nonconformities and corrective actions; monitoring; measurement analysis and evaluation of results, including the extent to which RTS objectives and road traffic safety targets have been met; and audit results and evaluations of compliance with legal and other requirements to which the organization subscribes
- Opportunities for continual improvement, including consideration of new technologies
- Relevant communication(s) from interested parties, including complaints
- Road traffic crash and other road traffic incident investigation

The management review should be the basis for improvements, understanding of nonconformities, and corrective action. It is also the basis for continual improvements.

Conclusion

ISO 39001 is available and has been tested and used on the market around the world. It is structured in a way that makes parallel use with ISO 9000 and ISO 14000 straightforward. There are accredited certification bodies that can certify traffic safety management systems to ISO 39001. In short, the system is available and used in organizations with traffic safety ambitions.

One potentially significant limitation of ISO 39001 is that the ambition level is defined by the organization itself. It is fully possible to work in a systematic way but with low ambition. The actual ambition level is not checked in a certification process. An organization can be certified but still have poor performance. This is important to bear in mind when/if ISO 39001 would be used on the market to further focus road traffic safety.

Discussion

The need for a systematic approach to road safety within organizations is growing, and in particular large corporations are expected to improve and report on their ambitions, performance, and results of their efforts. This concerns the entire value chains from sourcing for raw materials to the end user experience. The need for standardized universal road traffic safety management systems is therefore growing.

The United Nations General Assembly Resolution 74/86 from 2020 express that: "*Calls upon* businesses and industries of all sizes and sectors to contribute to the attainment of the road safety-related Sustainable Development Goals, including by applying safe system principles to their entire value chain...." To apply "safe system principles" is simply setting a zero death and serious injury target for the organization and its value chain.

Using ISO 39001 to get to grips with the road traffic safety impact and progress of an organization can lead to a systematic approach to the problem not only for the persons directly employed by the organization but also for those contracted and otherwise dependent to the organization's processes and products. This is a radical step in the history of traffic safety and a strong complement to the traditional line of responsibility from the state/regulator to the individual driver of a vehicle.

The approach to traffic safety as defined by ISO 39001 is that the top management of the organization is responsible for road traffic safety performance and the way transports are conducted by the organization within their value chain. While the expression "value chain" is not used in ISO 39001, it is a relevant way to encapsulate what is the purpose of the wording in ISO 39001 like "context of the organisation." A basic ISO 39001 requirement is that road rules are not violated. Such an expansion of the influence of an organization goes far beyond how road rules are normally defined and enforced. In general, they are directed towards the individual road user, even if the road user is an employed driver driving for duty at the time for a legal offense.

Road traffic safety is only to a limited degree considered by occupational health and safety regulation. If a crash with personal injuries to a professional driver normally would be seen as a matter for the occupational and health legislation, an injury to a third party would not. And an equivalent event for a contracted organization would be even less relevant in this respect. ISO 39001 as well as the way "value chains" are defined would on the other hand include all such events as relevant for the organization wishing to adopt the principles of ISO 39001. Furthermore, it is even a requirement for the organization to monitor and correct non-compliance of road rules occurring within the value chain for the organization. This is a true and radical difference to the society's view of legal traffic-related offenses and who should be fined or otherwise subject to a legal or administrative intervention.

It is also a requirement within ISO 39001 to include and consider the traffic safety effects related to the customers of the organization, if relevant. Vehicle production and transports of goods and passengers and other products are subject to the responsibility of an organization. The definition of a value chain has the same basic inclusion criterion. This is a real challenge for a vehicle manufacturer that would have to keep track of the "safety footprint" of their vehicle production in terms of fatalities and serious injuries to their customers and third parties (Rizzi et al. 2019). The same would apply to all kinds of vehicle production like cars, trucks, buses, motorcycles, and bicycles. Statistical information based on police reports or hospital records would be complicated to use for collecting information classified by value chain. In most cases where someone has been killed or seriously injured, the value chain classification would fall into several value chains. This is an area where much efforts should be spent in order to support the introduction of ISO 39001 and other road traffic safety management systems.

One of the most striking characteristics of modern quality management is that the delivering of products and services also includes control of defects and non-compliance (and nonconformity). Sustainability reporting also includes reporting of unwanted events and negative impacts on the society, environment, etc. and also includes how such impacts will be managed and eliminated in the future. This is no doubt very different from most legal frameworks within the road transport systems where a fault, offense, or non-compliance are subject to the society's ability to show that the offense has occurred and that someone can be judged guilty in relation to regulation. A traffic safety-related offense seen through ISO 39001 is a matter for the top management and must be handled as a non-compliance, and the organization must act to eliminate further such offenses.

The high demands and complexity of ISO 39001 might detract large organizations to comply and certify the entire organization and its value chain to ISO 39001. The step for many organizations to move from the current viewpoint that the safety of transports for an organization is mainly an issue for the individual driver to that it is the organization's duty to secure that all transports are safe is too big. And the availability of data will be quite problematic for a large organization to gather in a short timeframe.

Taking the approach of ISO 39001 in steps might therefore be a successful way forward. The FIA (Federation Internationale de l'Automobile) has presented a "Road Safety Index" (FIA 2020) aimed at valuing and rating an organization's value chain in relation to traffic safety. In this valuation, ISO 39001 is the main building block together with the definitions of workforce, etc., from the GRI (Global Reporting Initiative). The valuation divides the performance of an organization into "commitment, footprint, plans, monitoring, and safety culture." The headings represent different parts of ISO 39001, and each part builds on the former part, so that the last step, safety culture, in reality means that the organization operates under the entire requirements of ISO 39001. In short, the FIA Road Safety Index is a stepwise ISO 39001, not only encapsulating the data-driven parts of the management standard but also valuing the overarching safety culture of an organization. This is an important characteristic for any safety management approach.

The main purpose of the FIA Road Safety Index is to standardize road safety sustainability reporting for large organizations in relation to the financial market. By introducing a standardized benchmark and ranking system, large corporations can strive for progress to show both the financial market and the wider society. This is a double function of the FIA Road Safety Index. Building on the definitions, content, and requirements of ISO 39001 is an important characteristic and helps organizations to apply a systematic approach to traffic safety, well in line with other management systems and principles. The most complex issue seems for both value chain safety footprint and the application of ISO 39001 to an organization to define the precise range of a value chain. How many layers of suppliers and contracted parties that should be included in the value chain and "interested parties" would be a matter for the organization to define. No doubt those that are directly influenced through contracts with the organization are relevant, even if their main service or product delivered to the organization is not a mobility service, logistic task, or a vehicle. It could, as an example, be the transport of a component or the travel of a maintenance staff to a facility controlled by the organization. How many tiers this should cover to be a relevant inclusion in a value chain and seen as an interested party might be a matter of common practice rather than defined in a systematic way. In any case, there needs to be a clarification.

The possibilities to use technology for monitoring and quality assurance of vehicles, drivers, and driving were limited at the time of the development of ISO 39001. This has rapidly changed, and to have vehicles connected in real time is almost unlimited today, across the globe. It is also possible to control vehicles, for example, their speed, geographically and also depending on time, etc. This kind of geofencing is a step forward in quality assurance and would from a management system perspective mean that a certain aspect of performance is guaranteed. For an organization, this would be quite attractive as less resources can be spent on monitoring and detection of non-compliance and nonconformity as well as corrective actions. Speed, fitness to drive, non-aggressive driving styles, etc. could all be controlled and seen to be quality assured.

Vehicle technology is also developed rapidly, at least for passenger cars. As there does not seem to be a matter of high costs for mass produced cars to have advanced driving assistance systems (ADAS), there is no obvious reasons not to have the highest standards prescribed within an organization, not even for low- and middle-income countries. What seems to be problematic is that car manufacturers sometimes do not offer vehicles they produce with the highest standard to all parts of the world. Furthermore, trucks and in particular buses do not have the latest standard of safety equipment available. This is something that could be stimulated by more organizations using ISO 39001. In any case, there are no legitimate expressions that accept a lower safety standard of vehicles and associated products or services in different parts of the world.

A systematic approach to road safety for organizations would also be relevant for procurement, in particular public procurement. While there does not seem to be a widespread use of safety requirements for public procurement, it is one of the nine recommendations of the Expert Group for the 3rd Global Ministerial Conference on Road Safety to do so. It is estimated that 10–20% of the global GDP is related to public procurement, and this could form a massive economic incentive for improving road safety. The principles of ISO 39001 would fit well with the general concept that it is the provider of a product or service that control the quality and that the transport of the product and service is included in this quality requirement. This would mean that in public procurement, it is an obligation to comply with road rules without any specific clause or contract specifying what road rules that must be followed.

In general terms, the gains in applying a systematic approach to road safety, with evidence-based solutions and treatments to a fixed set of factors, are large and sustainable. The safety factors in ISO 39001 are shown to have a major impact on traffic safety (Krafft et al. 2007; Gitelman et al. 2014). With traffic safety policies more related to organizations, it is natural to seek for management systems and standards that are widely accepted. And with the 2020 United Nations General Assembly Resolution explicitly pointing towards the role and expectations on businesses and industries and their entire value chains, the need for standardized practices and reporting will grow. It seems also natural that when organizations through the financial sector will be asked to publish their safety footprint, there will be an increased demand for action.

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What the Car Industry Can Do: Volvo Cars 23

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Abstract

Motor vehicle manufacturers have a central and a very important role in reaching the target of zero fatalities and serious injuries in road traffic. Although the continuous development of safer products has made a significant contribution in reducing the number of casualties, the responsibility still remains profoundly with motor vehicle manufacturers in continuing the process of protecting car occupants and not harming other road users. However, the possible contributions do not end here. Sharing research data based on real-life traffic crashes and incident experiences, cooperating with other traffic safety stakeholders, and sharing real-time data on traffic information with authorities and other road users also have a role to play in reducing the number of road casualties. In addition to this, motor vehicle manufacturers will be able to contribute by assuming the corporate social responsibility in using safe transportation linked to producing vehicles, parts, and services and sharing the latest level of technology advancement with customers in countries without government mandates on safety.

It is important to stress that all these efforts need to have a global perspective. For the vehicle manufacturers, this implies that all the technical developments in motor vehicle safety, collaborating with governments and sharing knowledge on safety, must be performed and available also in parts of the world with a vehicle fleet of traditionally lower advancement levels.

In line with the efforts of reaching zero fatalities, Volvo Cars has defined its own Safety Vision. This states that no one is to be seriously injured or killed in a new Volvo vehicle.

The aim here is to share the view of Volvo Cars on the possible contributions and actions of motor vehicle manufacturers in the collaborative efforts of reaching towards zero fatalities and serious injuries within the road transportation sector.

Keywords

Overall safety strategy · Vision zero · New safety technologies · Future mobility · Autonomous vehicles

Introduction and Background

Traditionally, cars have, ever since the launch of the first volume selling motor vehicles in the 1920s, been designed, built, and used to fit a generic traffic situation using an infrastructure that has gradually been developed with the mind and purpose to fit and encompass all road users and only slowly adapted to manage an increased, denser, and more intense traffic situation. This infrastructure did not, however, develop in a way needed in order to keep up with all the challenges of modern traffic in terms of pace, density, and traffic mix which has resulted in a continuous increase in the number of traffic casualties.

In addition to this, car manufacturers have viewed themselves as providers of consumer products that primarily needed to meet the customers' expectations with respect to comfort, speed, styling, and economy. Besides meeting the government standards, safety was not a prioritized area of development and not considered to be a unique selling point in customers' buying decisions.

However, this has radically changed during the last 20–30 years. Car manufacturers have realized that they are part of a bigger picture and being part of a transportation and societal structure that is more than just putting cars on the road. This was, however, not only forced upon them but was also a realization that their products not only did a very important task of transporting people and goods for the benefit of the society and supporting the civilization that modern people have gotten to know and become adjusted to but also created major challenges when it comes to increasing traffic casualties, major health problems due to air pollutions and stress, congestions, and unhealthy and unpleasant local environments. This also became very obvious in the early 1970s when traffic casualties escalated up to a level that was totally unacceptable both from the perspective of the society and its citizens. At the same time, the first government safety standards were issued, both in the USA and in Europe. Well-known obvious failures of car designs with resulting catastrophic consequences and major headlines gave rise to the creation of consumer groups pushing for safety and major safety recalls for repairing the unsafe products. Gradually this created a new way of looking at road traffic safety in that it needs a holistic perspective and more involvement of all stakeholders, including governments, vehicle manufacturers, consumer groups, insurance companies, road authorities, and academia. At the same time, more focus on safety evolved from customers supported by comprehensive and objective consumer information. The information was provided by a number of actors such as governments, insurance institutes, academia, motorist organizations, and consumer organizations. This type of consumer ratings gradually grew in importance and is now extensively used in the advertising for sales of new motor vehicles and has proven to be a useful tool for customers in their car-buying decision-making.

The development of safer motor vehicles has made a steady progress during the last 30 years and has today reached an impressive level of performance of protecting occupants. However, although the vehicles offer an elevated level of safety, parts of this performance do depend on the proper usage and behavior with respect to proper positioning and seating positions, usage of restraints, loading, number of occupants, vehicle modifications, and avoiding violations such as driving while under influence, speeding, and other traffic misbehaviors.

The modern motor vehicles do act in many ways in making road traffic safe and protecting occupants and other road users. New technologies in the form of systems helping and supporting the driver's handling of the vehicles, navigation and information systems aiding drivers to navigate and stay comfortable and with less pressure, stability systems assisting drivers in handling conflict situations, lateral and longitudinal support of the driving, automatically acting systems that autonomously brake or keep a safe distance to other vehicles, drowsiness and distraction alert systems, and drunk-driving interlock systems have been developed.

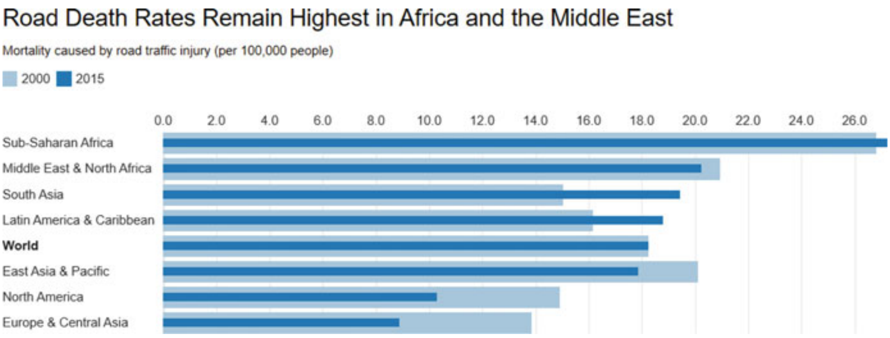

Fig. 1 Road deaths per 100,000 in 2000 and 2015 (World Bank 2015)

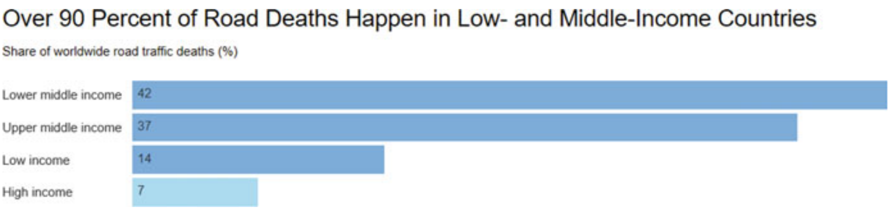

Fig. 2 Share of worldwide road traffic deaths (%) (World Bank 2015)

In parallel to the increased activity of manufacturers to improve motor vehicle safety there have been extensive activities and efforts by governments and policymakers to reduce the number of road casualties globally. The estimated present level of fatalities in the world today (2019) is around 1.3 million people. A large proportion of this occurs in the low- and middle-income countries, and a large number of these are unprotected road users. It is estimated that 90% of the fatalities occur in the middle- or low-income countries globally (World Bank 2015).

Among the governments or policymakers run efforts is the Swedish Vision Zero policy which has been the role model for many other government initiatives ever since it was adopted in 1997.

In parallel to the government run safety initiatives, there are a number of anticipated major shifts in the different ways of being mobile, e.g., mobility as a service and ride-sharing. These will use different variations of more professional drivers, and ultimately there will be self-driven vehicles having an elevated level of safe driving incorporated into the core of the vehicles and are expected almost to eliminate the human error factor in the cause of traffic incidents and accidents.

In conclusion, many initiatives, both by governments and policymakers, are on-going or planned, the motor vehicle manufacturers are making impressive progress with improving the safety performance of their products, and significant progress has been made with reshaping the infrastructure in many parts of the world. The potential for this to be distributed globally and having an outcome closer to the Vision Zero goal is significant and encouraging.

Traffic Safety Improvements: Past and Present

For the first decades after the beginning of the era of producing vehicles for mass consumption, no significant progress was made towards improving motor vehicle safety. During this era, traffic casualties were considered to be part of the picture of road transportation and something that had to be accepted.

In the 1950s and 1960s, the car industry focused mainly on impressive car designs, engine sizes, and speed. The American style of extravagant fins and lots of chrome peaked late in the shift between the 1950s and 1960s, but still, the focus was on other things than road safety. However, the most significant safety innovation of all times, the three-point safety belt, was engineered during this era. It was first introduced in series production by Volvo in 1959. Volvo also waived its patent on this restraint, opening up for a mass introduction in passenger vehicles which was to enable a significant reduction in traffic casualties. Alas, both the customer acceptance and the penetration of this important innovation were amazingly slow. Also, governments were slow in mandating both to equip the vehicles with the restraint and to introduce occupant belt usage requirements. In some countries, mandating belt use in the front seats did not occur until the mid- to late 1980s, and mandating rear seat belt usage on a broader scale did not occur until a decade later. Mandating the equipment of three-point seat belts for all occupant positions is still not the case for all markets.

Early in the 1970s, with the traffic casualties reaching staggering numbers, governments, car manufacturers, and the general public started to realize that this was not a sustainable development. With increasing numbers and increasing speed performance of the vehicles, if drastic measures were not taken, the projections of casualties for the next decades were abominable and simply unacceptable.

As stated earlier, governments started both to establish agencies dedicated to traffic safety and to create the first set of safety standards in the late 1960s and early 1970s. The US federal safety agency National Highway Traffic Safety Administration (NHTSA) was established in 1970 and its first set of Federal Motor Vehicle Safety Standards (FMVSS) the same year. In 1966, before the creation of NHTSA, another federal agency National Traffic Safety Agency, under the leadership of its first administrator Dr. William Haddon Jr., pushed for a more scientifically driven approach for reducing traffic casualties. Dr. Haddon created the concept of the Haddon Matrix which is looking at all factors – human, vehicle, and environmental factors – and pre-crash, crash, and post-crash interventions as a systematic strategy for cutting the number of injuries and fatalities in traffic.

Realizing the potential in exploring the possibilities of new safety innovations, NHTSA initiated the first global biannual safety conference named ESV (Experimental Safety Vehicles) in 1971. (In 1994 the name was changed to Enhanced Safety of Vehicles.) The focus here was to display vehicle safety concepts aimed for a later implementation in series production of vehicles.

As described in previous chapters, by the first years in the new millennium, the number of traffic casualties in the high-income countries in the world had been drastically reduced. The concept of reaching for zero casualties in the transportation

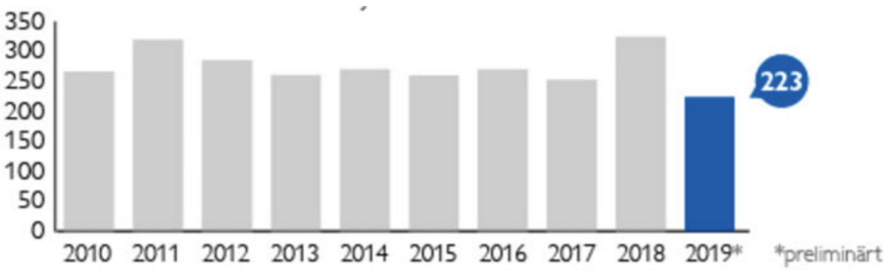

Fig. 3 Road fatalities in Sweden, 2010–2019 (National Swedish Road statistics, Transportstyrelsen (2020))

sector was first introduced in Sweden in the mid-1990s. In 1997, the Swedish Parliament adopted the Vision Zero strategic principles as the aim and target for the efforts for the further efforts on improving traffic safety in Sweden. The Vision Zero plan, adopted by the Parliament, stated targets of reduced traffic casualties that have gradually been updated with time, but the plan with its principles has been successful in drastically reducing the number of fatalities and serious injuries in Swedish traffic and has become a model for many other government initiatives ever since it was adopted.

When introduced, the Swedish Vision Zero strategy was considered as a paradigm shift in that it transferred the focus from reducing the number of accidents to reducing the number traffic casualties and that traffic efficiency should not be in the way of reducing traffic casualties.

The number of traffic deaths in Sweden peaked during the period 1965–1970 with approximately 1300 fatalities, which means around 16 fatalities per 100,000 inhabitants. In the 1970s and 1980s, significant efforts were made, both by the authorities, manufacturers, infrastructure owners, and other stakeholders, to reduce the number of fatalities by initiating more cooperation, collecting and sharing data, and applying more of a holistic approach. By mid-1990s, the annual fatalities had been lowered to around 500. At the same time, the number of vehicles and the number of vehicle kilometers travelled had increased significantly.

These results were, however, still neither acceptable nor satisfactory. In 1996, the Swedish Road Administration (Trafikverket) presented its proposal for a Vision Zero, i.e., a vision that is stating that nothing else than zero fatalities should be the long-term target. In 1997, the Swedish Parliament adopted the plan for Vision Zero, and in 1998, it adopted a target of half the maximum number of fatalities by 2007 as compared to 1997. This would result in a maximum number of fatalities of 270 per year. Although this number was not met for the first decade, a new target of 220 fatalities by 2020 was adopted by the Swedish Parliament in 2008. In 2019, the number of fatalities was 223, i.e., close to the target set in 2008 and a significant reduction. The next step would be another halving of the number which would mean around 110 fatalities per year by the year 2030.

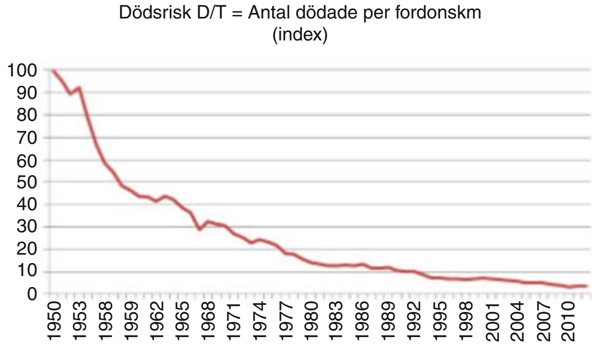

Fig. 4 Ratio of number of fatalities to vehicle km travelled in Sweden (Brude 2012)

The achievement of getting close to the target of halving the road deaths is remarkable considering that the economy is booming again, and the effects of the level of economy can clearly be seen when looking at the fatality numbers.

The numbers of fatalities dropped dramatically for the years 2009–2010 which coincided with the global economic problems.

When analyzing the ratio of fatalities to the vehicle kilometers travelled, the result shows a reduction of around 5% fatalities per year which is indeed significant and must, in many ways, be considered to be an undisputable advancement of traffic safety in Sweden.

The figure below shows the relationship between the road fatalities and the number of driven vehicle kilometers. Although the available statistics does not cover the last decade, the results clearly show the value of having strong visions for the strategic work on traffic safety.

The ratio between the number of fatalities and 100,000 inhabitants is around 2.6 which is one of the lowest worldwide.

Much of this effort was linked to infrastructure improvements. By shifting the focus from avoiding crashes to reducing personal injuries, infrastructure measures such as replacing crossings by roundabouts and installing median fences on highways and creating so-called 2 + 1 roads, i.e., roads where there is an interchange between having two or one lanes in each direction, have proven to be highly effective in reducing personal injuries.

In parallel to the infrastructure improvements, the performance of the vehicles' occupant safety was considerably improved. In Sweden, a vehicle fleet with a high level of occupant protection has had a significant impact on lowering the reducing the number of fatalities and serious injuries.

What is still causing a concern is that some types of fatal crashes, such as bicycle and motorcycle crashes, do not show the same trend of dropping in numbers.

In addition to the Swedish Vision Zero, there are a number of initiatives to reduce the number of fatalities globally. Among those is the UN Decade of Action for Road Safety 2011–2020 which is adopting a global perspective and inviting all stakeholders into these efforts. Although the number of fatalities continue to rise globally, it can be assumed that the effects of these initiatives will make a clear footprint in the years to come.

After the peak of the number of traffic casualties in the high-income countries worldwide in the 1970s and 1980s, this has considerably and steadily declined, due to various measures, during the last decades. However, the global number of traffic fatalities and the number of injuries have steadily risen and are by 2019 estimated to be around 1.3 million fatalities and 50 million serious injuries.

So, in spite of the considerable efforts made by governments, policymakers, and vehicle manufacturers, the staggering levels of traffic casualties globally are continuing to rise. There are also other factors preventing a more successful reduction of casualties. One important factor is the status of the global economy which influences the travel distances (vehicle km or vehicle miles travelled, vkmt or vmt) which clearly influence the number of road casualties.

Obviously, ***all this is unacceptable***.

Swedish Vision Zero from an Industry Perspective

Volvo Cars believes that the Swedish Vision Zero is one of the most profound groundbreaking principles for adopting a human approach to a sector where earlier intolerable levels of casualties and human suffering were accepted more or less as a fact and almost as the cost we had to accept to keep up the levels of transportation for a modern society.

By basing the Vision on the criteria based on human tolerances, i.e., that small mistakes should not lead to serious consequences and that all stakeholders must be involved in the process of creating a safe road environment, this creates an earlier unforeseen possibility to come to terms with the unacceptable levels of human suffering.

The approach of the Swedish Vision Zero has been one of the guiding principles for the company when setting the goals for the Volvo Cars Safety Strategy.

Already when the company was founded in 1927, it was stated that, since cars are driven by people, the focus therefore must be safety. Setting the targets according to the human tolerances was therefore to be the guiding principle. This is also adopted in the Swedish Vision Zero strategy.

With establishment of the Swedish Vision Zero, this gave the company more support for its endeavors for pushing the limits of motor vehicle safety. It also gave more support within the company that the adopted long-term strategy was the correct one. Another outcome was that it also opened up for a more strategic cooperation with the Swedish government on the basis that by sharing a vision for zero fatalities and serious injuries, a foundation was established for joining forces towards reaching this goal. More about this cooperation will follow in a later chapter.

Using the Swedish Vision Zero as a role model, a number of countries have established their own Vision Zero targets. This includes many of the European countries, the European Commission, many of the states in the USA, and many other countries globally. This in turn gives the industry clearer guidance on the way forward and the principles for the role of the industry in their efforts for improving road safety.

Volvo Cars believes that the Swedish Vision Zero has established both a mind-set and the tools for enabling reaching the goal of zero deaths and serious injuries. This has proven to be invaluable and will be the best support for the future in removing the unacceptable consequences of an unsafely designed road system.

The Roles and Responsibilities of Car Manufacturers for Improving Traffic Safety

As discussed in the previous chapter, the major and primary responsibility of a motor vehicle manufacturer is to produce safe products, products that will protect occupants and vulnerable road users to a high level and to what is technically and economically feasible. The focus must always be to work towards real-life safety for occupants regardless of size, age, and gender. For in-vehicle occupants, the primary focus must be to optimize safety for those who are using the vehicle's restraints and are not violating any traffic rules and regulations, e.g., not speeding and not driving while under the influence and that are belted. However, to the extent possible, protection should be offered for all occupants if this does not impede the protection of other occupants. Strong encouragements and efforts should also be given to having occupants act in the proper manner. Seat belt reminders, alcohol detection and interlocks, and speed limiters are effective measures available that need to be offered to the car-buying customers.

However, the responsibilities of the manufacturers do not end with producing safe cars. Car manufacturers have an important role to play also when it comes to assuming their social responsibility for making sure that all the activities related to manufacturing, transportation of goods, service purchasing, and employee road travels on official business are made with a level of safety that is in line with the targets of eliminating road casualties. In practice this means that manufacturers have an opportunity to influence and set requirements on such activities as safety requirements on the vehicles for goods transports to factory facilities and supplier practices for safe transportations. The safety requirements on the goods vehicles could be, e.g., requiring measures for the protection of vulnerable road users, requiring speed limiters on delivery vehicles and trucks, belt reminders, and drunk-driving prevention measures in all vehicles.

In preparing for the 2020 UN Third Ministerial Conference on Road Safety: Saving Lives beyond 2020, The Next Steps, that is to be held in Stockholm in February 2020, a report of the Academic Expert Group has listed a number of recommendations for Stockholm Declaration that is to be the legacy of this conference. Recommendation number one discusses "Sustainable practices and reporting" and what policies and practices manufacturers, businesses, and enterprises should include both in their internal activities and also applied in the processes and policies of the full range of suppliers, distributors, and partners throughout their value chain or production and distribution system.

In the continuous process of designing and producing new car models and constantly improving safety, manufacturers are recording and gathering data from crashes and incidents that are in turn used to improve the next development of car design. Some manufacturers also go beyond this and carry out their own crash investigations and do detailed analysis including time histories and follow-up medical records of the involved persons in the accident. This means that extensive knowledge is available that may be used as a base for the good of the motor vehicle safety community.

Manufacturers have an obligation to share knowledge on how their products affect the well-being of any one exposed to the risks linked to transportation. A lot of data may be shared without violating antitrust laws or exposing company intellectual properties or infringing on the privacy of the individuals involved.

Manufacturers are encouraged to work with governments, authorities, academia, and other organizations in establishing research platforms for moving safety forward. These platforms or cooperations will offer the opportunity to create a more holistic view on how to move traffic safety forward. Many of those cooperations and research platforms exist already today but could and should be expanded. In Sweden there are both a national cooperation and a research platform as well as cooperations with individual manufacturers. In 2008, Volvo Cars and the Swedish Traffic Administration signed an agreement of cooperation. The aim was to get an overall view on the relationship between motor vehicles and the infrastructure and how this relationship could be improved and augmented. More information on this cooperation and outcomes will be discussed in a later chapter.

In 2019, Volvo Cars launched an initiative to share traffic safety research results with the traffic safety community. The initiative is called Equal Vehicle safety for All (EVA). The purpose of this initiative is to make Volvo Cars' collection of more than 100 research reports available and accessible to researchers, governments, and other vehicle manufacturers and suppliers. This is the collected research creating the foundation for a whole selection of Volvo's safety technology innovations.

In the case of modern vehicles, there is a high level of penetration of connectivity. This means that communication between vehicles or between vehicles and the infrastructure, either through cellular cloud connectivity or direct Wi-Fi connectivity (direct short-range communication, DSRC), will be useful for sharing data between vehicles.

Among the possibilities for sharing real-time data between vehicles are data on slippery road ways. The electronic stability systems, standard in most vehicles today, have the capacity to identify and measure icy patches on the road. This information can then be sent to central alarm centers that in turn can share this information with other connected vehicles. In parallel, information can be sent to the road maintenance units that can be dispatched to distribute sand or salt on these patches. This is a very efficient and accurate way of quickly acting against a road threat in a very precise manner. This type of arrangement is now already in operation in some places pioneering this type of data sharing, and there are also manufacturers who are ready for taking part in this type of cooperation.

Volvo Cars introduced the possibility for this type of data sharing with the car models produced in the mid-2010s and today covers all car models in production.

Having a large number of data probes out in traffic, there is also a large potential also in sharing other types of data, e.g., bad air quality, congestions, issues on the road, etc.

In summary, according to the view of Volvo Cars, the recommendations for motor vehicle manufacturers' responsibilities may be defined as:

- Making safe and reliable products that offer the highest level of safety regardless of age, gender, or size and both for people inside the vehicles and unprotected road users outside of the vehicles
- In line with the manufacturers' social responsibility, aim towards having all activities related to manufacturing, transportation of goods, service purchasing, and employee road travels on official business made with a level of safety that is in line with the targets of eliminating road casualties
- Sharing knowledge on research and data gathering from incidents and crashes that may be an asset for further research and product development
- Sharing real-time data gathered by modern connected vehicles to other cars, to road authorities, and to other important stakeholders
- Cooperating with governments, authorities, infrastructure owners, academia, and the motor vehicle industry in finding the most optimal way in creating a safe and efficient road traffic system
- Distributing the knowledge and advancements of modern motor vehicles globally by offering the same level of safety to all markets regardless of the existence of government standards

Volvo Cars Safety Vision

The Volvo Cars Safety Vision states that no one should be seriously injured or killed in a new Volvo car. This vision was adopted in 2007 and was a result of the very encouraging safety work done for decades and the projections of what was feasible and achievable linked to the future technical potential developments. This is also in line with Volvo Cars' heritage. Already at the start of the company, Volvo decided to focus on safety as one of the core values of the company.

The Volvo Safety Centre is continuously monitoring the outcome of crashed vehicles by collecting data and by cooperating with a number of stakeholders, e.g., the authorities in a number of countries in order to gather data on Volvo cars involved in crashes and the outcomes of the occupants.

Structured Safety Design of Vehicles

Real-Life Safety: The Foundation for the Safety Design

The development of occupant safety must be based on the improved protection in real life. Having a structured way of learning how vehicles perform in real crashes and the relationship and behavior of occupants and other road users to the technologies, such as restraint systems, are key to this knowledge. In learning about the traditional occupant protection systems perform, Volvo is using an approach named "Circle of Life." Crash and incident data, gathered since the early 1970s, are forming the base for setting the requirements for the performance of all safety systems, on complete vehicle level, as well as on system and component levels for the vehicles that are to be developed. Once the next generation of vehicles has been exposed to the real-life environment and exposed to crashes and incidents, new data is gathered which in turn will form the basis for the updated requirements which will form the foundation for the new vehicle development.

This way of using real-life data, naturally, needs a structured way of gathering data or having access to this data. For Volvo Cars, gathering crash and incident data was part of the company's approach to vehicle design starting in the early 1970s. At this time, the company has, in its corporate accident data base, gathered data from more than 40,000 crashes involving 70,000 occupants. However, given a more cross-functional and more open relationship between manufacturers towards sharing vehicle crash data, and the availability for accessing other sources of data, all manufacturers now would be able to approach improved vehicle safety using the real-life safety approach.

Assessing the benefits of new technologies and innovations may, however, pose some challenges. In particular, to a large degree, this is the case for advanced avoidance and support technologies. Here, assessments and projections of technology effectiveness will be essential before the proper data is gathered. Using available research data and data from behavioral studies will indicate, without giving the precise level of effectiveness, that the introduction of a new vehicle technology will help to enhance safety and therefore has a value for being added to the vehicle's overall occupant protection system.

Overall Safety Strategy

Traditionally crash safety has been the focus for improved safety performance of vehicles for many decades. Although many systems for avoiding crashes existed, these systems primarily were based on basic technologies with none or limited use of advanced electronic components and intelligence.

From the advent of the new millennium, new advanced safety systems started to be engineered and introduced into the vehicle fleet. The first system to be introduced was ABS (anti-locking braking system) which was then followed by ESC (electronic stability control system). In particular ESC has proven to be a valuable contributor to increased vehicle safety by stabilizing the vehicles in a number of instability situations and helping to avoid conflicts and crashes.

The development of these systems was the starting point for a whole set of systems helping to avoid or mitigate crashes. At the same time, the crashworthiness systems continued to be developed, and also new post-crash systems, such as on call systems, started to be developed and introduced on the markets.

All these developments paved the way for a new playing field where manufacturers' safety strategies turned into viewing the overall picture instead of each safety mode separately. The target when using a more holistic view on the safety strategy is primarily to cut the chain of events leading to a crash as early as possible and to, hopefully, totally avoid a serious situation and the crash. As an example of this, see picture of Volvo's Safety Strategy below.

Even if the chain is not completely cut, the interaction of the avoidance or mitigation systems and the crash protection systems may significantly improve the chances of survival even if the end result is a crash. The action of the preventative systems may reduce the impact energy so that the vehicle's protection systems can handle the remaining energy. To exemplify this, e.g., a pedestrian detection and braking system may reduce the impact energy sufficiently in order to move the injury risk level significantly from a non-survival level into a level for only minor or intermediate injuries.

The different stages of the chain of events leading to a crash and the events after a crash can be divided into the following stages: risk management or normal driving phase, threat management or conflicts and near-crash phase, injury management or crash phase, and post-crash phase.

During the risk management or normal phase, many preventative actions could be taken, actions that would assist in ruling out any further negative development. Examples of those actions are improved comfort in the passenger compartment; improved ergonomics and HMIs (human machine interface); systems encouraging improved driver attention and reducing the risk of distracted drivers, e.g., the risk of driver's eyes not focusing on the road; alcohol interlocks and sobriety checks for reducing the risk of driving while intoxicated; and improved navigation systems helping to reduce the risk of stressed drivers. In additions to this, the systems for assessing the drivers' drowsiness levels and for helping drivers to steer back on the road when not paying attention also have the potential of cutting the chain of events leading to a crash.

For the conflict part or the threat management phase, the focus is to assist the driver in avoiding a collision and taking the situation back into the normal phase. Typical systems acting during the conflict phase are ESC (electronic stability control systems), BAS (brake assist systems), and FCWs (forward collision warning). All these systems interact with the drivers and are activated when the in-vehicle sensors are detecting a development moving away from the normal phase.

The near-crash or avoidance and mitigation phases occur during the time span starting 2–3 s before a crash (two to three TTC – time to crash) and until the crash occurs. This is the time span when it is too late for the drivers to act but still time for the systems to react and try to prevent or reduce the consequences of a crash.

If the chain of events is not cut, the vehicle will enter the crash phase. If the preventative systems have been active in reducing the level of impact, the restraint systems together with the occupant protection systems will be in a better position to reduce the risk of injuries to the occupants. Regardless of the impact reducing potential of the preventative systems, the potential of protecting the occupants in a

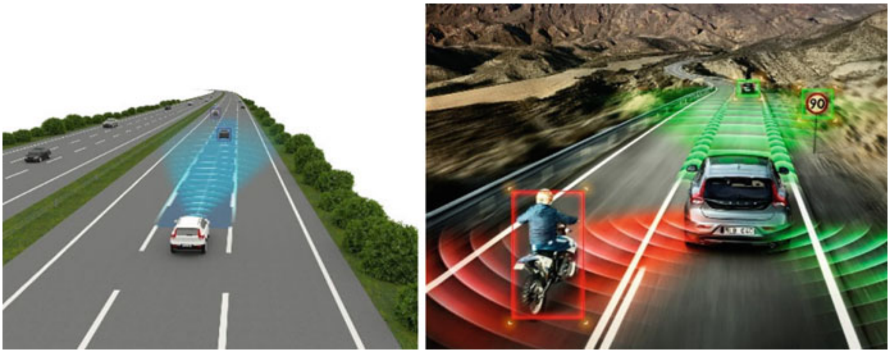

Fig. 5 Examples of active safety support systems available on the market

modern motor vehicle with the most advanced crashworthiness system is undoubtedly high. Modern vehicles have a whole set of combinations of efficient crashworthiness protection systems that have proven to be giving elevated levels of occupant safety. Among other things, car manufacturers have spent extensive resources in adapting the body structure for an optimized level of energy absorption by using various steel qualities, among those a high level of ultrahigh strength steels. Also, the restraint systems, e.g., inflatable restraints, belts with load limiters and pre-tensioners, child seat restraints, and interior systems absorbing energy during impacts, all are part of the occupant protection while in a crash.

Numerous systems active during this time span have been developed, and more are in the pipe line to be developed or launched. Systems such as automatic emergency braking (AEB) systems, lane departure warning and lane keeping aid systems (LDW, LKA), and pre-crash belt tensioners and seat adjustment systems have all been introduced and have proven to be effective in reducing injuries and fatalities. As an example the effectiveness of low-speed autonomous emergency braking of these systems leads to a reduction of 38% of real-world rear-end crashes (Fildes et al. (2015)).

The last stage in the crash sequence is the post-crash phase. During this phase actions can be taken to, e.g., brake the vehicle in order not to create multiple crashes and reduce the risk of fires by minimizing the fuel leakage and automatically calling for assistance from rescue personnel by sending messages of locations and crash severity via so-called e-call systems.

Included in the overall strategy is also the need to protect vulnerable road users. This includes both minimizing the risk of crashing with a VRU and minimizing the outcome. Manufacturers have spent extensive resources on making the front part of the vehicles benign and also to develop systems for detecting and braking for pedestrians and bicyclists, preferably avoiding a crash; but in the case that it cannot be avoided, minimize the impact. Volvo Cars was the first manufacturer to introduce this type of technology in 2010, and since then the technology has cascaded into all segments of passenger vehicles. However, the heavy truck industry has been slow to react, and as of yet (2020), the technology is not available in this motor vehicle segment.

With further preventative technology advancements, this safety strategy will be even more dominant in the future. For this reason, it is important that the advancements are shared among all road users on all continents. Cascading strategies from the premium segment of vehicles to the large-volume production of vehicles are already occurring and will be more rapid with lower unit prices and more adaptions into newer vehicle platforms. Even though there is a significant time lag, the technologies are starting to penetrate both into the middle- or low-income markets and into the used car fleet, the reason why there should be hope for experiencing significant reductions in casualties rather close in time.

The development of self-driving or autonomous vehicles also has a potential of reducing the number of serious injuries and fatalities in the road transportation system. It is estimated that around 90–94% of all crashes have a human error as part of the causation. Since the human error part is estimated to be almost nullified when applying autonomous technology, it is estimated that 90–95% of the crashes occurring in today's traffic may be eliminated. Even before the AD technology has fully penetrated the vehicle fleet, the cautious behavior of the self-driving cars will have a soothing effect on the overall traffic management and vehicle speed.

Also, the advanced technologies developed for letting cars be self-driving, such as sensors, detection algorithms, and duplicate reliable data processors, may be active also when the cars are not in autonomous mode and will potentially help to significantly raise the level of awareness for the drivers, and the support systems may be even more efficient in assisting drivers and for acting when drivers are no longer able to be part in avoiding or mitigating the crashes.

In summary, a holistic safety strategy looking at all modes of driving and crash causations will be paramount in taking vehicle safety towards zero fatalities and serious injuries. Most of this development is driven by the market forces without government standards pushing manufacturers. In the past, government standards were the driving force for improving vehicle safety. Today, most of the new advanced technologies are not regulated but have been introduced on the market following high levels of customer demand due to the existing clear and comprehensive customer information, primarily through different vehicle rating programs, so-called New Car Assessment Program (NCAP). With more data sharing and more focus on the whole chain of events leading to a crash and by using this in the priorities of development of new advanced technologies, significant steps towards zero are expected by the efforts of vehicle manufacturers.

Focus on Designing Around People

"Cars are driven by people, the guiding principle behind everything we make at Volvo therefore is, and must remain, safety." This statement was made early in the history of Volvo, at the time when a human-based focus was not the norm and common practice adopted by all other manufacturers.

By using this principle of designing around the humans, this emphasizes the focus on creating an environment in the vehicle around all occupants that enables, besides

Fig. 6 Volvo safety strategy

comfort and convenience, the car to support a safe and pleasurable ride which enhances the trust of the occupants and a comfortable ride.

For many years, this was primarily done by making a very reliable and trustworthy design of the vehicles in addition to adding features that improved safety and gradually improving the ergonomic driving environment. Many of the early technical innovations for safety, such as the three-point seat belt, very clear in its message of safety and creating a feeling of making a difference when used, have been important in this strategy.

During the last decades, many technical advancements have been made in improving and adapting the ergonomic features within the passenger compartments, all helping to create a comfortable environment reducing the fatigue of both drivers and other occupants. For drivers, extensive research has been performed in order to reduce the risk of both distraction and avoidable driver mistakes due to inappropriate vehicle-to-driver communication. Among those features are, for drivers, assistance systems that both communicate all important information in a clear, comprehensive, and undistracted format that avoids both misunderstandings and unnecessarily increasing the drivers' anxiety and stress levels as well as improving the trust and level of assurance of the vehicle's safety systems and thus improving comfort and well-being.

Other systems could also act as safety features. For example, infotainment systems and navigation systems have a potential of assisting drivers, thus relieving tension and reducing stress and in this way giving the driver a better position in carrying out the driving task.

Driver Distraction and Attention Selection

While cars are still driven by and in control by humans, safety is highly dependent on the driver being alert and focused on the driving. Drivers being distracted for various reasons such as carrying out secondary tasks in addition to driving, being exposed to high workloads, different distracting scenarios occurring outside of and around the vehicle, interaction with other occupants in the car, etc. may fail to be fully capable for a short or longer time to safely carry out the driving task. Examples of secondary tasks are dialling and texting using cell phones, web browsing, watching movies or television, selecting music on playlists, and inputting address on electronic displays, i.e., tasks that require the drivers to take their eyes off the road for a short or longer time. This kind of distraction may also be created by complicated vehicle controls requiring the drivers to move both the attention and eye view away from the road and the driving.

Accident statistics show that distraction is a major contribution or a part of the causation of a high number of fatalities in many countries. Only in the USA this number is estimated to be around 3500 per year. Distraction is also reported to be a factor in around 8.5% of all crashes involving fatalities.

Too low workloads may also be unsafe by creating a low attention level that in turn requires a longer time for drivers to act in case of the need of a critical action.

Legal restrictions have been imposed on what kind of secondary tasks and what driver activities are to be allowed while being behind the wheel. Those restrictions include banning the use of handheld cell phones, texting, watching movies or television, and performing secondary tasks in general while driving.

Most countries in both the Eastern and Western world, including local provinces and states, have these legal restrictions in place. Some jurisdictions are also actively enforcing these by actively monitoring and fining drivers found to be violating them.

In addition to formal legal restrictions, there are also guidelines being created in trying to guide manufacturers on the best standards for designing the vehicle's controls, displays, and electronic interfaces with the drivers. For example, the US federal agency National Highway Traffic Safety Administration (NHTSA) in 2013 published (Phase 1) guidelines for in-vehicle electronic devices. These were created as an effort to discourage manufacturers in introducing distracting devices in their vehicles. In 2016 NHTSA published Phase 2 of the guidelines covering distraction caused by devices brought into the vehicles such as cell phones and other electronic devices not part of the vehicles' original equipment.

Some trade organizations such as manufacturer trade organizations and consumer organizations have also created recommendations and guidelines for reducing the risk of distraction linked to vehicles' electronic devices.

With the development of new and advanced driver assistance technologies, driver monitoring is becoming a key for assessing the driver's attention to his/her driving task. With this technology it is possible to adapt a whole set of support systems and also assess if to lower the availability of the number of vehicle features that could possibly be distracting for drivers in a low-attention mode.

A number of other ways of reducing the workload for drivers and minimizing the risk for distraction will be offered, among those speech and gesture guidance.

Driver monitoring may also be linked to other useful support systems, such as drowsiness systems and systems for minimizing the risk for drivers being under the influence of drugs or alcohol.

Fig. 7 Driver monitoring camera

Driver assessments of drowsiness or distraction may also be combined with other detection systems such as analyzing steering wheel movements. By combining various assessments of drivers' attentiveness and readiness to perform their driver duties in a safe way, decisions may be made also whether to increase the settings of warning and automatically activate systems to compensate for a lower driver performance.

Potentially, with more mature driver assessment system, this kind of support systems could also be extended for other ways of making the continuous ride safe, such as so-called limp-home modes, where the vehicle could be still driven and moving forward but only with reduced speed and raised vigilance levels of the support systems.

Improved Protection for All Occupants, Independent of Age, Gender, or Size

One of the most important requirements in the principle "design around you" is that all occupants need to be given the same level of occupant protection regardless of gender, size, and age.

This implies that the restraint systems need to be adapted to the specific needs, geometric sizes, and tolerance levels of the full range of occupants likely to use the different seating positions in the vehicle. Many technical innovations have been developed and implemented for these adaptions, such as belt load limiters and adjustable seat belt anchorages as well as occupant sensing systems used for decision-making in deploying or not deploying the inflatable restraint systems.

Many of the protection systems implemented have a wide coverage in the efficiency of protecting the occupants without special adaptions. For example, whiplash protection systems have proven to give a good improvement in protecting the occupants even though generic testing tools and in-vehicle protection systems are used. However, further advancement can potentially be made by adapting the tools and criteria to both genders, sizes, and age differences. Actions have been taken to create a whiplash dummy more adapted to the typical female sizes and applying female tolerance levels. By using different dummy sizes in the testing and applying the tolerance levels for more fragile body constitutions, this would cover not only the gender aspect but also the age and fragility aspect.

Similar actions should be taken when it comes to other testing tools such as frontal and side anthropomorphic test dummies, new injury criteria, and updated, more stringent tolerance levels.

In 2019, Volvo Cars created an initiative named EVA (Equal Vehicle safety for All). Through this initiative, Volvo Cars is making a number of research reports public and is keeping a library open for other researchers and manufacturers. The reports cover findings from both testing and investigations of real-life accidents.

These reports basically make a number of data points available that may be puzzled together to be used for making significant advancements in knowledge that may be used both for safety design improvements and further development of test tools and test methods and setting injury criteria.

With further advancements of the technologies, in particular driver assistance systems, more possibilities and potentials for individual adaptions will be available. Already today, systems exist for measuring driver alertness and distraction levels and systems that can be set in advance. Among those are forward collision warning (FCW) systems and automatic emergency braking systems (AEBS) that offer different settings depending on the individual capabilities. Those settings do, however, basically require drivers to do this manually in advance, using their own view of their own capacity and capabilities.

The next step after this would possibly also include health assessments and alerts to the drivers given their health status. It is, however, very important always to use this with the full support of the driver and not to infringe on the drivers' integrity. If supported and appreciated by drivers, such adaptions would be seamless and dormant until needed and should preferably not to be used as a correction of the drivers' behavior but instead be considered as your invisible friend who is there to help you when needed.

For customers who want feedback on the driving performance and suggested improvements, such information could possibly be embedded in the vehicles' data recorder and provided upon request.

Already today, schemes exist for rewarding drivers who are following basic rules of safe driving performance, e.g., insurance company pay-as-you drive programs where car owners can get insurance premium discounts. This kind of incentive would have an even larger potential of being beneficial by giving continuous driving performance feedback by the systems developed as part of the designed-around-you principle.

Child Restraints and Child Safety

As stated in the previous chapter, it is of paramount importance, and it is the responsibility of all car manufacturers to offer the same level of occupant protection for occupants in the vehicle regardless of occupant sizes, ages, and genders.

This creates a special focus on protection of children given their unique biomechanical characteristics with different body and mass proportions and different sustainability and resilience characteristics than adults and other more mature occupants.

This becomes very obvious from looking at the body proportions of children at different ages when comparing this with adults.

With this background, offering lower and insufficient protection for the most vulnerable category of occupants in a vehicle is simply not acceptable. Child restraints offering protection for all sizes of children is a prerequisite and necessity in order to reach a high level of protection for child occupants.

The first versions of child restraints giving an efficient protection for infants and toddlers started to appear in the mid-1960s.

Since the first prototypes in the 1960s, the design and development of efficient child restraints have resulted in enormous improvements in the knowledge on how to best protect infants and toddlers and how to best seat them in the vehicles and have also led to an array of available restraints in many countries.

In Sweden, by the late 2010s, the number of children dying in traffic when restrained in a child restraint annually is extremely low. In most cases there is some kind of misuse involved, and this normally is part in causing this tragic outcome.

There are many actions taken in order to reach this respectable record. One reason is that all major stakeholders in Sweden, i.e., authorities, safety advocates, road safety interest organizations, suppliers, vehicle manufacturers, and vehicle importers, share a common view on how to approach all aspects of protecting children in cars. Among those are the principles of how to position children in the vehicles at different ages and what kinds of child restraints are suitable at different sizes and ages of children. This in turn is used by the responsible institutions for direct communication with parents or parents to be, in preparation for how to best protect the children at different stages of development. One of the basic principles used in this communication is that children should be rearward facing as long as this is practicable and possible. A rearward-facing restraint offers support for the head

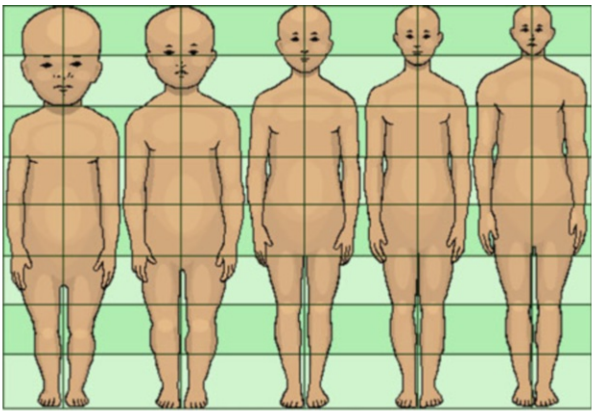

Fig. 8 Body proportions. Children vs adults

Fig. 9 Early rearward-facing child restraint prototype

and the back of an infant in the case of a frontal crash. By giving this support, the risk of neck injuries, one of the most dominant injuries to small children, is substantially reduced.

Consequently, the recommendation for all parents and caretakers is to have all children, up to at least the age of 4 years or as long as practicable, positioned in rearward-facing child restraints.

Once the children are too large in size to be fitted in rearward-facing child restraints, appropriate forward-facing toddler seats, giving protection in all types of crashes, should be used.

In 2016, Volvo introduced a new generation of rearward-facing toddler seats. For these restraints the recommended ages are 9 months to 6 years and between 9 and 25 kg in weight.

Although the child has outgrown the toddler seat, it is still not readily prepared for using the adult seat belts without adaptions. The geometries of the belt anchorages are normally positioned in a way to offer good protection for adults. Children at the ages between 3 and 10 years do have characteristics which are not completely compatible with adult seat belts. Children at these ages do not have some skeleton features such as pelvic bones developed. The pelvic bones are used for transferring the forces from the lap belt portion of the three-point belts to the body skeleton for an adult occupant. In the case of a child, the hip should be raised in order to transfer the load into the thighs and the lower part of the skeleton.

All of this leads to the use of a platform for raising the children in order to better adapt the belt geometry of the seat belts and to give the children better protection, so-called booster seats. Those booster seats may have only a belt-positioning platform to position the lap belt or both a platform and a back that positions both the lap and shoulder belt parts of the three-point seat belts. The recommendation is that booster seats should be used up to the age of 10 years.

In order to have this type of restraint readily available, some manufacturers, among those Volvo, offer built-in child restraints, restraints that are incorporated in the car seats and that can be easily activated and placed in position for seating a child.

Fig. 10 Volvo rearward-facing infant and toddler seats

Fig. 11 Built-in booster cushion

These may be offered in one or more positions. Multi-stage booster seats have the potential of a better adaption to the size of a child.

Built-in booster seats are highly recommended restraints that should be adopted by all manufacturers in order to have an easy access to the best possible child protection.

One of the restraining forces for offering the best possible child protection is what is legally possible when it comes to certifying those restraints. Within the present legal framework, there are legal requirements that do not open up for the most efficient restraints offering the best protection for the children. There are a number of reasons for this, however not acceptable. Among those are that customers are not ready and capable of installing the more advanced in a way that is required in order to offer this protection and not being misused. The knowledge on how to best protect children in vehicles have come far since Volvo offered the first design of a child seat early in the 1970s. It is time to allow for more flexibility within the legal framework allowing for more advanced child restraints in the future.

Adaptions for Occupants with Special Needs

The principles of a transportation system open for all and equal protection for all imply that vehicle manufacturers should make adaptions for occupants of different sizes and varied needs as far as this is practicably possible. These adaptions could be offered as optional equipment or part of the vehicle's built-in features. At Volvo, there is a special section of the company named Volvo Special Vehicles whose assignment is to redesign the production vehicles so as to be better adapted to individuals with special needs and other challenges.

These adaptions include special swerving seats for easier access for a person in a wheelchair and special arrangements of the seats and controls for addressing other physical challenges.

Other car companies also offer these kinds of modifications to their vehicles, either through factory-installed equipment or through aftermarket modifications using original accessories.

Preventing Serious Violations

Preventing Driving While Under Influence (DWI)

The three most common causes for traffic fatalities due to motor vehicle crashes are still failure to use the seat belts, speeding, and driving while under influence of alcohol or drugs.

Most countries in the developed world have laws for maximum blood alcohol content (BAC) while driving. The allowed levels vary significantly between different countries and different parts of the world.

Three different levels of allowed BAC can be identified: 0.02%, 0.05%, and 0.08%. There are also countries that have a limit of 0% but with low levels of enforcement.

Sweden is applying the 0.02% limit. This is a statement from the authorities that drinking and driving cannot be tolerated. This is also highly enforced by the police.

Many European countries apply 0.05%. The only major exception from this is Great Britain who applies 0.08%.

In the USA, most states also apply 0.08%. This level of allowed BAC is generally considered to be too high in relation to what are the acceptable levels found in human behavior and traffic safety research.

In the early 2000s, Volvo decided to develop and offer an alcohol interlock as an optional equipment for all new vehicles. This device, called Alcoguard, was launched to customers in 2008.

It consists of a wireless handheld device that is connected to the vehicle's ignition system. The device has a mouthpiece that the driver must blow into before the engine may be started.

Fig. 12 Volvo Cars Alcoguard system

Volvo is so far the only manufacturer that offers an alcohol interlock of its own design as optional equipment, but many car manufacturers do, however, offer the cabling necessary for installing an interlock in the vehicle design.

The interlock devices presently offered within the automotive sector as an optional equipment all suffer from having a set of major issues making the device undesired by customers and drivers. Among those issues are high costs, low level of reliability, and the need for frequent calibrations. A design using a mouthpiece also suffers from the opportunity of an intoxicated driver to hand over the mouthpiece to another occupant, most likely to the occupant in the front passenger seat.

Significant research and product development efforts have been made focusing on less intrusive, more reliable, and less costly solutions than blowing into a mouthpiece.

Among those are designs for blowing into a faucet located in the center hub of the steering wheel, skin detection systems to be located on the steering wheel, and infrared beams placed in front of the driver’s face.

Many of those solutions are still in the development stage and are not yet ready for commercial introduction. Some of them, however, look promising and may meet the requirements to be accepted by customers and drivers.

The US Federal Government in the form of Department of Transportation is looking at continuing its drunk-driving prevention project DADSS (Driver Alcohol Detection System for Safety) that they have been working on for more than a decade. The technology is still not ready for production, but is now sufficiently developed for pilot testing in fleets.

The device for detecting too high BACs also suffers from the fact that it only covers one of the factors for driver intoxication and lower driver performance. A number of other causes exist for drivers being under influence that would affect the driving capability. Misuse of different drugs is one of the primary causes of driver intoxication and lower driving capability. Although, in many cases, the persons misusing drugs are also likely to misuse alcohol, this still does not always go hand in hand.

A completely different way of approaching the ways for reducing the consequences of drunk-driving and all other types of drug misuse and intoxication in the traffic system would be to measure the drivers’ driving capability in real time. This would focus on the main issue, the risk for creating incidents and crashes instead of measuring something ***leading*** to a risk of creating this. By doing this, other factors creating risks would be covered, not just intoxication but also, e.g., distraction and drowsiness.

As discussed in the section linked to distraction and drowsiness, driver monitoring is becoming key for assessing the driver's attention and capability to carry out the driving task.

Volvo Cars believes that the issues of driver intoxication and distraction should be addressed by installing in-car cameras and other sensors that monitor the driver and allow the car to intervene if a clearly intoxicated or distracted driver does not respond to warning signals and is risking an accident involving serious injury or death.

The intervention could involve limiting the car's speed, alerting an e-call assistance service, and, as a final course of action, actively slowing down and safely parking the car.

With this technology it is also possible to adapt a whole set of support systems and also assessing if to lower the availability of the number of vehicle features that could possibly be distracting for drivers in a low attention mode.

A number of other ways of reducing the workload for drivers and minimizing the risk for distraction will be offered, among those speech and gesture guidance.

Since a decade back, systems exist that have the potential to detect distracted or drowsy drivers. In 2007 Volvo Cars launched a system named Driver Alert. This system measures the way the driver is handling the steering in relation to the lane markings on the road. The basic theory is that fully alert drivers are making micro corrections using the steering wheel, while more drowsy or distracted drivers are making more jerky movements. This theory has proven to be valid, both in field operational tests (FOT) and in order research.

The potentials for these systems are considerable and obvious. Car manufacturers are therefore strongly encouraged to continue these efforts into balancing driver capabilities with the vehicle's driving features and the possibilities in order to reach a safe state of driving when looking at all conditions.

Speeding

The issue of allowing the possibility of speeding on public roads instead of restricting the top speed of the vehicles close to the speed limits is something widely debated between policymakers and manufacturers. Systems, called speed limiters, are developed and available for assisting and encouraging drivers in selecting a speed corresponding to the actual speed limit of the stretch of road in question. Many manufacturers are offering these devices either as optional equipment or as a standard factory-installed device. The present highlighted discussion between governments and manufacturers is whether to require speed limiters that prevent a higher speed than the speed limit plus a margin regardless if the driver's wish is to drive faster. The argument is that there are no circumstances where speeding has any additional benefits for society or adding to traffic safety but instead leads to serious consequences for both the society and the individuals, and therefore speeding should be no option for drivers.

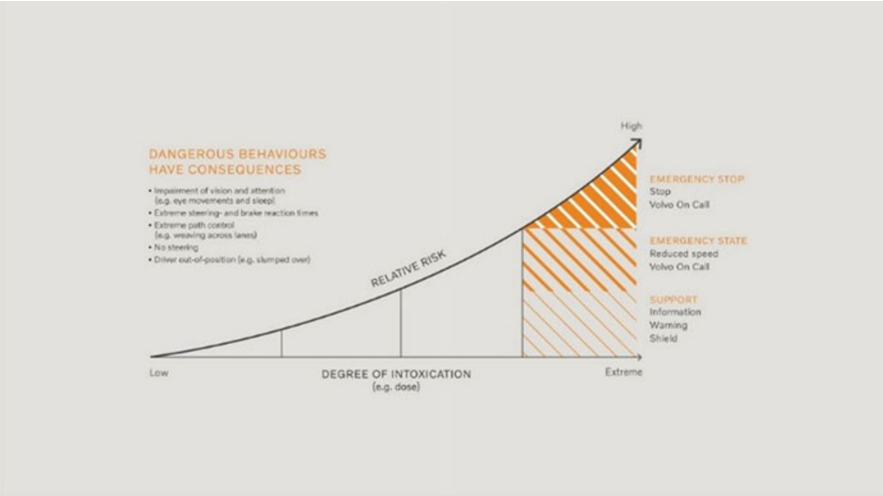

Fig. 13 Graph showing the risk linked to intoxication and the possible measures. (Volvo Cars)

Even though the basic arguments for forcing a non-speeding road transportation environment are sound and wise, this should only be instituted when both the technology and the road infrastructure have matured sufficiently to offer a high level of reliability for applying an accurate speed for all situations, all road types, and all road sections. Forcing out new innovative systems that are not fully developed and sufficiently tested, and at the same time as the interface with the infrastructure is not fully reliable and quality assured, faces the risk of drivers and cars ending up in awkward situations with unintended speeds not matching the speed limits which in turn could lead to creating driver and customer opposition and distrust that might be long lasting and will be difficult to repair. An example of this occurring was with the seat belt interlock mandate for all new vehicles in the USA manufactured in the period 1972–1973. These mandated devices prevented the engine to start unless the driver was buckled up. Unfortunately, the reliability of the devices installed by the manufacturers was poor, and many cars refused to start even if the drivers were buckled up. The uproar and the customers' dissatisfaction resulted in a buying resistance and consequently to a revoked requirement for installment of these devices. It even got as far as ending up with an act in Congress prohibiting setting a new mandate for forcing the fitment of similar devices in the future. It also caused a delay in adopting mandatory seat belt laws in the states in the USA and a delay in the seat belt usage rate in the USA.

Actions for increasing enforcement of the speed limits are often put forward as an effective means of reducing the levels and the extent of speeding. Enforcement is, indeed, an efficient but expensive means for limiting speeding. Extensive number of traffic police, speed cameras, video recordings, and road appliances for tracking speeding vehicles – all these are costly and cannot cover all road sections. A larger penetration of driver assistance speed-limiting systems and, eventually, when the technology is mature and reliable and the road infrastructure has achieved a quality-assured speed limit posting, mandatory speed-limiting systems would offer a more efficient way of reaching a level of less speeding violations.

Although most countries and territories have adopted speed limits for all roads, there are still a few unique areas and types of roads that offer free speeds without limitations. The best-known type of road with free speeds is the German Autobahn. Discussions have been intense within the European community on the suitability of keeping this unique policy in the heart of the European continent. Still, this is applied, and although congestions reduce the actual speeds, appalling crashes occur, and the arguments of the possibility to drive fast legally prevents and deters many manufacturers in applying reasonable top speeds for their cars and to actively support mandatory speed-limiting devices.

Some manufacturers, including Volvo, have launched concepts where the vehicle's key could be programmed for adapting certain features such as the car's maximum speed. This kind of device allows the owners to set limitations on the car's top speed before lending their car to other family members or to younger and inexperienced drivers such as teenagers that only just received their drivers' licenses.

In 2019, Volvo Cars stated that it had made the decision to restrict the maximum speed for all its new cars and models to 180 kmh by 2020. This decision was made after careful considerations and market investigations on the customer preferences and needs. The company has received a lot of support for making this decision within the safety community. This is also a way for the company to assume its corporate social responsibility for protecting both the humans and the environment.

In the context of high speeds and protecting the occupants, belt usage is extremely important. Higher usage rates in many countries in addition to the higher levels of seat belt reminders have assisted this development.

However, in many countries, higher belt usage rates only apply to the front seats. Rear seat usage rates are appallingly low on many markets. Both governments and manufacturers should increase their efforts to inform occupants on the importance of being belted in the rear seat.

As an example, the Swedish National Society for Road Safety (NTF) ran ads in the Swedish media a decade ago called "No elephants in the car please!" These ads clearly showed customers the risk for the front seat occupants of having an occupant unbelted in the rear seat. For example, it informed customers that for a crash at 50 km/h and an occupant whose weight is 75 kg, the corresponding weight considering the g-forces in the crash would be 3000 kg (3 tonnes)! This campaign was considered to be successful and has helped to significantly increase the belt usage rate in the rear seat.

The campaign was considered successful, and surveys afterwards showed a higher consciousness of car occupants to be belted while in the rear seat.

A recent development supporting the actions to prevent speeding is the introduction of the geofencing technology, an innovation forcing different kinds of restrictions to be applied to specific geographical areas. Examples of restrictions are maximum speed and only using electromobility within a city center area. This would be a very efficient means of, e.g., forcing compliance with speed restrictions outside of schools and shared spaces with vulnerable road users. Volvo Cars fully supports the deployment of this type of technology and believes that it will be an important contributor to reducing speeding and traffic casualties in critical city areas.

In conclusion, Volvo Cars believes that cars staying within the speed limit will be necessary in meeting the Vision Zero target, and measures for limiting the top speed and installing speed-limiting devices in motor vehicles will be an essential component in a strategy for preventing speeding violations.

The Responsibilities of Car Manufacturers for Sharing Car Technology Developments Globally

The levels of traffic safety globally vary significantly. This is due to a fragmented picture of many factors, such as infrastructure status, the structure and development level of the transportation sector, how the road system is being used, levels of enforcements and traffic education, incentives and factors for improving safety, societal factors of age, gender distribution, general social status, and rural, urban, and infrastructure planning. An important factor is also the generic level of age and size distribution in the vehicle fleet as well as the technical level of advancements of the fleet.

Governments here have a major responsibility for both encouraging a renewal of the fleet at appropriate intervals as well as incentivizing technology advancements and setting minimum performance requirements for safety. However, there are a number of developing countries who have neither established any encouragements for adopting new technologies nor set any minimum legal safety performance requirements.

For Volvo, the level of safety needs to be the same regardless of any government mandates, third-party testing, or other outside requirements. Humans of all genders, sizes, and ages should be protected on an equal level. So, provided there are no unique circumstances dictating a special variant, no differentiation should be made on equipment and performance levels. Volvo Cars strongly advocates all manufacturers to adopt the same generic policy.

Cooperation Between Different Traffic Stakeholders

Traditionally, the roads for the last 100 years have been designed based on fairly standard principles of offering a space where different road users could apply whatever means of transportation that was available and with rather basic standards for sharing this road space, staying safe, and reaching the goal for the journey.

Although the designs of the modern roads have indeed made significant advancements, the concept has still been to offer an open space for all vehicles, and then the vehicle manufacturers designed the vehicles assuming basic standard requirements for being able to carry the occupants safe and not to harm other road users.

However, with more advanced vehicles, higher speeds, more congestions and competition of the road space, and the need to significantly reduce the road casualties, the need for closer cooperation between vehicle manufacturers and the authorities has become clear during the last two decades.

Also, in order to get closer to the Vision Zero, a holistic view must be applied in order to balance both the vehicles' occupant protection in relation to the planning and design of the infrastructure. For instance, this is relevant when it comes to applying tougher requirements for road vehicles in different types of collisions. Applying tougher standards in order to meet very small numbers of collisions will automatically lead to less optimized levels of actions to improve all aspects of crash protection, e.g., restraint systems, passive crash protection, and other advanced occupant protection systems which add both costs and potentially weight. The consequences may potentially be new road vehicles being larger in size, being more expensive, and with lower levels of fuel economy, i.e., less attractive to both policymakers and customers, which in turn would reduce the pace towards reaching the desired level of traffic safety.

During the last decades, many efforts have been made in order to review the approaches to cooperations and to set the standards for both the design of roads and vehicles. Many of these cooperations have opened up for reaching clear views on how to most efficiently use the possible means for improving traffic safety and how to find a holistic view of how all stakeholders may be involved in reaching this.

However, in order to be able to efficiently explore the full possibilities of these cooperations, it requires the right mind-set of all stakeholders involved in reaching a Vision Zero target and the organizational and legal means for making real progress and setting standards that enable real progress. The stakeholders must be able to share a view of what would be the most optimized contributions of each one and how this would work together in a holistic and integrated approach.

In September 2007, the Swedish Road Administration and Volvo Car Corporation signed an agreement on cooperation for improving traffic safety in Sweden. This can be seen as extension and link up with both the Vision Zero target that was adopted by the Swedish Parliament in 1997 and Volvo Car's Safety Vision that was launched in 2007. The Swedish Vision Zero target did state the principles for how to approach the design of the transport system by stating that:

- The transportation system must be adapted to the human tolerances.
- "Normal" human mistakes should not have severe consequences. Instead, the transport system should be forgiving with respect to those mistakes.

The agreement of cooperating as signed by the parties included a number of areas of cooperation, including:

- A division of responsibilities for a whole set of conflict scenarios.

  These scenarios include, among others, frontal crashes, car-to-car side impacts, car-to-car rear impacts, car and VRU conflicts, car and wild animal conflicts, etc. Each scenario defines the speed of which the responsibility changes hands from the vehicle to the infrastructure. For example, for frontal crashes, a speed is defined for when the responsibility of keeping all occupants safe when a frontal crash occurs is transferred from the car and its occupant protection systems to the infrastructure, i.e., adding certain features to the infrastructure in order to avoid this type of scenario. For car-to-VRU conflicts, a maximum speed is defined for when the cars' active and passive protection systems should be able to jointly avoid serious injuries to the VRU and when instead the infrastructure should instead be designed in a way to avoid car and VRU conflict by separation. Please see attached figure below.

- Definitions of requirements for various interfaces between the advanced safety systems in the vehicles and certain features on the infrastructure.

  A number of advanced driver assistance systems, e.g., lane departure and lane keeping aid systems, need clear lane markings in order to define if the vehicle is rightly positioned and help the driver and the vehicle to correct the position if needed. For the case of the advanced systems enabling autonomous driving, lateral positioning will be guided through the assistance of lane markings.

  Thus, in order to be fully recognized by the detection systems in the vehicle, certain requirements are identified on the lane marking, e.g., size and contrast. The agreement also identified the requirements for the assurance of the existence of lane markings for all applicable roads.

  The agreements also covered other features needed in order to assure the compatibility between the vehicle's advanced systems and the infrastructure.
- Sharing of traffic and crash analyses in order to enable the best measures in infrastructure and vehicle design and avoiding traffic casualties.

The agreement of cooperation and dividing of responsibilities has become a role model for other similar approaches in sharing the view of how best to apply the capabilities of vehicles and infrastructures.

Cooperation between different stakeholders and sharing of data will be increasingly important when moving forward to improve traffic safety. This will be of even higher importance for the development of self-driving or autonomous vehicles.

The US government has announced the intentions of data sharing similar to what is done within the field of civil aviation. Here all stakeholders sit together and openly share critical data and agree on certain principles and standards. It should, however, be remarked that there are major differences in the foundation and principles of the transportation sector versus the civil aviation sector.

One of those major differences is that the industry is governed by antitrust laws which establish rules for the cooperation between manufacturers and how much of agreements limits the need for constant stretching of the boundaries of technical developments in occupant protection for motor vehicles. Agreeing on standards would limit the individual manufacturers' need for always looking for going beyond competitors and create a competitive edge. Also, there are many more actors in the road transportation sector that would significantly reduce the possibilities on agreeing on standards. In addition to this, motor vehicles are used in vastly different conditions and by largely different users and in totally different environments. All of

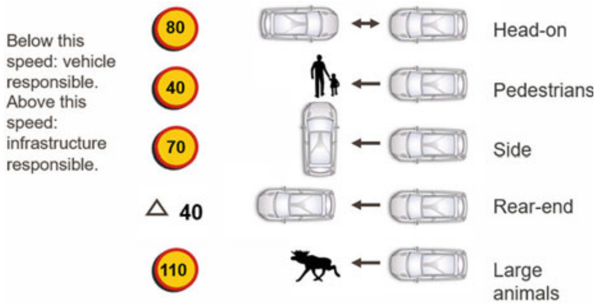

Fig. 14 Division of responsibilities between vehicle manufacturers and authorities

these various factors make the opportunities for agreements on standards and principles a huge challenge, both legally and in practice.

Manufacturers Sharing Research Data

In order to make motor vehicles safer, the knowledge gathered from real-world crashes is key and an invaluable asset. Since 1970, the Volvo Accident Research Team has compiled data from crashes involving Volvo vehicles. This data is and has been essential in understanding what happens during a collision.

With the EVA Initiative (Equal Vehicle safety for All), Volvo is sharing the results and knowledge of 50 years of research. By letting all other interesting parties download this, it will help to make cars safer. Volvo Cars is encouraging other OEMs and suppliers to join in on this effort.

EVA is assisting in identifying a number of data points that may be assembled and rejoined in order to get a more complete and comprehensible view of how to analyze the research data and help to use this data for improved and innovative safety systems.

What becomes clear from the research data is that women presently run a higher risk of getting injured in crashes than men. By using the research results available, it is possible to scale the data points in order to adapt them and be able to scale this to be able to accommodate for both the size and tolerance differences between men and women. This is part of a continuous effort in reaching the goal of having equal protection for all occupants, regardless of gender, size, age, and other tolerance level differences.

This strategy for reaching equal protection between the genders should be and must be the target of all OEMs in designing cars for the future.

One result showing the advantage of using this approach is the development of new technologies in the design of the Volvo Whiplash Protection System “WHIPS,” a system that is built into the front seats and is designed to reduce the loading on the neck of the occupants. When looking at the data of occupant injuries after this restraint had been on the market for a number of years, it was clear that there was a significant lower number of whiplash injuries, in particular for women.

Further Improvements of the Infrastructure

As discussed in the earlier chapter, the design and basic structure of the infrastructure in most parts of the world have had the same outlook for the last century. Some parts are clearly not compatible neither with the present status of the modern vehicles nor with the level of intensity of modern traffic. Infrastructure improvements to reduce the risk for simple human mistakes having serious consequences should be the primary focus in making structural changes in combination with eliminating the types of crashes that will create the highest number of human casualties instead of focusing on transportation efficiency.

As examples of improvements with high potentials of reducing the risk of serious crashes are adding a median barrier on multi-lane highways and other roads or reshaping junctions with crossing high speed traffic with roundabouts or multi-layered viaducts.

Head-on collision is, by far, the most critical crash scenario and the most difficult one, when it comes to impact violence and possible measures to protect the occupants. Having median fences on higher-speed roads would efficiently remove this type of scenario from the radar and put other types of scenarios more in focus for further improving occupant protection, scenarios where measures would be more efficient in reducing fatalities and serious injuries.

A new type of median fence was created in the early 2000s, i.e., a wire fence that guides the car that is swerving towards the oncoming lane back into the ego lane. This type of fence has proven to be highly effective in eliminating head-in crashes (Vadeby 2016).

In-plane crossings and junctions, with high speed limits, share the basic flaw of requiring the full attention of the drivers at all times, and a mistake might lead to serious consequences. This flaw is equally valid for crossings with traffic lights. Human mistakes or drivers running a red light makes this type of scenario severely critical.

In line with one of the principles defined by the Swedish Vision Zero strategy, a human mistake should not lead to serious consequences, but the road structure should be forgiving and absorb this mistake without casualties.

By replacing in-plane crossings and junctions with roundabouts or multi-layered viaducts, the risk of driver mistakes leading to serious consequences will have the potential of being significantly reduced.

Roundabouts require the drivers to reduce the speed and look out for other vehicles in the roundabout which in turn increases the attention level. Although the number of low-speed crashes is likely to increase, the number of casualties goes down.

Measures for reducing the risk of cars injuring or killing pedestrian or other vulnerable road users could be separation of cars and VRUs. Another way practiced in many cities in Europe is to create chaos mixing the different types of road users, thus reducing the speed and creating a low-risk environment. The principle practiced for these examples is an allowed speed of approximately 7–10 kmh and that VRUs in these areas always have the right of way.

Most modern vehicles are or have the possibility of being connected. This opens up for introducing the concept of geofencing into the infrastructure. The technology linked to this may, by connecting up vehicles, restrict the usage of vehicles in a number of different ways. Forced reduced speed limits next to schools, hospitals, or residential areas, limiting driving using combustion engines in city centers, or only allowing pedestrian-friendly cars (e.g., equipped with automatic braking systems for pedestrians) are among those opportunities.

Further Vehicle Development/Autonomous Vehicles

In parallel with the developments of motor vehicle safety, improving occupant crash protection, supporting drivers to avoid or mitigate crashes, and also activating autonomous systems, e.g., autonomous braking and steering, the development of autonomously driven vehicles offers a high level of opportunities for improving traffic safety.

In looking at the cause of motor vehicle crashes, it is estimated that around 90–94% of them involve human error. Autonomously driven vehicles, where the control of the driving is completely resting with the cars, have the potential of almost eliminating the risks associated with human error.

At the moment, there is an intense activity among the manufacturers to develop and test highly autonomous vehicles. The majority of these activities concern passenger cars or smaller vehicles, such as pod cars or smaller buses, but the heavy vehicle industry is also getting more into this important development.

Most national governments, states, or provinces worldwide have adopted rules for testing. Many vehicle manufacturers also have received permits to test self-driving vehicles on public roads.

An autonomous vehicle will have extensive capabilities both to drive safely and by being well prepared for any risks that may be encountered on the operational design domain (ODD) that it is operating on. By having very highly defined maps and extensive sensor and dual redundant computer capabilities, it will be able to deal with all the risks that can be somewhat likely on this ODD. The driving strategy that is pre-programmed into the vehicle and the downloaded map means that it will drive in a way that is exceedingly safe and it will make tactical and strategical decisions based on this.

A whole catalogue of risk situations will be pre-programmed into the vehicle's central computer. The basis for this is the data of crashes and incidents that have been collected for many years, both by the company through its accident investigation team and by governments and academia, and that forms a basis for covering both the most common incidents and crashes as well as rarer or edge cases. The basis for the AD vehicle design is that vehicles should be prepared for any crashes or risks that are somewhat likely to occur on the whole fleet, consisting of hundreds of thousands of vehicles during decades of driving and on similar ODDs globally.

This knowledge of what kinds of crashes or incidents cannot be gathered by purely road testing but needs to be based primarily on previous knowledge plus what can be added from purely AD-related causes (Lindman 2017).

RAND cooperation has estimated in its report (RAND Corporation 2016) that it would be necessary, by applying only public road testing, to drive hundreds of millions or billions of miles to verify the safety. Even with aggressive and ambitious testing programs, it would take tens or even hundreds of years to reach the levels of miles required. So, test driving alone cannot be used to demonstrate the safety level.

Therefore, the data bases with crashes and incidents are used to provide the knowledge needed. This data is used to simulate the situations that the vehicle's sensors need to register, and the vehicle's central computers then have to analyze and decide on the most appropriate actions. Any knowledge gathered from the road testing will, of course, also be added.

So, basically, the autonomous vehicles need to apply road driving strategies and tactics, preparing them for any reasonably scenarios that may occur on the ODDs. Primarily, this means that the vehicles should be able to handle situations without any drama and risk. If something unanticipated occurs, there should always be an exit strategy to handle the situation.

Within the public domain, both in media and within the academia, so-called ethical dilemmas are widely discussed. An ethical dilemma suggests that autonomous vehicles may end up in situations where they have to decide between undesirably scenarios. This is not recognized as a reality among vehicle manufacturers. With the principles for designing the safe handling of the driving, the autonomous vehicles will have a way of dealing with this safely by avoiding being faced with this kind of dilemma.

The technology is yet, however, only at the first initial stages of development, and it will take decades before it can make a serious impact on the number of traffic casualties. Normal cars of different ages and safety levels will also remain on the roads for still a long time in the future.

However, autonomous vehicles have the potential of making an impact by influencing the traffic flows and being a balance to the traffic. Autonomous car will have the built-in capabilities of planning the driving in a tactical and optimized way so that all aspects of comfort, safety, and fuel economy are balanced. The cars will, of course, also stay within the speed limits.

Volvo Cars believes that governments, authorities, manufacturers, suppliers, and other stakeholders should join forces in encouraging this promising development. In particular, the legal requirements' framework should be adapted to embrace and encourage this evolution.

New Ways of Using Transportation

The transportation sector in the modern society faces many challenges, including congestion, health issues due to air pollutions from vehicle emissions and stressful lifestyles due to long commutes, valuable space lost in cities due to parking and spacious infrastructure, and unacceptable traffic casualties.

All of these point at an unavoidable transformation for how people will be mobile in the future. Individual mobility needs to be gradually expanded into different ways of using shared mobility. Different ways of being mobile are expected to be developed in the next decade, such as mobility as a service, peer-to-peer sharing, vehicle fleets and carpooling, etc.

This in turn is aimed to lead to a reduction in the density of vehicles and less risks of individual mistakes leading to crashes. The vehicles used for car sharing are also expected to have a higher standard of vehicle technology including the latest level of safety technology.

This shift in transportation is consequently offering a potential in reducing the number of traffic casualties at the same time delivering many other benefits.

For many cities in the world, among the challenges linked to modern transportation are living quality, the well-being, and the safety of the inhabitants. The mix of different road users of city streets, with vast differences in sizes and tolerances, from large trucks and buses to unprotected humans and speeds not compatible with the tolerances of the vulnerable road users, is causing huge numbers of killed and seriously injured humans on city streets globally.

With the shift in mobility, smaller units the size of passenger cars or vans, optimized to the size of the need of shared mobility for every journey and route, may replace larger outsized buses and other large-size vehicles occupying the major parts of streets and creating challenges for pedestrians, bicyclists, and smaller motorcycles to navigate safely. Thus, smaller units for shared mobility replacing the outsized public buses in many crowded urban areas may offer a benefit not just for occupying less city space but also for reducing the number of traffic casualties further assisting the efforts towards Vision Zero.

In line with the future focus on shared mobility, Volvo Cars has founded a whole new company, M, whose mission is to offer smart car sharing. This supports the shift from ownership to access to vehicles. Other manufacturers, such as BMW, Audi, and Mercedes, also have successfully formed and ran similar shared mobility companies.

With seamlessness and accessibility to mobility, this role model of car sharing offers the potential of reshaping and reclaiming cities that will offer people more space, more comfort, and improved habitat and living conditions.

Cars are parked more than 95% of their lifespan. With the trend of shifting from ownership to sharing, valuable space, now used for parking, and access to parking may be reclaimed and used as part of making moving around in cities safer. In particular, this also will offer a potential for improved safety for pedestrians by remodelling the vehicle and pedestrian interaction.

Discussion

At the same time as the global situation with constantly increasing numbers of traffic casualties is deeply concerning, the success stories coming from systematic and structured systems safety design are remarkable and indeed promising. By combining the potential of modifying the infrastructure, prioritizing the reduction of human injuries instead of the number of accidents, with the technical developments of improved occupant protection and protection of other road users, the resulting reductions of traffic casualties are striking.

The ingredients in these efforts are proven and all necessary in being successful: firstly, an ambitious government vision broken down into goals and action plans; secondly, a motor vehicle industry with long-term targets of improved occupant safety and also the safety of other road users; thirdly, a cooperation between the governments and manufacturers in order to yield optimized benefits out of all the efforts of improving traffic safety.

The clearest shining success story exemplifying this is the Swedish Vision Zero. Reaching a reduction of traffic fatalities in Sweden from initially 16 per 100,000 inhabitants in the 1970s to 2.7 in 2019 is truly remarkable.

Focusing on minimizing the consequences of simple human mistakes, setting the tolerances in the road transport system at the human tolerance levels, inviting all stakeholders to participate, creating a shared view on the division of responsibilities, and sharing data and research knowledge all are ingredients that cannot be foregone in the strategic task of eliminating all traffic casualties.

Setting the safety of the road users as the number one priority and creating design standards for the infrastructure in line with human tolerances have revolutionized the thinking of the safety community. The examples mentioned earlier of replacing crossing with roundabouts and installing median fences on higher-speed roads in order to avoid head-on collisions have proven to be highly effective. These redesigns in turn have opened up for vehicle manufacturers to modify their safety strategies and reprioritize some of their own safety targets.

Significant progress on traffic safety has also been made in other places, particularly in Western Europe. A number of countries, such as the Netherlands, Denmark, and Great Britain, have achieved impressive low numbers of traffic casualties.

The same progress is, however, not seen within all of the countries within the industrial world. On some of the major markets, it appears that the progress of reducing the number of fatalities has more or less stalled and is not meeting the government targets.

The EU is trying to push its low-performing member countries in adopting ambitious targets for the traffic safety.

For the USA, the highest numbers of traffic fatalities were recorded in the early 1970s. These numbers were around 55,000, i.e., the same as the number of US soldiers killed throughout the Vietnam War!

However, during the first part of the 2000s, the USA made some significant progress in reducing the traffic casualties, unfortunately, during the last couple of years, this trend has changed and is now rising again. The number of fatalities in the USA was as low as 32,000 in 2014 but is now back up to 37,000 again. This is indeed a cause for concerns.

For the developing world, the numbers of traffic casualties continue to rise. In many countries in Africa and in the Middle and Far East, the numbers of fatalities reach as high as between 25 and 35 fatalities per 100,000 inhabitants.

The target of the UN Decade of Action 2011–2020 project was to save one million lives by suggesting a number of measures such as improving the safety of the road infrastructure, further improving the safety of road vehicles, and focusing more on road safety management and the leading killer of people aged 5–29 years. Most of the fatalities are pedestrians, cyclists, and motorcyclists. This is the case in particular for those living in developing countries. For the next Decade of Action, 2021–2030, road traffic safety is one of the goals: goal number 3, “Ensure healthy lives and promote well-being for all ages,” with target 3.6, “By 2020, halve the number of global deaths and injuries from road traffic accidents.”

Both from human suffering and a sustainability perspective, the global numbers for road fatalities and serious injuries are clearly not acceptable, and drastic measures are needed. In line with this, the targets for the next decade of action are dire and should be uncompromisable and require all stakeholders to be involved and contribute. As mentioned earlier, most fatalities are vulnerable road users, particularly in developing countries. Systematic planning of the safety improvements of the infrastructure focusing on VRUs and more efforts of the management of road safety in those parts of the world would potentially make a huge difference to the outcome for this category of road casualties. The major contribution of vehicle manufacturers, more pedestrian-friendly body structures, and benign exteriors are clearly beneficial and should be introduced for all new vehicles, and the legal requirements for the vehicle performance in the protection of VRUs and adopted by the UN ECE WP29 need to be adopted by all major markets globally.

The present trends among governments in developing countries, however, do not aim for this level of harmonization of vehicle safety requirements.

Vehicle manufacturers are also strongly encouraged to align their vehicle designs so as to meet the UN ECE requirements as a minimal level of vehicle performance even in countries who have not adopted any vehicle safety requirements.

Unfortunately, there is still a significant gap in the level of vehicle technology introduced in modern vehicles for developing countries as compared to industrialized countries.

This fact is something that is needed to be handled by both the governments and vehicle manufacturers. Governments may harmonize the vehicle requirements with those recommended by UN ECE, offer incentives for the introduction of new advanced vehicle technologies, and inform customers on the benefits of these systems, and vehicle manufacturers should voluntarily speed up the efforts of offering the safest vehicles on all markets.

However, even given the potential of further improvements to motor vehicle safety, the most significant challenges remain for improvements of the infrastructure, enhanced behavior of the road users, and road safety management, particularly in the developing countries.

Conclusions

The Swedish example of safe traffic management in the form of the strategic work linked to the Swedish Vision Zero is a very striking example of how successful such an effort can and should be. The citizens’ safety cannot and must not be traded in for transport efficiency or for economic reasons. The safety of humans must always be paramount in these efforts.

The actions already taken in terms of improving motor vehicle safety and infrastructure changes and applying a safe systems approach to transportation are clearly in a positive direction and will, over time, give a significant reduction in traffic casualties, but with the seriousness in the present situation, stronger and more drastic measures need to be taken rather hastily. All road traffic stakeholders need to cooperate and bear the burden of responsibility for actions leading to progress in aiming for the Vision Zero target in the number of fatalities and serious injuries globally.

It is encouraging, however, when viewing the efforts to systematically approach this situation by involving all stakeholders and the different initiatives that are coming from major international bodies like the United Nations and the European Union.

In spite of the tremendous improvements in traffic safety during the last decades, the present global situation with approximately 1.3 million fatalities is deeply concerning. Since transportation is the backbone of modern society, many hesitations remain on behalf of some stakeholders on how measures for improved motor vehicle safety may affect the transportation flow and efficiency. However, by creating a collision-free traffic environment, with significant less friction in the system, this will create huge benefits by improving the flow of goods and the well-being of road users. Transportation research also clearly show that improved and efficient transportation goes hand in hand with improved vehicle safety.

Among those contributions are making safe and reliable products with the latest advancements in motor vehicle safety and knowledge that are distributed so as to benefit all markets and all road users globally, sharing important research data related to real-life traffic situations and sharing real-time data recorded by the vehicle and related to traffic safety, using safe and sustainable transportations related to all production and distribution activities, and cooperating with all stakeholders in moving safety forward.

Looking at all important players taking part in this effort and with their ambitions and the invested resources, together with the vastly increased knowledge from research gathered during the last decades and combined with the technological advancements and the future anticipated changes in the ways to use mobility in the future, the prospects to succeed with the Vision Zero target look promising and indeed inspiring. ***So, to us all within the global safety community, we are on a mission together, let's do it!***

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What the Car Industry Can Do: Mercedes-Benz' View

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Abstract

The car industry faces some extreme challenges. Alongside the key task that we face of making individual transport climate-neutral, and alongside the new technological opportunities for communication and networking across our whole environment, it is clear that the user behavior of vehicle drivers and of all other road users is also going to change. Bearing all these aspects in mind, our overriding goal remains to make the traffic on our roads safer. Many of the activities in this context are summarized in the Mercedes-Benz "Vision of accident-free driving." The current plateauing of road fatality statistics across the countries of the West is a clear signal that we need to intensify our efforts even further. And indeed, there are still plenty of levers that can be applied in order to optimize and improve these figures.

Following a review of the current situation from the perspective of Mercedes-Benz, the opportunities for further optimization of vehicle safety are now presented in the guise of the latest Experimental Safety Vehicle, ESF 2019, which above all addresses the new possibilities offered by increasing connectivity and automation. Many of the innovative concepts under consideration have a chance of reaching the market in future vehicles, either as they are or in a modified form; in other cases the discussion around them will lead to new ideas and proposed solutions.

The Integral Safety Strategy by Mercedes-Benz is a holistic approach that defines safety in four phases: (1) safe driving, (2) assisting in a critical driving situation with accident prevention systems and anticipatory protection elements such as PRE-SAFE® systems, (3) during a crash, for example, occupant and partner protection, and, finally, (4) after a crash, deploy systems for the rescue phase. All four phases must be high priorities during the development of the vehicle.

Even with an optimistic view of the vehicle-based opportunities, this chapter will demonstrate that vehicle measures alone will not be sufficient to solve all traffic safety issues, as road transportation is just too complex. All the factors that impact road safety, and which will need to play their part in delivering "Vision Zero," must be addressed; in other words, infrastructural measures and people in traffic, too. As with the Mercedes-Benz strategy of Integral Safety, we shall only be able to make major advances toward "Vision Zero" if all influencing factors are properly investigated as part of an integrated examination of road safety.

Keywords

Vision of accident-free driving · Experimental safety vehicle · Pre-accident phase · PRE-SAFE® · Integral safety · Reversible protection measures · Crash brake · Traffic casualties · Stagnation · Speed differences · Different road users · Megatrends · CASE · High relative speed · Physical constraints · Accident risk · Infrastructure · Non-uniform traffic · Vulnerable road users · Preemptive or proactive protection systems · Situatively appropriate protection · Electric mobility · Pyrotechnically activated · Concept vehicles · ESF 2009 · ESF 2019 · Innovations · Cooperative behavior · Highly automated vehicles · Human centric lighting · Daylight+ · DIGITAL LIGHT · PRE-SAFE® Child belt · Slack in the belt · PRE-SAFE® Child side · Side impact protection elements · ISOFIX · Monitoring vital signs · Virtual crumple zone · Partner protection · PRE-SAFE® Impulse · PRE-SAFE® Impulse side · Dissipation of energy · Electric high-performance belt tensioner · Environment sensors · PRE-SAFE® Impulse front · Variability of the seating position · Protective principle "Flight" · Holistic safety concept · Steering wheel · Pedal cluster · Steer-by-wire · Integral sidebag · Rear seat passengers · Beltbag · Rear airbag · Tubular structure design · USB-C port · Heated seat belt · Securing the hazardous area · Warning triangle robot · Self-driving Cars · Roof warning triangle · PRE-SAFE® Side lighting · Emergency lighting

Introduction

The concept and approach summarized as "Vision Zero" was initially developed as a strategy toward the end of the 1990s. It was a strong message, back then. Perhaps it was the steady reduction in the number of road fatalities in Europe around this time that stirred up hopes that this vision could be achieved within the foreseeable future. The idea of "Vision Zero" was adopted in many areas of the world, although at times with varying interpretations: "Zero road accident fatalities," "No serious injuries," or even "No more road accidents."

At Mercedes-Benz, too, the focus had long been on what might be the next stages in the development of vehicle and road safety. Following major advances in the areas of driving assistance systems and accident protection, the question was: What might come after ABS/BAS/ESP or after offset crash simulations, front and side airbags? Some industry experts were already then of the opinion that the future belonged to active safety alone and that there was little potential left to improve occupant protection.

This was not an opinion that was shared at Mercedes-Benz. Just how false the assumptions of such skeptics were has been proved by the next 20 years of development in this field, as I shall go on to show. In 1996, a specialist unit, "Strategies and concepts for vehicle safety," was established within the passenger car development unit at Sindelfingen, tasked with clarifying the questions swirling around at that time. Its aim: to outline two quite new, but closely related approaches to vehicle safety and to bring these to life.

The first of these was that particular consideration in vehicle safety terms should be given to the pre-accident phase of an accident. In this new, anticipatory phase, we even find an overlap between active and passive safety, something of a paradigm shift in safety development. Measures aimed at preventing an accident, or mitigating its severity, run in parallel with those readying the occupant protection systems for the expected impact, rather than consecutively. Innovations in this phase would later be clustered together by Mercedes-Benz under the term PRE-SAFE® systems.

And the second was a fundamentally new strategic approach that took as its premise that future-oriented vehicle safety would only be possible with a holistic understanding of this discipline:

– From the moment the risk of an accident arises
– Through the pre-accident phase
– The actual impact phase, in other words, the crash phase
– To the recovery of the occupants after an accident

Equal priority should be given to each of these phases, marking the birth of what would subsequently become known as the Mercedes-Benz strategy of "Integral Safety" (Fig. 1).

These two approaches were first incorporated into Mercedes-Benz's safety strategy in 1999 and influenced the way for a new era of vehicle safety. They led, step by step, to many innovative solutions as the strategy of Integral Safety was resolutely pursued over the ensuing years.

Making use of the time before the accident was the new direction taken in development work. It was already clear back then that major progress could be achieved with this new philosophy. However, the experts were engaged in long discussions about the right sensor systems that would allow the vehicle to decide to deploy restraint systems before the actual impact. The solution for a quick market introduction was that PRE-SAFE® initially concentrated on reversible measures that were triggered based on data of existing sensors.

The concept of Integral Safety was first introduced at the IAA in Frankfurt in 2000, followed in 2001 by the first demonstration of PRE-SAFE® at the ESV Conference in Amsterdam (Schoeneburg et al. 2001). The first series introduction was in 2002, in the facelifted S-Class of the day, with reversible seat belts and seat priming, as well as automatic closing of the side windows and sliding sunroof.

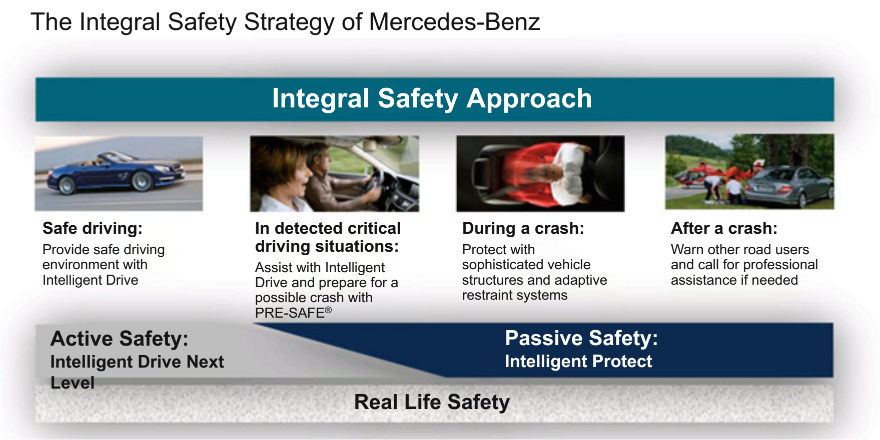

Fig. 1 The Mercedes-Benz concept of "Integral Safety"

The Vision of Accident-Free Driving

The holistic understanding of integral safety and the use of anticipatory measures released new impetus and led to a dynamic new development. While in the first instance, development work focused primarily on reversible protective measures to prepare the occupants for a possible accident, it quickly became clear that the new solutions could also include dynamic handling interventions. And so it was that, as early as 2001, the concept of automatic pre-crash short-term braking in the moment immediately before the impact came about, known internally as the "crash brake." The aim here was to dissipate energy as a preemptive measure, thereby reducing the severity of one's own accident and that of any other partner to the impact – a virtual or electronic "crumple zone," as it were, in front of the vehicle. This approach can be seen as the key innovation in accident avoidance, marking the inception of future accident-prevention safety measures. Even though controversially discussed at the beginning, the idea of being able to avoid the accident altogether in future began to take hold of the engineers' minds. And it was against this backdrop that the "Vision of accident-free driving" began to evolve in the research division at Mercedes-Benz. Accident avoidance can be regarded as the highest level of "vision zero," as it would not only address fatalities and injuries, but also the accident itself.

But at no point did the team surrender to the illusion that this beacon moment would be reached within the foreseeable future – and certainly not by means of vehicle-related measures alone. It was, however, a vision that was extremely important for all the safety experts at Mercedes-Benz, ensuring that projects and resources could all be focused in one direction.

Traffic Involves Risks

Every form of mobility comes with its own specific risks. And that has not just been the case since the invention and wider availability of the automobile. In 1903, for example, there were already 215 fatalities on London's roads (Niemann 2002). The causes were, of course, different from today. Around the turn of the century, more than 90% of such accidents involved horses, horse-drawn vehicles, and carriages. Whenever people travel along a single plane at a finite speed, irrespective of how, there are risks involved. No surprise, then that in 1886 the first motor car also came under the spotlight with regard to safety. In 1888, Karl Benz touted his "Patent Motor Car" as being "comfortable and absolutely danger-free"! to operate, while its "steering, stopping and braking are lighter and safer than with conventional carriages" (Stolle 2004).

However, as we all now know, an increase in motorized traffic on the roads is likewise fraught with danger:

– Driving speeds increased.
– The infrastructure (roads) was not suitable for this type of traffic.
– The automobile, in its early days, was still unreliable and unsafe.
– Traffic levels continued to grow.

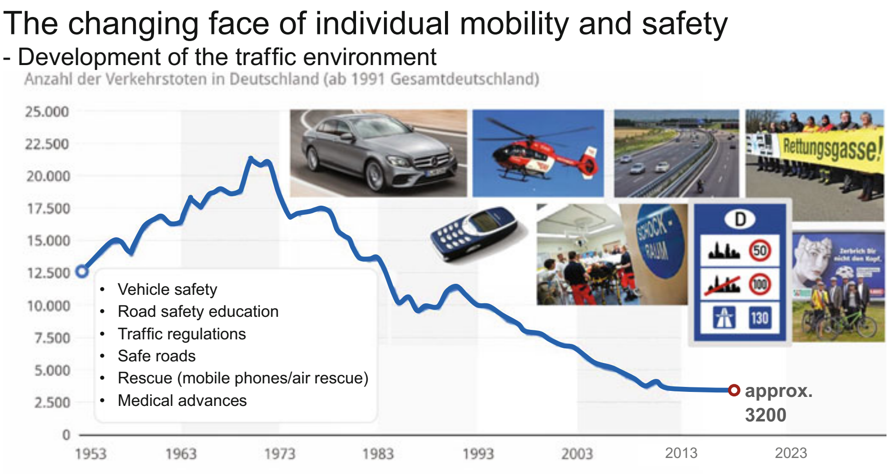

Fig. 2 Road traffic fatalities in Germany since 1953 and the development of associated factors

Such risks had still not been overcome by the 1960s or 1970s. The accident figures continued to escalate; the number of road traffic casualties rose steadily. It was not until 1971 that a turning point in this development was reached in Germany and the accident statistics could be steered on a sustained basis in a new direction. A decade of declining accident casualties set in, despite an increase in the traffic on the roads.

It became evident to the authorities and to all car manufacturers that more vehicle safety was a key to reversing the trend and reducing the number of fatalities on the road. Many pioneering innovations, such as the airbag, ESP, or the configuration of the vehicle body structure to more realistic accident circumstances, brought about sustainable improvements in road safety. Legislators, too, began to put the right framework in place with regard to infrastructure and road traffic regulations.

In the 1970s, it was clearly understood that the automobile alone would not be able to resolve the problem of road safety and that the only way to deliver sustainable and lasting success would be through taking a holistic view of the traffic system. The success story since the 1970s, therefore, is not the result of just one factor but, as so often in life, of many factors (Fig. 2). Alongside vehicle safety, it has been road safety education, new traffic regulations, modernization of the traffic infrastructure, much faster and more effective emergency services and, not least, major advances in medicine that have contributed to the steady reduction in road fatalities over past decades.

Current Developments in Road Safety

However, a look at the latest developments, particularly over the last 10 years since 2010, should give us in Germany, and in many other countries in the west, cause for concern. Looking at the positive trend in road fatality figures in Germany from the perspective of the 1990s, hope back then was perhaps justified that the number of traffic casualties would continue to fall steadily. For some it may possibly even have aroused hope that death on the roads would soon be a thing of the past. The realistic observer, though, would probably have realized that this downward trend would at some point level off. The only question was when, and at what level. And this is, indeed, what has happened. In 2010, this downward trend showed an unexpected significant change of direction, with the trajectory yielding to something resembling stagnation (Fig. 2). Whereas, in the past, road deaths in Germany had fallen by around 500 a year, it now took 10 years to achieve this. What had happened? Do the prevailing circumstances in vehicle and road safety mean that, as feared, we have now reached the end of the road? What new stimulus is now necessary if we are to make further progress and turn that dream of preventing the accident altogether into reality?

Factors Influencing Safety on the Road

First of all, this stagnation in the accident statistics means that there is currently a balance between the factors reducing and those increasing risk. Along with many changes that have the potential to avoid an accident, reduce its severity or protect those involved, there are regrettably also those factors that, for their part, increase the risk of coming to harm and balance out the unquestionably positive factors (Fig. 3).

The risk of an accident is influenced significantly not only by the vehicle itself, but also by the form that road transport takes, both now and in the future. Compared with other extremely safe modes of transport, such as rail or air, road transport is considerably more complex and associated with far greater individual freedom.

Fig. 3 Factors influencing road safety

– There is no separation, in terms of either space or time, between road users and the traffic flows within the same traffic environment.
– The differences in speed between different transport users within a very confined space are extremely high and all movements take place on the same plane.
– All types of different road users are separately under way within the same traffic space (from trucks and passenger cars to pedestrians and cyclists).
– The technological standards of the vehicles that come up against each other in traffic vary enormously.
– The individual skills and attitudes of the road users likewise vary significantly.
– And each road user acts independently.

The design of the transport infrastructure and the traffic environment, but also human influences and traffic regulations, play a significant part in determining the accident risk. Progress toward the achievement of "Vision Zero" will only happen if a holistic approach is taken to addressing all these parameters. The question for us as vehicle manufacturers, too, is to what extent the vehicle itself has an influence and which levers we can apply in relation to the vehicle, particularly in view of new developments in individual transport.

The Automobile and Road Transport in a Time of Change

The automobile and traffic will continue to change in many ways. What is certain is that this process will move far more quickly as far as the actual vehicle is concerned than it will in relation to the constraints applicable to traffic in general. Despite many questions that remain open, the future "megatrends" are clear. These are clustered together at Mercedes-Benz under the acronym CASE. CASE stands for "Connected," "Autonomous," "Shared & Services," and "Electric." And when it comes to assisted driving and increasing automation, expectations are high as far as "Vision Zero" is concerned. But how closely is the automation of road transport linked to the elimination of accidents or "Vision Zero"?

Let us now take a closer look at the possibilities as well as at the limits of automation. Automation makes it possible to move the vehicle through traffic at an appropriate speed and in conformance with legislation. In an automated mode and within the limits defined by physics, the vehicle is able to accelerate, decelerate, undertake evasive maneuvers, or disobey driving commands (Fig. 4). The vehicle can also receive and act upon warnings, or warn other road users or the infrastructure. But all this is only possible if corresponding conditions exist, such as an adequate time window for the action, traction, space for the evasive measure, or the correct functionality of the vehicle.

In a real-life context and in normal traffic, there will always, though, be many dangerous situations in which these constraints, however perfect the level of automation, will mean that the accident cannot be completely avoided. The very fact that road users are moving at a finite speed in a nonuniform traffic environment makes it fundamentally possible that directions of movement will cross or

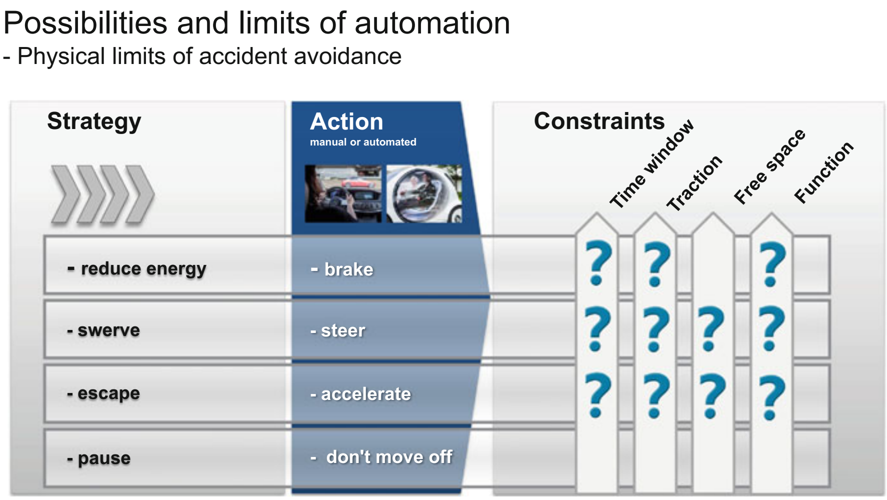

Fig. 4 Physical limits of accident prevention

converge unexpectedly. With any two-way traffic on narrow roads without separation of the carriageways, for example, there is always the inherent risk of a collision with a high level of accident severity due to constricted passing and the high relative speed, to give just one example of a possible scenario. Furthermore, for decades to come, many road users will still not be using automated modes of transport, or can by their very nature not be automated (pedestrians, cyclists, and animals). Nor are the physical constraints necessarily there in terms of the road itself to allow driving commands to be correctly interpreted into reactions on the part of the vehicle. Defective infrastructure or weather-dependent limitations, such as aquaplaning or icy roads, will exist in the future too. And, ultimately, the possibility cannot be completely excluded that, even as automation becomes more prevalent, there will be a residual risk as a consequence of technical defects or functional limitations of the vehicle. And as long as automation, in certain situations, requires the intervention of human beings, or as long as there is an option for the driver to overrule regulated, automated driving, that human influence and thus the potential for misuse will continue to represent a latent danger with a risk of accident.

The shared, general traffic environment – still largely with today's infrastructure and with continuing individual influences from human beings – is therefore likely to remain the prevailing traffic scenario for a long time to come. There is no doubt that increasing automation offers tremendous potential for improving road safety. But it will continue to be necessary, even in the future, to design vehicles with accidents in mind – regardless of whether they are driven by automated means or not. Given today's infrastructure and a nonuniform traffic – a mixture of automated/conventional driving –, the vehicle on its own will not be able to prevent accidents for many years to come.

Implications for the Vehicle

So, going forward, the vehicle must continue to reflect the concept of Integral Safety (Fig. 1). In terms of accident prevention, the mitigation of accident severity, the protection of external road users and of the vehicle occupants themselves, as well as the post-accident phase, major efforts will continue to be required if we are to get closer to "Vision Zero." However, to anticipate the potential for preventing accidents attributable to the increasing automation of road traffic by reducing the priority given to accident prevention is something to be avoided at all costs.

In order to **drive safely**, the vehicle in manual mode must be in a position to "forgive" and compensate as much as possible for errors made by its driver. It is designed to assist and to intervene automatically in the event of danger. There is no question that this is an issue that needs to be discussed in considerable depth and with great sensitivity. When driving in automated mode, the connected vehicle must be in a position, as it communicates with its surroundings, to move safely through traffic and to use intelligent algorithms to recognize the potential for danger well in advance and take corresponding action. The vehicle can thus generate advantages for other road users as well as for its own occupants. The more vulnerable road users in particular, such as pedestrians, cyclists, and motorcyclists, who are subject to inherent limitations in terms of accident protection measures, can benefit in this respect. The vehicle of the future must leverage its anticipatory, safe, and cooperative style of driving to win the trust of its occupants and of those partners with whom it shares the road.

The **PRE-SAFE® phase** will become more and more important as time goes by. Innovative solutions that move vehicle occupants into the best position to provide protection in the event of an accident will become more and more important as the level of automation increases. Preemptive or proactive protection systems, as already seen with the Mercedes-Benz PRE-SAFE® Impulse safety systems, will continue to improve and enhance the possibilities for protecting occupants. In line with this idea of preventive action, it is also important, in situations where an accident appears imminent, to warn anyone else near the vehicle and thereby to mitigate the potential danger for other road users.

There will also be plenty of scope for action, going forward, in the third pillar of the Integral Safety concept, **situatively appropriate protection in the event of an accident**. Automating the actual task of driving will change the behavior and habits of the occupants in the vehicle. We can expect to find that people who are no longer permanently tied to the controls of their vehicle will want to position themselves differently within the vehicle. This idea poses major challenges in terms of occupant protection and of the vehicle interior, which until now has always been configured to ensure the correct position of the occupants in the vehicle. Electric mobility, too, presents new challenges in terms of protection in the event of an accident. The current range of Mercedes-Benz vehicles with electric drive system, for example the EQC, demonstrates that there is no need to compromise when it comes to matters of safety. The vehicle structure and all electric components, such as the high-voltage battery, for instance, are configured to cope with the many ramifications of real-life accidents. With electrically powered vehicles, it is even possible to exploit quite new potential for protecting both occupants and any other parties involved. The powerful onboard electrical system, for example, offers the possibility of using electric means to trigger protection systems that until now were pyrotechnically activated, thus making them reversible, or in other words reusable.

For the last pillar of "Integral Safety," the **post-accident phase**, there are also lots of new ideas for the future. Modern communication tools make it far easier to activate the chain of rescue. There will also be solutions that no longer make it necessary for anyone involved in an accident to secure critical traffic situations manually themselves.

As a means of addressing all the issues that we have been talking about and to create a platform where Mercedes-Benz's possible approaches can be discussed with safety experts, the press, and customers, the decision was reached within our company to create a so-called Experimental Safety Vehicle known as the "ESF," for the German words for this term. "Learning by doing" has always been the motto behind the development of concept vehicles of this nature.

The ESF Experimental Safety Vehicles as Technology Platforms

Experimental Safety Vehicles were used as far back as the 1970s in the context of the "International Technical Conferences on the Enhanced Safety of Vehicles" (ESV) as a basis for the design, practical demonstration, and discussion of safety concepts for future vehicles (Weishaupt 1999). It became evident that these concept vehicles had a particularly valuable role to play as tools for learning and as opinion formers in professional circles as well as among the wider interested public. They provided a means of testing and ensuring the feasibility and acceptance of such future solutions for accident prevention.

That earlier idea of demonstrating futuristic technologies as part of an experimental vehicle was picked up again in 2009. The ESF 2009, based on the S-Class of the time (Fig. 5), proved just as successful. The key features of the more than 20 innovations incorporated into this concept vehicle demonstrated new PRE-SAFE® solutions or improved occupant protection in the rear of the vehicle. Today's current Mercedes vehicles, meanwhile actually incorporate many of the ideas shown back then.

The positive experiences made in relation to new safety-related technologies on the basis of the ESF vehicles provided the impetus for once again adopting this promising approach when it came to the latest investigations into the implications for vehicle safety of increasing vehicle automation and electric mobility.

The Mercedes-Benz ESF 2019 Experimental Safety Vehicle

In 2016 it was agreed that, to mark 50 years of accident research at Mercedes-Benz, a new ESF 2019 would be built as a way to demonstrate innovations and ideas in line with the following requirements:

Fig. 5 The ESF 2009 with the most important earlier ESFs from Mercedes-Benz

– Opportunities and potential solutions stemming from increasing connectivity and communication
– Occupant protection systems that need to adapt as a consequence of the increasing automation of road transport.
– Safety and electrical mobility
– The safety potential of new technologies

The search for solutions across the full spectrum of Integral Safety brought together an ever-widening consortium of different specialist units. This spurred on the creativity of the concept team, releasing a powerful and motivating dynamic impetus. The absence of pressure, when an ESF is being designed, to make something immediately series-ready, furthermore allowed the team to introduce various avant-garde and very futuristic solutions (Schoeneburg et al. 2019).

The ESF 2019 on the basis of the GLE saw many of the topics listed above addressed and solutions mooted (Fig. 6). The development and planning of this research field represented a whole new ball game for everyone involved as they worked through the concept and implementation phases. As far as the innovations that it incorporates are concerned, it marks a new milestone in vehicle safety. The following chapters will now examine the most important innovations of this concept vehicle in detail (Niemann 2019).

Informed Confidence – Cooperative Behavior and Intuitive Communication

Informed, rather than “blind,” confidence is a key factor determining the successful integration of a highly automated vehicle into the future traffic environment. This assumes, first and foremost, that the algorithm is configured for cooperative behavior – comparable with a considerate driver. Typical examples include stopping at a pedestrian crossing, allowing a gap so that other traffic can filter in, or moving to one

Fig. 6 The ESF 2019 on the basis of the Mercedes-Benz GLE

side to create an emergency lane. And secondly, particularly with respect to highly automated vehicles, the concern is to find ways to provide information about the vehicle's intentions that will be immediately and intuitively understood by other road users. Researchers at Mercedes-Benz are looking, for example, at the use of turquoise-colored light signals to indicate that the vehicle is in a highly automated mode. The ESF 2019 also demonstrates how the vehicle might communicate with its surroundings, thereby mimicking the gestures and facial expressions of a driver. In addition, highly automated vehicles can help other road users to avoid accidents, by sharing their awareness of potential dangers with their immediate surroundings. By using their extensive environment sensors and their connection to a backend server, they can provide warning of wrong-way drivers or localized hazards, for example. Any warning of a hazard is given via visual and acoustic signals. Even when parked, a vehicle like this can warn other road users if they appear to be heading for a collision (Fig. 7).

Biologically Effective Light – Daylight+

For some years now, scientists around the world have been investigating the trending topic of "Human Centric Lighting." What is meant here, primarily, is the psychological as well as physiological impact of light on a person. Light can have either a calming or stimulating effect, thereby reinforcing attention levels during the day or supporting the winding-down phase in the evening. In recent years, a series of scientific studies have been undertaken at Daimler AG to investigate the psychological and physiological impact of daylight, as well as of "biologically effective light," on vehicle drivers and passengers. The focus of this work was on those aspects with implications for driver-fitness, as well as on improving the occupants' overall sense of wellbeing. In the ESF 2019, the adaptive Daylight+ system ensures the provision

Fig. 7 Informed confidence/cooperative communication with the environment

of biologically effective light to the driver at the wheel. The light helps to counteract the driver's tiredness and, by doing so, can ensure that the driver remains alert for longer. Ultimately this leads to improved driver behavior and increases vehicle safety noticeably. In addition, it is possible to revitalize oneself during a break in driving with a "light-shower," as a quick way of freshening up. A light-shower might therefore, for example, be used at the end of a power nap (a short period of sleep outside the main night-time sleeping phase), as a means of getting into a physiologically beneficial condition. The system thus gives the driver the opportunity to ensure that they are fit enough to continue their journey safely. This function could also easily be integrated into a highly automated vehicle; the vehicle can detect in advance when the driver is ready to drive again themselves (e.g., once a tailback has dissipated or as soon as the vehicle leaves the city and reaches the open road). In plenty of time before this happens (perhaps a quarter of an hour), the light-shower starts, revitalizing the driver for the imminent task of driving. Alertness improves, making the journey altogether safer. In highly automated driving mode it is also possible to lean back and enjoy a light-shower as preparation for the busy day ahead (business meeting, sports event, or similar).

Seeing and Being Seen

Many hazardous situations and accidents arise at night. The revolutionary DIGITAL LIGHT headlamp technology facilitates pioneering driving assistance and communication with the driver and can create almost perfect light conditions in any driving situation. The new headlamps of the ESF feature chips with a multitude of microreflectors. The advanced functionality here means that this adds up to several million micro-reflectors per vehicle. Cameras and sensor systems also detect other road users, while powerful computers evaluate the data plus digital navigation maps in milliseconds to give the headlamps the necessary commands to allow them to adapt the light distribution in the ideal way in any situation. With the innovative software-

Fig. 8 DIGITAL LIGHT – projection of symbols onto the road in HD quality

controlled DIGITAL LIGHT technology, symbols can also be projected onto the road in HD quality (Fig. 8). This not only provides the driver with information in their direct field of vision but, in the ESF 2019, also allows them to communicate with their surroundings.

Child Safety

The basis for this innovation in the ESF 2019 is a standard child's seat, suitable for children from 0 to 4 years of age (Fig. 9). The seat has a rotation function, which means that it can be used facing either toward the front or toward the rear. This feature also offers the option of turning the seat in the stationary vehicle to a 90° position to make it easier to lift the child in or out. This standard process is used for the mechanical pretensioning of the PRE-SAFE® Child Belt System. The special feature here, which provides the basis for all other features, is that the seat is wirelessly connected and thus able to exchange information with the vehicle. As a result, it is possible to introduce some important safety features and, on the other hand, to offer certain hitherto unknown comfort and convenience features.

PRE-SAFE® Child Belt

The preventive tensioning of the seat belt integrated into the child's seat can, for example, take up any slack in the belt and thus also reduce the peak loads in a crash,

Fig. 9 Networked child seat with PRE-SAFE® functions

thanks to the way the vehicle electronics are networked with the seat. A PRE-SAFE® system sends a radio signal to the child seat which will then, in the event of an impending front, rear, or side impact, activate the belt pretensioner. This process does not depend on an external power supply and is furthermore reversible.

PRE-SAFE® Child Side

Side impact protection elements are designed to further enhance the protection of the child in the child seat. They are triggered as a preventive measure in a detected critical situation that can lead to an accident. This happens whichever way the seat is positioned to face, but always only on the door side. The side impact protection system extends over a length of 100 millimeters and is designed to reduce peak acceleration in a crash. The PRE-SAFE® signal is a radio signal transmitted by the car to the seat with the effect that, if a side impact threatens, the side impact protection elements will be extended and belt pretensioning activated. The system is mechanically pretensioned by manually pressing the side impact protection elements into the seat. It does not depend on an external power supply and is furthermore reversible.

Installation Monitoring

LED status lights mounted on the seat itself provide direct feedback about the installation, monitoring the following parameters: ISOFIX connectors, supporting leg, seat buckle, belt tensioning, PRE-SAFE® readiness, seat base rotation function locked into position, radio connection with the vehicle, and external power supply. These parameters are likewise sent to the vehicle, providing the driver with clear information about the child seat in the vehicle display. In the event of incorrect installation of the child seat, an animation in the display helps the driver find a solution to the issue.

Monitoring of Vital Signs

In addition to the installation data, the seat monitors the child's vital signs and presents them in an easily understandable way. The temperature around the seat, as well as the child's pulse, breathing, and state of wakefulness are monitored. During a journey, the driver is furthermore kept informed by helpful animations of the state of the child's wellbeing, without being at all distracted. This information relates to the time spent sleeping, waking, or sitting and can be retrieved live on a mobile phone via the Mercedes me App.

Baby Live Video

When the vehicle is stationary or travelling at low speed (<5 km/h), an HD camera integrated into the child's seat can be used to transmit a live video to the vehicle display or to a mobile phone (Mercedes me App).

The Virtual Crumple Zone:

Besides understanding how road crashes happen and how the safety systems perform, the ultimate goal of accident research is to find ways to mitigate or even prevent accidents all together. The stiff passenger cell, combined with a physical "crumple zone" specifically designed to absorb the energy of an impact by deforming, will always remain a vital concept but should be viewed increasingly as the last resort. New mechanisms must be able to trigger well before the actual moment of impact in order to replace the effect of a physical crumple zone. To do this, the vehicle needs to have at its disposal the necessary information that will allow it to react of its own accord at as early a stage as possible. To react, in this context, means that, if there is an impending risk, the vehicle will automatically slow down, take evasive maneuvers, or possibly even accelerate. The information needed in order to realize this is comparable to that needed for the implementation of highly automated driving. It includes performant sensors (e.g., for the measurement of distance, proximity, and location), together with comprehensive networking capability between the systems in the vehicle and with the vehicle's environment.

The ability to monitor the full surroundings of the vehicle visually, but also to become aware of them before they become visible, for example, through car-to-car communication, will be an indispensable skill in the future. No less important is the accurate evaluation of these countless pieces of information and the ability to use them to identify the correct course of action. Intelligent information received via sensor systems and communication tools will expand enormously the "field of view" and the "field of the not-yet-visible." If the spontaneous occurrence of a hazardous situation means that the accident-prevention measures outlined here are not sufficient to avoid a collision completely, the vehicle will actually initiate measures before the collision, in other words before the moment of impact with the other party involved that will help reduce the consequences of the accident. We call this concept the "virtual crumple zone" (Fig. 10). This covers the time from the moment

Fig. 10 The virtual "crumple zone"

when the vehicle first reacts to the information from its sensors during the pre-accident phase to the moment the deceleration of the vehicle instigated by its physical crumple zone begins. Examples of such reactions include braking or the forward acceleration of the occupants. The virtual crumple zone is not spatially defined but will depend on the specific circumstances. It comes into particular effect in cases where it recognizes that the collision is already unavoidable. In order to provide the best possible protection for the vehicle's occupants as well as for other parties to the collision, all available (surroundings-related) information will be used to trigger all measures, such as the reduction of speed, as soon as possible. By the time an object penetrates the virtual crumple zone, the information from the system about the impending crash is already available. The vehicle now has just a few milliseconds in which to deploy practical measures to protect the occupants and the other party involved as best possible.

With respect to partner protection, the virtual crumple zone also permits cooperative crash configurations whereby, for example, the height of the vehicle can be adjusted to the opposing party.

The Fundamental Premise Behind PRE-SAFE® Impulse and PRE-SAFE® Impulse Side

Further components that are also activated as soon as the other party to the accident penetrates the virtual crumple zone are the PRE-SAFE® Impulse systems. Deliberate forward acceleration of the occupants can reduce their relative velocity within the vehicle and thus the extent of the forces acting on them in a crash (Fig. 11). In an impact from the side, this safety system propels the driver or front-seat passenger, for example, toward the middle of the vehicle by means of small air cushions in the seat backrest. The occupants thus move in a direction that takes them away from the intruding side wall, thereby creating additional space. The other restraint systems, such as the sidebag, are configured to accommodate this forward momentum and will use the now enlarged deformation space for the dissipation of energy.

It may also be necessary – particularly with new interior concepts designed to allow a position of comfort for the driver during highly automated driving – to

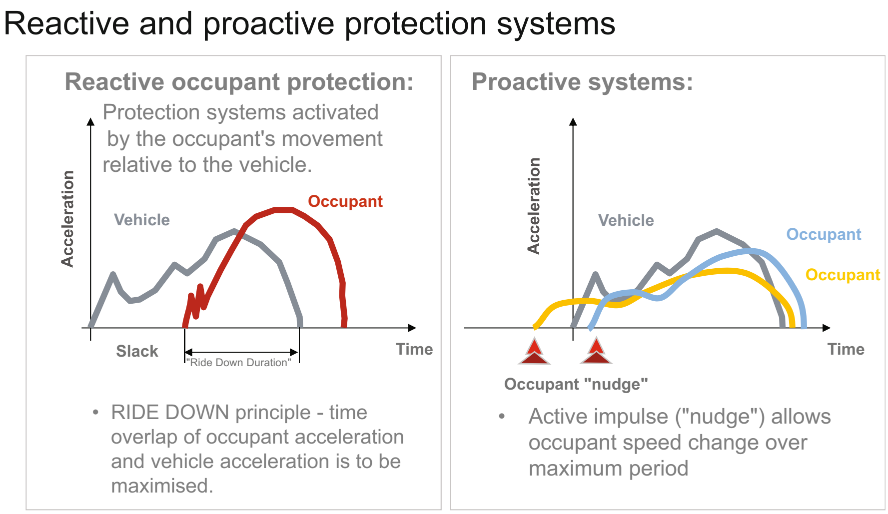

Fig. 11 The concept of "proactive" protection systems – PRE-SAFE® Impulse

preposition the occupants in readiness for the impact. This idea in turn influences the design of the seats and seat belt system, since the primarily longitudinal direction of the forward impetus (front/rear) means that the electric high-performance belt tensioner cannot be used with this positioning.

PRE-SAFE® Impulse for a frontal impact has been available since the S-Class generation launched in 2013. The PRE-SAFE® Impulse Side system that was demonstrated in the ESF 2009 has been available as an option in the E-Class since 2016. As the performance capability of the environment sensors in the vehicles grows, so too does the number of predictable scenarios, thereby raising a whole raft of new possibilities for the further development and deployment of PRE-SAFE® Impulse systems.

PRE-SAFE® Impulse Front: Electric Belt Tensioners Instead of Pyrotechnics

If the algorithm responsible predicts a frontal collision and the accident appears imminent, the PRE-SAFE® Impulse Front system can move the occupant back as far as possible and out of the danger zone. To achieve this, the system in the ESF 2019 is fitted with seat belt units that feature very powerful electric motors. In just a few milliseconds an impulse is sent through the seat belt that allows the front-seat occupants to become part of the deceleration process from a very early stage and, in some situations, can move them out of the danger zone. The tensioning force of the belt can also in this case be adjusted to the situation predicted by the sensor systems. It is therefore also possible to suggest various possible stages of escalation for the current PRE-SAFE® belt tensioning device. The further development of the system means that a pyrotechnical belt tensioning device is no longer needed in the belt unit of the ESF 2019. This brings benefits in terms of the space required for installation and thus of the options for integration. Particularly in cases, as here, where the belt unit has to be integrated into a seat, since the variability of the seating position makes a seat with integrated seat belt a vital requirement in the ESF 2019.

PRE-SAFE® Impulse Rear

This new system attempts to prevent collisions at the end of a line of tailbacked traffic, or at least to mitigate the severity of the accident. As soon as the ESF 2019 comes to a standstill in traffic, numerous sensors work to monitor and interpret everything around it. If the vehicle behind appears to be approaching too fast, its driver will be alerted to the situation by hazard warning lights and a tailback warning projected onto the rear window of the ESF 2019. If the system recognizes that a rear-end collision is nevertheless imminent, and assuming there is sufficient space between the ESF 2019 and the vehicle in front, the system will briefly take advantage of this gap to undertake a calculated evasive maneuver in a longitudinal direction. Maximum acceleration is applied very briefly, followed by hard braking. In an ideal situation, the accident can be avoided this way. Certainly, in most cases the severity of the accident will be reduced by this targeted and time-controlled motion; the impulse is synchronized precisely in such a way that the impact takes place at the end of the acceleration phase. There are two advantages to this: first of all the relative speed of the crash is noticeably lower; secondly, by this time the occupant's head is already braced against the head restraint, thus significantly reducing the risk of neck injury (whiplash).

This system is able to exploit the benefits of electric mobility, since the low latency required in the sudden demand for acceleration is more easily achieved with an electric motor than with a combustion engine, due to the speed at which the rated torque is reached. With PRE-SAFE® Impulse Rear, for the first time, the protective principle of "flight," in other words acceleration rather than deceleration of the vehicle is applied for the protection of occupants and other parties involved.

Occupant Protection Systems for the Driver, New Interior Layout

Automated cars such as the ESF 2019 bring the vision of accident-free driving that little bit closer. However, in an era of automated and autonomous driving, what is needed is a holistic safety concept with many innovative solutions, as passengers may enjoy more flexible seating options in the interior than they do today. The ESF 2019 adapts itself to the situation: when it is driving in fully automated mode, the steering wheel and pedal cluster are retracted (Fig. 12). Together with the level, padded floor, this is not only able to reduce the risk of injury in a crash, but also clearly indicates that the vehicle is in automated mode.

Fig. 12 New steering wheel and pedal cluster concept

Fig. 13 Seat-integrated seat belt and electric high-performance belt tensioner

Coordinated interaction between the seat belts, belt tensioners, belt force limiters, and airbags is a standard feature of Mercedes-Benz restraint systems. As the passengers in automated vehicles might not always be in the best possible seating position in relation to present restraint systems, new ideas are necessary. For example, the belt system has been integrated into the front seats (Fig. 13), so that even when the occupant is in a more relaxed position, the belt fits as closely as possible. The belt system also features an electrically powered high-performance belt tensioner, as previously mentioned. This not only tensions in PRE-SAFE® situations, but is also able to react immediately before the moment of impact to tension the occupant's seat belt to an extent adequate to ensure that even when projected forward, he/she is pulled back into a more favorable, upright position.

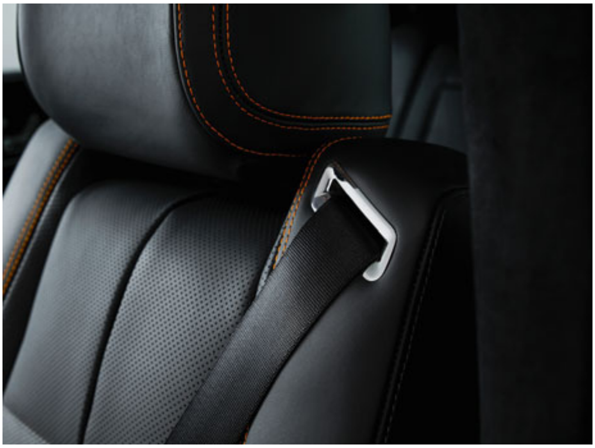

Fig. 14 New driver airbag for highly automated vehicles

The new flexibility in the interior requires new airbag systems with alternative installation spaces. In the ESF 2019, for example, the driver airbag is located in the dashboard, not the steering wheel (Fig. 14). This deployment concept, already familiar from the front-passenger airbag, plus the three-dimensional airbag shape it makes possible, allows greater coverage. For a better view of the instruments and displays, and to position the airbag where it is least obstructed, the steering wheel has a flattened upper section. The Steer-By-Wire technology in the ESF 2019 – in which steering commands are transmitted electrically and not mechanically – supports the new, somewhat rectangular steering wheel geometry (Fig. 12). As the steering ratio is now variably controllable, it is no longer necessary to use both hands to grip the steering wheel when steering. Maneuvering, for example, requires significantly less movement of the steering wheel, even for a large turning angle.

Another completely new development is also due to the greater seating flexibility: the integral sidebag (Fig. 15), which deploys from the side bolsters of the seat backrest on both sides. The wing-shaped airbag wraps itself around the shoulders, arms, and head of the seat occupant. What is so special about it is that it not only protects the passenger on the side facing the impact. As a so-called center airbag, it can also cushion the passenger on the side away from the impact (known as a far-side impact) and prevent him/her from moving too far toward the middle of the vehicle and a possible passenger alongside.

Safety of Rear Seat Passengers

The attention paid to the safety of rear seat passengers at Mercedes-Benz has always far exceeded the legal requirements. Examples here include the rear belt tensioners and belt force limiters, sidebags, and Windowbag that have already been available for several generations of the vehicle. An inflatable rear seat belt was offered for the

Fig. 15 Integral sidebag for any seat position

Fig. 16 Rear bag within the seat backrest for a particularly gentle deployment

first time in the Mercedes-Benz S-Class. This beltbag, as it is known, can reduce the risk of injury to rear seat passengers in a frontal collision by reducing the load on the ribcage. The larger surface area of the belt strap created in this way results in better distribution of the forces acting on the seat occupant, thus lowering the risk of injury.

In the ESF 2019, the beltbag is further complemented by a new-style airbag for the rear seat passengers. This improves protection of the head and neck area in particular and leads to a further reduction of the risk of injury (Fig. 16). This new type of airbag deploys out of the front seat backrests and, by gently cushioning the head, lessens the forces acting on the seat occupant. The functionality of these rear airbags differs, however, from that of a conventional airbag. They use a unique concept that is deployed here for the first time anywhere in the world. Only the actual structure of the air cushion that gives the airbags their shape is actively inflated. The remaining capacity of the airbag is filled by drawing in the ambient air. This new-style tubular structure design allows the air cushion to deploy without any risk to either adults or children.

Safety and comfort are core values for automotive customers. Innovations will continue to reinforce these core values in future, too. A seat belt extender simplifies the buckling-up process for passengers in the rear and helps to improve seat belt wearing rates. An invitation to the passenger to fasten the seat belt is also conveyed in the form of a light integrated into the seat buckle. It is even conceivable that, in future, the fastening of the seat belt could be rewarded by making it possible to charge a mobile phone via a USB-C port in the belt buckle once the buckle is fastened. Components could thus play their part in enhancing not only comfort, but also the effectiveness of the safety systems. A heated seat belt creates a warming effect close to the body, which is actually very pleasant and, indeed, efficient, negating the need for the occupants to keep their coats on in winter. This also brings clear benefits in terms of safety in the event of an accident: without a jacket or coat there is less slack in the belt, thereby improving the starting position for the occupant in the event of a crash.

Securing the Hazardous Area (Accident or Breakdown)

Anyone experiencing a breakdown or perhaps an accident is going to be exposed to a high level of stress. You have to get yourself and potentially other vehicle occupants to a place of safety and the emergency services and/or recovery services need to be alerted. It’s also essential to secure the scene of the incident, which in certain circumstances can mean walking 200 m or so up the road against the traffic to put the warning triangle in place. In the ESF 2019, all this is the responsibility of the warning triangle robot. This is activated either automatically or by the driver and will then drive of its own accord to the prescribed position in order to secure the scene (Fig. 17).

As soon as the robot has emerged from its box underneath the vehicle, the illuminated warning triangle that is integrated into the roof opens up to warn

Fig. 17 Securing the scene of an accident – warning triangle robot and roof warning triangle

approaching traffic of the danger with a flashing light signal. Once the danger has passed, the warning triangle robot automatically returns to its box. This way no warning triangle gets left by the side of the road, and the driver is not exposed to a dangerous situation once again. Self-driving cars, such as app-based or automated ride-sharing services, represent another potential area of use. In the event of a need to secure a hazardous situation arising during a driverless journey, or even during a completely unmanned journey, this action can be undertaken automatically – a clear safety advantage. Although of course self-driving cars of this nature are more likely to be used in big cities. The ability to secure the scene of an incident in a tailback situation will here gain corresponding importance. In a situation like this, the putting up of a warning triangle by the warning triangle robot, as indeed the erection of a conventional warning triangle, could not only be dangerous but also have no significant effect. The visibility of a warning triangle on the ground is severely restricted by the very limited gaps between the vehicles. The consequence here is that the other road users might only become aware of the hazardous situation when it is already too late, which could lead to further accidents. As a way of compensating for this, the ESF 2019 includes an additional fold-out warning triangle integrated into a roof-mounted module. Complex accidents in which a vehicle suffers several impacts or even in some cases rolls over multiple times can also occur. In a scenario like this, however much it goes against the grain to picture it, there is no guarantee that either the warning triangle robot or the roof warning triangle could be deployed.

PRE-SAFE® Side Lighting

The level of damage may also be such that we cannot be sure that the hazard lights will even still function. An incident like this can have dramatic consequences. The unlit vehicle involved in the accident could remain unseen by other road users, with the risk that they then fail to brake and run into the unlit obstruction. For cases like these, the ESF 2019 includes an electroluminescent lighting system, known as PRE-SAFE® Side lighting. PRE-SAFE®, since this lighting can also be activated preventively if the vehicle's sensors detect the potentially critical approach of other road users at a junction (Fig. 18).

The emergency lighting is made up of several layers of thin foil, with the electroluminescent material lying between two conductive layers (electrodes), where it is electrically insulated. One electrode is translucent, while the second foil reflects the light. The total thickness of the foil is less than 1 mm. This foil has the advantage that, even if is partially destroyed, the function will remain effective in the undamaged sections. As a result, even after an accident involving a very high level of damage, the vehicle remains visible to other road users, even in the dark.

Summary

The ESF 2019 from Mercedes-Benz shows that there is still plenty of leverage in the vehicle itself to draw closer to that major goal of "Vision Zero." Topics such as highly automated driving, electric mobility, and connectivity are all addressed here.

Fig. 18 PRE-SAFE® Side lighting in critical situations

It marks the latest step in a tradition of Experimental Safety Vehicles that dates back to 1971 and uses precisely defined concepts to suggest potential solutions, which are characterized by their growing networking and communication capabilities, new forms of drive systems and complex patterns of user behavior as a consequence of significant changes in individual mobility (Fig. 19).

This research vehicle, with all the innovations it presents, serves as a learning object for engineers, while also being a valuable opinion-forming tool when it comes to devising future measures to enhance vehicle safety. However, it is just as clear that much still needs to be done if we are to prevent serious road accidents altogether.

“Vision Zero,” in other words – in an ideal world – a vision of accident-free driving, remains our guiding principle and not a target that we want to have reached by day X. Perpetual, ongoing effort is going to be needed in order for us to get closer to achieving this vision. The approach of Integral Safety that has been thus shaped by Mercedes-Benz will therefore continue to form the basis of our activities in the interests of robust vehicle safety for many years to come. Accident avoidance and the mitigation of accident severity remain major priorities in this respect, not least because in many accidents, particularly those involving unprotected road users, the “classic” concept of passive safety can only ever offer limited leverage. Exploitation of the pre-accident phase too, however, offers tremendous potential and will in future deliver many crucial

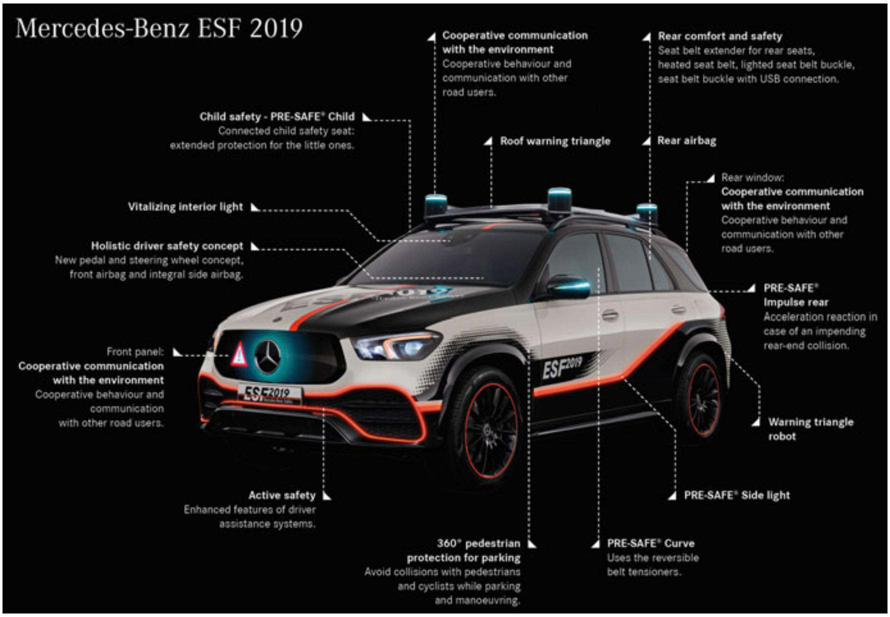

Fig. 19 Overview of the innovations found in the ESF 2019

contributions to the prevention of accident casualties. Preemptive, proactive PRE-SAFE® systems open up completely new perspectives on this discipline.

Having said that, superlative safety engineering in the vehicles themselves must also win through to prevail in the traffic environment. History shows us that it can sometimes take a very long time before life-saving safety systems, for example ESP or the Windowbag, become widely available. In many cases, an impetus from the legislators is needed to accelerate this process.

Regrettably, as I said at the beginning, not all accidents can be avoided through the possibilities offered by the vehicle alone. Human beings and infrastructure are very often the determining factors. "Vision Zero" will therefore only succeed if all parties involved who have any influence at all on the road traffic accident situation commit themselves to this vision and focus all their efforts on its realization.

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Consumer Ratings and Their Role in Improving Vehicle Safety

25

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Contents

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Abstract

Safety ratings for cars, published by New Car Assessment Programmes (NCAPs) around the world, have mobilized consumers and enabled them to make a more intelligent, better-informed buying decision based on a car's crash test performance. Consumer ratings involve comprehensive, objective, and realistic crash testing of cars, and the application of best-practice, consumer-oriented criteria and thresholds to promote safety enhancements beyond the legal requirements. Over time, the New Car Assessment Programmes have tailored their crash tests to focus on real-world priorities in the protection of car occupants and vulnerable road users. They have also successfully incorporated the assessment of new crash avoidance technologies, such as autonomous braking systems, in the ratings. All of this has made NCAP a driving force behind many improvements in the safety of vehicles throughout the world and a key instrument in reaching vision zero.

Keywords

NCAP · Consumer ratings · Vehicle safety · Crashworthiness · Crash avoidance · ADAS · Assisted driving

Introduction

Over the last decades, the improvement of vehicle safety has emerged as one of the most cost-effective and leading strategies to reduce road casualties. Vehicle safety technology accommodates everyday human mistakes: by actively encouraging the driver to adopt safe driving habits; by maintaining control of the vehicle in critical situations; and, in the event of a crash, by reducing injury to occupants and the consequences of those injuries. According to the European Road Safety Observatory report on Vehicle Safety (2018), safety technology "... is fundamental to a Safe System approach which requires safe interaction between users, vehicles, the road environment and prompt access to the emergency medical system. Vehicle design, which takes account of the behavioural and physical limitations of road users and other system risks, can address a range of risk factors and help to reduce accident involvement, accident injury severity and accident injury consequences" (Fig. 1).

By now, safety systems have demonstrated their effectiveness in substantially mitigating injuries from crashes (Broughton 2003) and in preventing crashes. What makes the promotion of safer cars such a compelling proposition for society is that, year in, year out, new safety-enhanced vehicles are coming to the market, substituting older, less safe vehicles on our roads. As best practice activity, and following the recommendations of the Decade of Action's Global Plan for Road Safety 2011–2020 (World Health Organization 2001), many countries have successfully stimulated improvements in vehicle safety, mandating the use of safety systems like seatbelts and child restraints, and actively encouraging the uptake of new technologies.

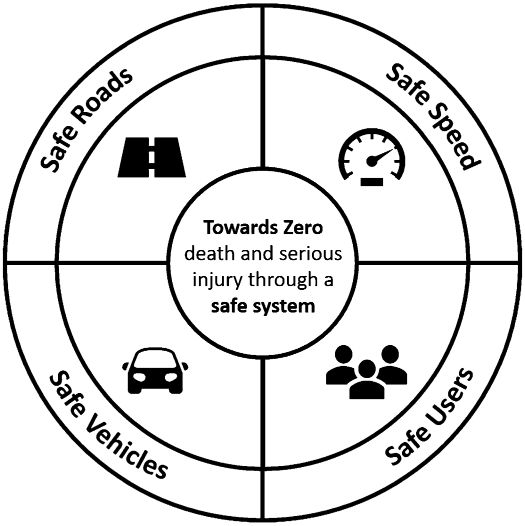

Fig. 1 Vehicle design contributes to the safety system approach by helping to reduce accident involvement, accident injury severity, and accident injury

Ever since the car became the most popular mode of transport in more developed countries, safety has been a top concern for car buyers and fleet operators. In many nations, regulations have been put in place to establish minimum levels of vehicle safety. Furthermore, consumer information regarding automotive safety has educated the public about safe vehicle design and the differences that exist between specific makes and models and thus influenced the level of safety provided by vehicle manufacturers. Therefore, consumer demand for safer cars has become a catalyst to car manufacturers and governments to improve vehicle safety standards throughout the world.

In 1979, the National Highway Traffic Safety Administration (NHTSA) launched the first New Car Assessment Program (US NCAP) to provide information to consumers on the relative crashworthiness of automobiles (Hershman 2001). The outcome, the first public prospective safety ratings for cars, mobilized consumers and allowed them to make better-informed buying decisions. This in turn incentivized local vehicle manufacturers to innovate and provide safer vehicles at lower prices to attract more customers (Fig. 2).

The success of NHTSA's first safety ratings has since inspired other regions and organizations to develop their own consumer safety rating programs based on the same principle. Over the last 25 years, several official programs have emerged around the world, covering high-income markets such as Japan (Wani et al. 2001), the Republic of Korea (Korea Ministry of Land, Infrastructure and Transport 2014), Australia and New Zealand (Haley and Case 2001), Europe (Hobbs and McDonough 1998), and upper and lower middle-income markets like China, Latin America (Furas and Sandner 2013), and South-East Asia (Anwar Abu Kassim et al. 2013). The insurance industry has also launched its own safety ratings, with the Insurance Institute for Highway Safety (IIHS) (1995) in the USA as its main proponent. More

Fig. 2 US NCAP safety rating information published by NHTSA is required to be part of the Monroney (automobile price sticker) label

recently, Global NCAP (2015) has introduced the concept to emerging markets, such as India and South Africa, calling for minimum vehicle safety standards across the regions and holding the industry accountable for not adhering to the same ethics everywhere. The level of engagement worldwide and the NCAP activity that is still visible today underlines the importance of consumer vehicle safety ratings to many regional road safety policies and demonstrates that the NCAP approach can be successfully applied to countries with very diverse market conditions and vehicle fleets.

The European New Car Assessment Program (Euro NCAP) was established in 1997 with the aim of providing motoring consumers with a realistic and objective assessment of the safety performance of the most popular cars sold in the European Union (Fig. 3). Euro NCAP is a public-private partnership which operates independently from the European type approval system. At present, the organization has 12 members including the member state governments of the United Kingdom, Germany, France, Sweden, the Netherlands, Luxemburg, and the regional government of Catalonia; the International Automobile Federation FIA; motoring clubs ADAC and ACI; Consumers International; and Thatcham Research, primarily focused on the needs of the motor insurance industry (Van Ratingen et al. 2016). Among all NCAPs, Euro NCAP is considered one of the more established programs and its test and assessment protocols are often referenced by newer programs. The European Commission believes that Euro NCAP has become the single most important mechanism for achieving advances in vehicle safety in the European market (European Road Safety Observatory 2018).

Fig. 3 Euro NCAP's first launch included safety ratings for seven popular supermini's and raised major concerns about their crashworthiness

Consumer Safety Ratings as Policy Mechanism

Fortunately, today's modern cars offer more occupant protection and accident avoidance technologies than a typical model from a decade ago. Still, not all cars are equal; clearly some models are better equipped and may perform better in real life than others. The principle behind consumer testing is to reveal the "hidden" differences between cars, so that the potential buyer can take this knowledge into account when purchasing a new car.

Consumer ratings involve comprehensive, objective, and realistic comparative testing of cars and components which have been proven to be important in crashes, applying best-practice, consumer-oriented criteria and thresholds that allow discrimination between models. The results are shared with the public in an easy-to-understand way, often using "stars" to classify levels of performance. In order to stay relevant to the public, NCAPs must evolve over time and focus on new areas of safety and new life-saving technologies entering the market.

Consumer rating programs are essentially a form of "self-regulation." It is important to note that the power of consumer testing comes from its accessibility to non-experts, in its use of open and transparent test methods and simple presentation of results, allowing easy comparison of vehicles' performance. This active dissemination of their findings – online, on social media, in printed magazines, etc. – distinguishes NCAPs from legislative compliance testing, where tests are conducted in secret and results remain undisclosed to the general public. The influence of rating programs comes from their ability to provide the public with an enhanced understanding of the car's performance and bring a competitive advantage to those that perform best in safety testing. Ultimately, the availability and value of vehicle safety in society is determined by a combination of international and national regulation, consumer information, car industry policies, and product liability considerations.

The Development of NCAP

The roots of many consumer rating programs can be found in regional vehicle crash test legislation. This means that a compliance crash test has been adopted but altered in order to motivate manufacturers to optimize safety performance beyond the minimum legal requirements. To this extent, most NCAP programs have begun crashworthiness testing in frontal impact conditions using Hybrid-III adult crash test dummies (Backaitis 1994) to assess the injury risk.

As vehicles became increasingly better in frontal crash protection, new opportunities for improving safety further were considered. The different objectives, markets, and priorities of various consumer rating programs led to a smorgasbord of new tests that have found their way into consumer rating programs over the last decades. The following will provide you with an overview of the most popular rating tests.

Vehicle Frontal Crashworthiness

US NCAP's first full-width front barrier test was derived from Federal Motor Vehicle Safety Standard (FMVSS) No. 208 but executed at higher severity compared to the compliance test, in order to raise intrusion and acceleration levels in the occupant compartment (Hershman 2001). Similarly, IIHS, Australasia NCAP, Euro NCAP, and others adopted the moderate offset deformable barrier test (UN/ECE 1995) at a higher impact speed than regulation, alone or in addition to the full-width test. In most instances, the biomechanical injury criteria (HIC, chest accelerations, etc.) are not unlike those applied for regulation testing, but more demanding limits or additional requirements are often set. As a result, a car which barely meets legal requirements is likely to be limited to a one- or zero-star rating by NCAP.

The above approach of basing consumer ratings on compliance testing has allowed standards in occupant protection to evolve at a fast pace. In Europe, the start of Euro NCAP testing coincided with the full implementation date of directives for frontal and side vehicle impact (96/79/EC and 96/27/EC, respectively). From 1997 onwards, new batches of test results were launched about twice each year, sometimes during public car exhibition events (Fig. 4).

Soon car manufacturers, setting aside their initial reservations, started to sponsor the testing of their own cars. As new car models replaced those already tested, the improvements in occupant protection over and beyond the legal requirements, such as reinforced cabin structurers, driver and passenger airbags, and seat belt load limiters and seat belt retractors, could be clearly observed (Hobbs and McDonough 1998).

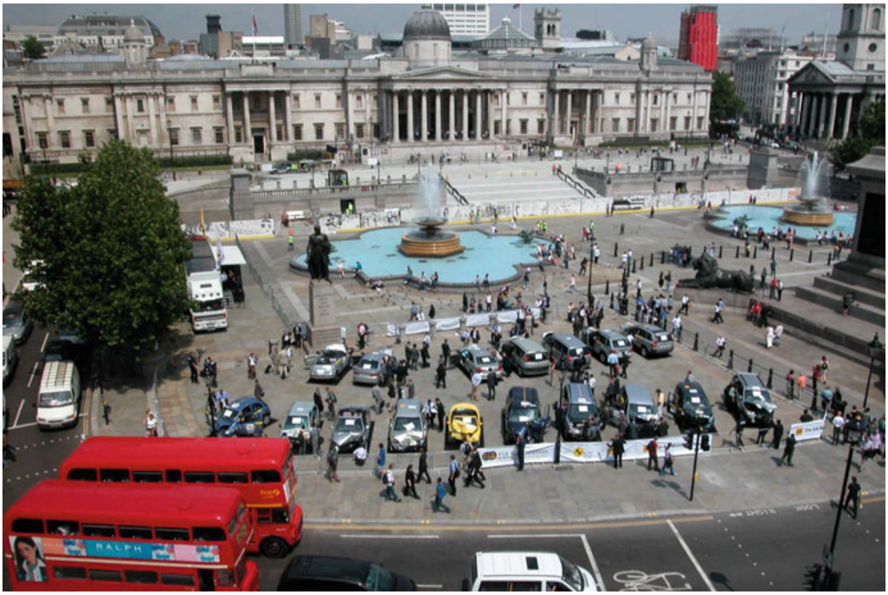

Fig. 4 Between 2000 and 2005, Euro NCAP exhibited crashed cars at public squares across several cities in Europe to raise awareness about vehicle safety among consumers

Following the success of the first five-star rating for the Renault Laguna in 2001, manufacturers increasingly saw this as the goal for all their new models for the European market.

However, success does not always come easy. Latin America is one of the world's worst performing regions with an annual road fatality rate of 17 deaths per 100,000 individuals, almost double the average rate registered for high-income countries (World Health Organization 2013). When Latin NCAP was first launched in South America in 2010, many models failed to meet the frontal impact test requirements, despite being produced by manufacturers who were routinely achieving five-star ratings in Europe and elsewhere. Cars which were ostensibly the same, often carrying the same name, were made to very different standards and were very differently equipped, in different parts of the world. Since then, visible progress has been made yet zero-star results are no exception. The program is still searching for the broad industry engagement that is needed to improve vehicle safety as the governments responsible have so far been unable to agree on realistic minimum safety requirements for the region. This reminds us of an important lesson: that consumer information works best when complementing regulation but cannot, and should not, replace it.

Since the early 1980s, improvements in frontal crashworthiness claim to have reduced the risk of death and serious injury for car occupants by half or more. For instance, IIHS reported a 46% lower risk in death and injury in head on crashes for good versus poor rated cars (HLDI 2019). Frampton et al. (2002) analyzed real-world collisions and medical records from injured drivers and identified significant reductions for serious and fatal injuries in new cars in frontal impacts. They attributed the observed improvement in injury levels to improvements in crashworthiness and the introduction of vehicles with airbags and more effective restraints. Comparing the fatality risk for car passenger in collisions with other cars, Folksam (Kullgren 2017) estimated that cars introduced in the period 1996–2004 had a 43% less risk than those launched in period 1985–1995. This risk has further reduced to 86% for the latest generation of cars, introduced between 2005 and 2014.

Even after many years of testing, the full-width and moderate offset frontal crash tests speak to the imagination of consumers and for this reason remain important tests for many NCAPs today. Despite this, frontal impacts are still the most common type of crash resulting in fatalities and this has driven an obvious interest in further improving frontal crash protection among NCAPs. Small overlap frontal crashes primarily affect a vehicle's outer edges, which are not well protected by the traditional crush-zone structures. The IIHS small overlap (SO) frontal crash test (Sherwood et al. 2013) is primarily a test that drives structural countermeasures although it may also be a challenge for some belt restraint and airbag designs because of the higher oblique loading component. Vehicle manufactures have responded by strengthening the occupant compartment, adding new structures to engage the barrier and creating an additional load path for crash forces (Fig. 5).

Other notable upgrade to frontal crash testing is the adoption of the advanced Test Device for Human Occupant Restraint THOR-M mid-sized male crash test dummy (Ridella and Parent 2011; Parent et al. 2013) and biomechanical injury criteria in two new test procedures: the moving deformable barrier (OMDB) test procedure for evaluating small overlap and oblique crashes (Saunders et al. 2011), announced by NHTSA (National Highway Traffic Safety Administration 2015) and Euro NCAP's

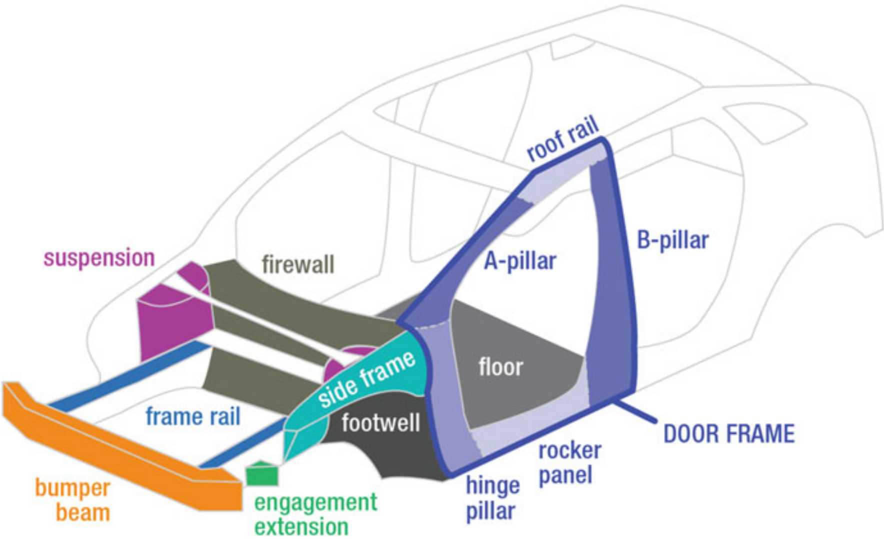

Fig. 5 Areas modified for small overlap performance. Not pictured: door beam, seat mount, wheel, steering column. From: Insurance Institute for Highway Safety. Status Report, Vol. 49, No. 11

mobile progressive deformable barrier (MPDB) test for vehicle compatibility evaluation introduced in 2020 (Sandner and Ratzek 2015; Sandner et al. 2019).

Encouraging Side Impact Protection

In most developed markets, side crashes account for about a quarter of passenger vehicle occupant fatalities and a more sizeable 40% of serious injury crashes. In the mid-1990s, vehicle makers started to install side airbags and strengthen the structures of vehicles to prevent ejection and provide a survivable occupant environment. Around the same time, moving deformable barrier and side pole crash tests were introduced in consumer rating programs to verify the effectiveness of these measures, to drive market installation rates, and promote further innovation.

NHTSA began testing passenger cars in side impact in NCAP in 1997 (Hershman 2001). The US NCAP side impact – a 90-degree side impact in which a moving deformable barrier, crabbed at 27 degrees, strikes a stationary vehicle - is taken from FMVSS No. 214 but run at approximately 62 km/h, 8 km/h higher speed than in the compliance test. In Europe, Australia, and Asia, side impact barrier tests are also performed but follow the perpendicular (non-crabbed) test configuration of the UN/ECE standard (UN/ECE 1995) at speeds ranging from 50 to 55 km/h. However, as head impact does not regularly occur in the barrier test, some have adopted an additional pole test to assess the benefit of head protecting airbags for side impact. In the USA, IIHS was concerned that these tests still did not completely capture the types of crashes likely to occur in the real world with SUVs and pickups. In 2003 the Institute initiated its own test with a different barrier – one with the height and shape of the front end of a typical SUV – and a new small female dummy, SID-IIs (Insurance Institute for Highway Safety 2017).

Since then, the various tests underpinning the side impact crash ratings around the world have continued to evolve. More recent developments include the application of an oblique pole test by US NCAP and Euro NCAP, among others; the adoption of the advanced WorldSID mid-sized male dummy (Scherer and Cesari 2001); the Advanced European Mobile Deformable Barrier (AE-MDB) (Ellway et al. 2013); an assessment of the head protection device extended to rear seats by JNCAP and Euro NCAP, and the application of far-side impact testing (Ellway et al. 2019).

The focus on improving side impact protection has delivered real benefits. IIHS estimated that the overall effectiveness of side impact protection measures, particularly side airbags and curtains, was a 45% fatality reduction for drivers of cars with head-protecting side airbags, and 11% reduction with torso-only side airbags (Insurance Institute for Highway Safety 2003). NHTSA showed statistically significant fatality reductions between 8% and 31% for four types of curtain and side airbags in near-side impacts for drivers and right-front passengers of cars and LTV (National Highway Traffic Safety Administration 2014). Folksam and Chalmers also reported a significant reduction in the injury risk in side impact for near-side occupants based on an analysis of STRADA (Swedish Traffic Accident Data Acquisition) data (Stigson and Kullgren 2011).

Forgiving Vehicle Front-End Designs for Pedestrians and Cyclists

According to the World Health Organization, over a third of road traffic deaths in low- and middle-income countries are among vulnerable road users (World Health Organization 2013). In high-income countries, pedestrian motor vehicle crash fatalities have decreased over the last decades but still account for 15–20% of crash deaths. The pedestrian protection subsystem tests, developed and validated by the European Enhanced Vehicle safety Committee (EEVC 2003), have been the basis for testing and assessment protocols by Euro NCAP, Australasian NCAP, Japan NCAP, as well as UN regulation. These tests, which evaluate the aggressiveness of vehicle front-ends in car-to-pedestrian impacts, comprise the legform to hood test, the upper legform to bonnet leading edge test, and the headform to bonnet top test, each with its own impactor, impact conditions, and criteria.

Car front-end structures initially improved only gradually as the vehicle industry resisted expensive engineering solutions and requirements that could compromise vehicle styling. The test method was also criticized for a lack of reproducibility, resulting from test point selection and poor test tool repeatability. In 2009, Euro NCAP addressed the lack of progress by introducing a new rating system that required minimum performance in pedestrian testing in order to achieve an acceptable star rating. It also solved the main concerns about the test procedures by various updates (Zander et al. 2015) and the adoption of improved impactor devices, such as ACEA head forms and the JARI Flex Pedestrian Leg Impactor (Konosu and Tanahashi 2005). The proportion of vehicles offering good pedestrian protection has since noticeably improved.

The inclusion of pedestrian subsystem testing in consumer ratings has brought about more pedestrian-friendly designs and has triggered new innovations such as "pop-up" or deployable bonnet technology. In the latter case, an extension to the subsystem test procedure was needed to evaluate the robustness and effectiveness of the deployable device itself. The method features sensor activation tests carried out with a special PDI2 legform (Concept® Technologie 2015) to check system responsiveness to pedestrians of various sizes, and numerical simulations using "certified" human models (Klug et al. 2017) to verify that deployment occurs before the head contacts the bonnet. This experimental-numerical method is the first of its kind in consumer testing.

A significant correlation between pedestrian subsystem scores and injury outcome was reported by Pastor using German National Accident Records from 2009 to 2011 (Pastor 2013). Comparing a vehicle scoring 5 points and a vehicle scoring 22 points, pedestrians' conditional probability of getting fatally injured was reduced by 35% (from 0.58% to 0.37%) for the latter. Strandroth et al. (2013) also showed a significant reduction of injury severity for cars with better pedestrian scoring. The reduction of Risk of Serious Consequences (RSC) for medium-performing cars in comparison with low-performing cars was 17, 26, and 38% for 1, 5, and 10% of medical impairment, respectively. These results applied only to urban areas with speed limits up to 50 km/h, suggesting that in order to reduce injuries at higher impact speeds, other types of countermeasures should be considered.

Mitigating Rollover and Loss of Control Crashes

The 1990s and early-2000s saw the sales of Sport Utility Vehicles (SUV) and pickup trucks surge in the North America and Australia. These vehicles, with high centers of gravity, have an inherently greater risk of rolling over and, with such crashes causing some 10,000 fatalities annually in the USA by the start of the new millennium, it was not long before this accident type became a key priority. In 2001, NHTSA added a new test for rollover resistance assessment to their rating system using a "Static Stability Factor" (SSF), based on a vehicle's measured static properties. The US NCAP rollover resistance rating was later amended to include the results of a dynamic vehicle test in addition to the SSF (Hershman 2001). In 2009, the IIHS began testing the roof strength of vehicles, to ensure that the roof can maintain the occupant survival space when it hits the ground during a rollover (Insurance Institute for Highway Safety 2012). Today, consumer information on rollover resistance remains largely a North American phenomenon. A notable exception is Korean NCAP which adopted the dynamic rollover assessment in 2004 and since published a Driving Stability Rating based on rollover and braking tests (Korea Ministry of Land, Infrastructure and Transport 2014).

Another effective countermeasure to avoid the cause of many rollovers, especially fatal single-vehicle ones, is Electronic Stability Control (ESC), an electronic system that improves a vehicle's stability by detecting and reducing loss of traction. When ESC detects loss of steering control, it automatically applies the brakes to help "steer" the vehicle where the driver intends to go. ESC, or Electronic Stability Program (ESP) as it was better known at the time, made its breakthrough after the "flip over" crisis of the Mercedes-Benz A-Class in 1997, that generated widespread consumer interest. In the years that followed, several studies confirmed that ESC is highly effective in reducing single-vehicle crashes (Lie et al. 2004; Thomas 2006; Farmer 2010) bringing the anti-skid technology further into the focus. Installation of ESC equipment was successfully promoted by the international Choose ESC! campaign (Fig. 6), supported by the FIA Foundation, the European Commission, and others (2007). The technology was adopted in several rating programs, such as Australasian NCAP, US NCAP, and Euro NCAP, before it became mandatory for all passenger cars and light trucks in their respective markets. ESC remains an important condition for five stars in Latin and ASEAN NCAP and for other emerging markets, where this technology is still not mandated.

Promoting Seat Belt Usage

As protection for belt wearers improved, accident data increasingly showed that a higher proportion of seriously and fatally injured casualties were not wearing their seat belts (Frampton et al. 2006). To improve this situation, Euro NCAP (2003) first developed a protocol to encourage the fitment of Intelligent Seat Belt Reminders (SBR). Research had shown that most non-wearers could be persuaded to use their seat belt if they were given a suitable reminder. Although simple reminders have

Fig. 6 Left: The Choose ESC! campaign organized test drives and demonstration events around to world to promote ESC. Right: Euro NCAP added an ESC test in 2011

been available for many years, intelligent systems can be much more effective: almost unnoticed by belt wearers but increasingly aggressive and demanding for those who do not "buckle up."

For front seats, Euro NCAP requires a "final (reminder) signal," which must be audio-visual and must be presented at the latest 60 s after the engine start, after 500 m of vehicle travel or speeds above 25 km/h. The final signal must last for a minimum of 90 s and consist of a "loud and clear" audible signal and a visual indicator. For rear seats, Euro NCAP requires a "start signal," which may be visual only. For all seats, if a change in belt status occurs at speeds above 25 km/h, i.e., a belt gets unbuckled, an immediate audible signal must be given. The Euro NCAP protocol recommends occupant detection on the rear seats but does not require it.

Since 2003, Euro NCAP and Australasian NCAP rating systems have encouraged front and rear SBR by awarding points that count towards the overall score or, more recently, the Safety Assist component of the rating system. Thanks to this incentive, most light vehicles in these regions offered SBR for all seats ahead of regulation. From September 2019, UN/ECE regulation UN R16.07 requires seatbelt reminder systems in all front and rear seats on new cars.

When Japan NCAP introduced an overall rating scheme in 2011, SBR points became part of the evaluation. It also includes a reward for advanced seat belt reminders on the rear seats: additional points can be scored if the rear SBR alert includes an audible warning of at least 30 s. Such a warning, however, can only be triggered if passenger presence information is available (Mousel et al. 2015). Several other NCAPs, such as Korean, China, ASEAN, and Latin NCAP have included incentives for the SBR systems into their rating. From September 2019, the United Nations Economic Commission for Europe (UN ECE) Regulation No. 16 on safety belts and restraint systems requires mandatory fitment of safety belt reminder systems to the driver's seat and to any other seating positions in the same row as the driver's seat for all M and N category vehicles.

Lie et al. (2008) conducted an extensive study into the effect of enhanced SBR in six European countries. This study concludes that seat belt reminders fulfilling Euro NCAP's SBR protocol significantly increase seat belt use in daily traffic: around 80% of drivers who do not wear a seat belt in cars with no reminder do so in cars equipped with a system that has a visual signal and an associated loud and clear sound signal.

Safe Transport of Children

Many high- and middle-income countries require the use of approved child restraint systems (CRS) for infants and children, meeting specific criteria for certain age or size groups, even though the exact requirements in each country, region, or state may vary considerably. Especially in developed nations, child fatalities in motor vehicle crashes have steadily declined over the last decades, thanks to these laws and greater consumer awareness. However, vehicle crashes remain a leading cause of death and disability for children and young adults in many parts of the world today.

Safe transport of children in cars is the joint responsibility of parents, child restraint suppliers, and vehicle manufacturers. Responsible parents and caregivers must ensure that children are properly restrained in a correctly installed child restraint system that is appropriate for the size and weight of the child. Child restraint suppliers make certain their products meet (or go beyond) local regulations, offer adequate protection, and can be fitted easily and correctly in all cars. Finally, it is the vehicle manufacturers' obligation to guarantee that children are as well protected as adults in the event of crash and that special any provisions needed for children are offered as standard.

In practice, this joint responsibility leads to a set of complex interactions and a patchwork of solutions that make it difficult for average consumers to know how their child is carried in the best and most safe way. There exist several child seat consumer rating programs worldwide aiming to guide consumers into buying the best seat for their child. Organizations such as Consumer Reports in the USA (2019), China Automotive Technology Research Centre (2019) and collaborative programs, like the European Testing Consortium (Van Ratingen et al. 2019) (Fig. 7), Australian Child Restraint Evaluation Program (Suratno et al. 2007), and the Latin American Child Restraint Systems Evaluation Programme PESRI (2017), are regularly testing new child restraints for crash performance, ease of use, and how they fit into vehicles. These benchmarking tests have become powerful means to drive improvements in CRS design, as a good consumer rating is a must for child seat manufacturers to be successful in the market.

There are also many aspects of child protection which cannot be influenced by the child restraint manufacturer alone, but which require action on the part of the car manufacturer as well. In 2003, Euro NCAP introduced a child occupant star rating, specifically addressing the vehicle design and equipment for safe transport of children. The rating was based on the protection offered in the front and side crash

Fig. 7 Side impact test setup used a.o. by the European Testing Consortium to evaluate the protection offered by Child Restraint Systems

tests to a 3-year-old and 18-month-old child seated on the rear seat in a restraint of the type recommended by the car manufacturer. The assessment was complemented with other incentives with regards to communication (handbook instructions, information at dealerships, warning labels, etc.), an assessment of the ease of child seat installation, and availability of easy-to-use ISOFIX attachments and other relevant equipment, such as a front passenger airbag deactivation switch. Between 2013 and 2016, Euro NCAP introduced several updates to the child occupant assessment rating including a Child Restraint System Installation check, new incentives for iSize compliant seating positions, and the use of Q6 and Q10 child dummies in crash tests (Van Ratingen et al. 2019).

Among all NCAP programs, a similar assessment of child safety, based on different child dummies seated in child restraint systems in the rear, has been adopted by Australasian NCAP, ASEAN, and Latin NCAP. China NCAP introduced child safety assessment in full frontal 50 km/h rigid barrier test from 2010 (Hu et al. 2011). For the China NCAP 50 km/h full-width test, a P3 child dummy is positioned in the vehicle outboard rear seat, but in the opposite side, a Hybrid III small female dummy is positioned. The IIHS does not use child dummies in their front and side crash testing – a small adult female dummy, comparable in size to a 10-year-old child, is placed on the rear seat for the side impact test – but its LATCH ease-of-use ratings (Insurance Institute for Highway Safety 2015) are an indicator of how easy it is to achieve a correct, tight installation of a child restraint in a given vehicle when using the dedicated child restraint attachment hardware.

The use of child safety seats and improved car measures have been shown to reduce infant deaths in cars by approximately 71% and deaths to small children by 54% (National Highway Traffic Safety Administration 2002). Especially rearward-facing systems have demonstrated to reduce injuries between 90% and 95%, while forward-facing systems have been shown to have an injury reducing effect of approximately 60% (Tingvall 1987). Therefore, in countries where the usage rate is low, are to increase the use of child restraint systems and to provide adequate information about how they are correctly used in the vehicle in order to avoid misuse.

Whiplash Prevention

Whiplash-associated disorder remains the most frequently reported injury in insurance claims across many high-income countries. As whiplash injury to the neck often leads to long-term impairment, with 10% of people suffering long-term discomfort and 1% permanent disability, addressing "whiplash" neck injuries, understanding the cause and how to prevent the injury has been an important priority for the auto insurance industry and governmental bodies.

Whiplash may occur in all impact directions, but the injury is most frequently observed, and its risk most effectively addressed, in rear-end impacts. For this injury type, no biomechanically based vehicle safety regulations exist, mainly because of the limited (or inconclusive) knowledge available about the exact injury mechanism. However, research has demonstrated that, in the event of a rear-end collision, the vehicle seat and head restraint are the principal means of reducing neck injury (Farmer et al. 2003).

Starting from the assumption that lowering loads on the neck lessens the likelihood of whiplash injury, the first stand-alone consumer tests for seats and head restraints were developed by Folksam and the Swedish Road Administration (SRA) (Krafft et al. 2004) and the International Insurance Whiplash Prevention Group (IIWPG) of the Research Council for Automobile Repairs (RCAR 2006). Both initiatives used car seats mounted on a sled to evaluate and rate the ability of seats and head restraints to prevent neck injury in moderate- and low-speed rear-end crashes. Measurements were taken from the BioRID II dummy, an anthropomorphic test device with a flexible spine (Davidsson et al. 1998), which, in the case of IIWPG, were combined with an evaluation of the head restraint geometry. However, the tests adopted different philosophies with regards to relevant seat performance parameters, one putting heavy emphasis on real-world validation (IIWPG), the other using plausible hypotheses regarding the causes of whiplash injury (SRA).

IIHS has been publishing ratings of head restraint geometry since 1995 and has been rating head restraint systems since 2004 using a combination of their static measurement procedure and the IIWPG developed "single-pulse" dynamic sled test procedure. Between 2003 and 2008, the German Automobile club also published whiplash ratings. The ADAC test procedure was similar to the IIWPG test procedure but with an additional sled test and seat stability test (Lorenz and Sferco 2004).

Fig. 8 Typical whiplash seat sled test setup with the BioRID-II dummy, used by many NCAPs around the world including IIHS, Euro NCAP, JNCAP, and China NCAP

Australasian NCAP began publishing head restraint geometry ratings to the IIWPG protocol in 1997 and added the dynamic test in 2012. Also, Korean NCAP and China NCAP adopted a dynamic test based on the IIPWG pulse during the late 2000s (Fig. 8).

In 2008, Euro NCAP launched its first series of results of (front) seat testing based on its own geometric and “three pulses” dynamic sled test procedure, which combined aspects of the IIWPG, Folksam/SRA, and ADAC methods (Van Ratingen et al. 2009). In 2014, the Euro NCAP’s geometric assessment procedure was extended to include rear seats. Japan NCAP has conducted similar assessments of seats in Japan using different injury criteria and pulses starting from 2010 onwards (JNCAP 2014).

Kullgren et al. (2015) carried out an evaluation of the effectiveness of Euro NCAP, Japan NCAP, and IIHS whiplash protocols, respectively, using real-world crash data. Three analyses were undertaken comprising an analysis of test outcome data, a logistic regression analysis, a receiver operating characteristic (ROC) analysis, and a correlation analysis comparing crash and injury outcome. Correlations between the test scenarios of each of the three protocols – as well as the outcome associations with crash outcomes – suggested consistent improvements in the risk of permanent medical impairment. Encouraged by the positive impact of whiplash seat testing around the world, amendments to Global Technical Regulation on Head Restraints No. 7 to address minor whiplash injuries were finally agreed in 2019.

The Advent of Crash Avoidance

By the mid-2000s, crashworthiness ratings had been in common use around the world for a decade or more and the industry's efforts to deliver increasingly safer cars had resulted in many five stars successes. But while this represented a significant step forwards for consumer protection, concerns started to rise over the future direction and the message that the programs continued to deliver.

The key reason behind these concerns was the emergence on the market of a new category of safety technologies designed to automatically intervene in critical, near-crash situations and assist the driver in driving safely, the so-called Advanced Driver Assistance Systems (ADAS). Several car manufacturers have made their commitment to active safety clear, among them Daimler, but also Volvo, which was among the first to offer a collision mitigation system as a standard installation in a consumer vehicle. Yet, crash avoidance and ADAS technology was largely overlooked by consumer rating programs at this time (with the notable exception of Electronic Stability Control, which was encouraged by several NCAPs in the late 2000s).

The industry's shift from passive to active safety initially put the NCAPs on the backfoot as they grappled with the wide variety of new systems and functionalities entering the market and the lack of suitable, "regulation-quality" performance tests for these new systems. To make matters worse, only a few systems were offered as standard and the uptake of optional systems in the fleet was generally low. This seriously challenged the ability of NCAPs to quickly identify and confirm (based on real-world evidence) those technologies that delivered a true benefit to the consumer and to society. Consequently, the risk grew that the consumer ratings were becoming less relevant in the eyes of the public and the industry.

From 2012 onwards, NCAP's and the regulator's focus on ADAS has accelerated, and spearheaded by NHTSA, IIHS, and Euro NCAP, vehicles have been increasingly credited for offering certain recommended advanced technologies. This has educated drivers about how these systems operate and helped change the consumer's perspective on ADAS from "great gadgets" to "must have" technology.

Autonomous Emergency Braking

Autonomous Emergency Braking (AEB) is without doubt the most important active safety technology that has emerged since ESC. Using sensors such as radar, lasers, and cameras to identify other vehicles or other road users, AEB automatically applies the brakes if the driver does not respond in time, to avoid or mitigate a collision, saving countless lives, injuries, and inconvenience. Systems are most effective at lower speeds (<40 km/h) where more than 75% of rear-end crashes occur, but they are also valuable in mitigating the devastating effects of higher speed crashes by reducing impact speeds, if a crash cannot be avoided.

AEB, or Crash Imminent Braking (CIB), was one of the technologies covered under the Crash Avoidance Metrics Partnership (CAMP) (National Highway Traffic Safety Administration 2002) between NHTSA and the American auto industry.

CAMP was established in the mid-1990s to accelerate the implementation of crash avoidance countermeasures in passenger cars. Based on the groundwork by CAMP and their own research activities, NHTSA began recommending Forward collision warning (FCW) systems to consumers starting with the 2011 model year. NHTSA recently announced that it would include AEB systems (crash imminent braking and dynamic brake support) as a recommended technology and test such systems starting with model year 2018 vehicles (National Highway Traffic Safety Administration 2015).

Within Europe, four main initiatives have actively contributed to development of test procedures for assessing AEB and forward collision warning systems for car-to-car crashes. ADAC, with support from automotive suppliers Continental and Bosch, developed a standardized inflatable vehicle test target (Sandner 2013) in order to perform a comparative test of AEB systems on high-end vehicles. The RCAR Autonomous Emergency Braking group (Hulshof et al. 2013), led by Thatcham Research, designed a testing and (insurance) rating approach for AEB systems. The European Commission sponsored research project ASSESS (Assessment of Integrated Vehicle Safety Systems for improved vehicle safety) (European Commission 2009) and the German initiative led by DEKRA, called Advanced Forward-Looking Safety Systems (vFSS) (Berg et al. 2011), had similar project goals: to develop harmonized and standardized assessment procedures and related tools for selected integrated safety systems. Based on the outcome of these research projects, Euro NCAP adopted both low-speed and high-speed AEB systems in the rating scheme in 2014. In 2016, the first AEB pedestrian test was added to provide an incentive for systems with advanced detection capabilities (Grover et al. 2015), followed by AEB cyclist test in 2018 (Euro NCAP 2018), see Fig. 9.

The low-speed "AEB City" test also became an RCAR standard and is similar to the Insurance Institute for Highway Safety Autonomous Emergency Braking Test. Forward collision warning systems (FCWS) have been tested by KNCAP from 2016 onwards. China NCAP has adopted an AEB test protocol in its suite of tests beginning from 2018 and Australasian NCAP aligned with Euro NCAP for AEB and other active safety tests in the same year. Finally, Latin NCAP has announced its plan to evaluate AEB systems from 2020 onwards.

The IIHS states that (low speed) "AEB systems can reduce auto insurance injury claims by as much as 35 percent" (Insurance Institute for Highway Safety 2015). Euro NCAP, with support of the Australasian NCAP, studied the effectiveness of the low-speed AEB systems promoted through the rating scheme since 2014, and showed that low-speed AEB technology leads to a 38% reduction in real-world rear-end crashes, with no significant difference between urban and rural crash benefits (Fildes et al. 2015).

Lane Support Systems

Lane support technologies, such as Lane Departure Warning (LDW) and Lane Keep Assist (LKA), are designed to address single-vehicle run-off-road and head-on crashes. The IIHS (Farmer 2008), NHTSA (Barickman et al. 2007), and others (Scanlon et al.

Fig. 9 Autonomous Emergency Braking tests for vulnerable road users were first introduced in 2016 for pedestrians and in 2018 for cyclists

2015) have studied the potential of these crash avoidance technologies and have estimated big fatal crash reductions. However, current lane support systems often are still not well accepted by consumers, mainly because warning systems are perceived as annoying and unreliable. Perhaps for this reason, clear evidence that lane support technology is delivering on its promise has been slow to emerge. A positive indication has recently come out from field data in Sweden (Sternlund et al. 2016), suggesting LDW/LKA systems are reducing head-on and single-vehicle injury by up to 53%. Also, IIHS has lately found positive, albeit more modest, benefits (Cicchino 2018).

To improve the performance of these systems, US NCAP and Euro NCAP have introduced incentives as part of their respective consumer rating programs. The technology is tested in a straightforward manner by steering the LDW or LKA equipped vehicle slowly towards a solid or dashed line, thus triggering a warning or intervention. While NHTSA’s test can be performed by a driver, Euro NCAP’s test protocol requires path accuracy that can only be performed by driving robots that can also be used for AEB testing.

Recently, more intuitive, intelligent, and integrated systems are entering to the market that can avoid unintended road departures and critical overtaking lane change maneuvers, based on an assessment of threat (Emergency Lane Keeping). The latest Euro NCAP protocols have taken this development into account (Grover and Avery 2017). Besides NHTSA, Euro NCAP, and Australian NCAP, KNCAP has included LKA systems in the rating, while Latin NCAP has announced lane support system testing from 2020 onwards. ASEAN NCAP instead has given priority to Blind Spot Detection, which it sees as key enabler to reduce crashes between cars and powered-two-wheelers (Malaysian Institute of Road Safety Research 2018).

Speed Assistance Systems

Excessive speed is a factor in the causation and severity of many road crashes. In fact, it has a greater effect on the number of accidents and injury severity than almost all other known risk factors. Speed restrictions are intended to promote safe operation of the road network by keeping traffic speeds below the maximum that is appropriate for a given traffic environment. Voluntary speed assistance systems (SAS) are a means to assist drivers to adhere to speed limits, by warning and/or effectively limiting the speed of the vehicle. The only technical requirements for such devices are laid down in United Nations Regulation No. 89 "Speed Limitation Devices," which is not mandatory in Europe and does not specifically apply to M1 passenger cars.

Starting from 2009, Euro NCAP has rewarded manually set and driver advised speed limitation devices which meet the basic requirements of United Nations Regulation No. 89 but have additional functionality with regards to the warnings given and the ability to be set-at-speed. By doing so, Euro NCAP has created a first incentive to manufacturers to promote such speed-limitation devices, to make them available on more models and to fit them as standard equipment (Schram et al. 2013). Around 90% of vehicles achieving a five-star rating from Euro NCAP in recent years have a speed-limitation device, usually in combination with a cruise control system.

Recently, more advanced speed assistance systems have been introduced onto the market which are able to inform the driver of the speed limit at the vehicle's current position, based on digital speed maps and/or traffic sign recognition. The Euro NCAP rating system also encourages these speed limit information functions (SLIF). Although there are still limitations to these technologies, intelligent speed assistance systems that combine speed limit information and (over-rideable) speed-limitation, have much greater potential and will be more readily acceptable to the public. As a result, Euro NCAP extended the speed assistance protocol in 2013 to include the latest generation of Intelligent Speed Assistance (ISA) systems.

In 2019, the European Parliament has given the green light to new minimum EU vehicle safety requirements that will come into force from 2022, including over-ridable Intelligent Speed Assistance for passenger cars, vans, and buses (European Parliament 2019). The availability and popularity of Speed Assistance systems in other regions is still lagging, despite excess speed being one of the leading causes for crashes worldwide. Australian NCAP, KNCAP, C-NCAP, and Latin NCAP are promoting the technology as part of the safety rating to improve update in the market.

Combining Passive and Active Safety

NCAPs have been successfully promoting many different vehicle safety technologies as part of their programs but as more tests have been included, it also has become more difficult for consumers to understand and digest the ratings. Several approaches were adopted to deal with the situation of emerging advanced technology in the respective rating systems. In US NCAP, vehicles earn ratings of 1–5 stars in frontal crash and side crash performance, as well as in rollover resistance. Since 2011, vehicles also earn an Overall Vehicle Score rating, which indicates how the individual 5-Star Safety Ratings combine to reflect a vehicle's overall safety. NHTSA has utilized NCAP to encourage automakers to add advanced safety features on a voluntary basis and recently began evaluating which ADAS technologies might potentially be included in the near future. Today, the US NCAP checklist includes forward collision warning, lane departure warning, and backup cameras (followed by Autonomous Emergency Braking technology as of MY 2018 models). The checklist gives consumers a quick and easy way to compare the availability of safety features across models although fitment does not affect the star rating.

In 2009, Euro NCAP changed from three individual crash ratings to a single overall safety rating with a maximum of five stars. This overall rating combined the results of assessments in four areas: adult protection, child protection, pedestrian protection, and the new area of safety assist technology. The underlying tests included the full-scale frontal offset, side-impact barrier and pole tests carried over from the previous adult and child protection ratings, the seat tests for whiplash prevention in rear-end crashes and front-end component tests for pedestrian protection. The assessment of Intelligent Seat Belt Reminders was complemented with that of Speed Assistance Systems and Electronic Stability Control as part of Safety Assist. In each area of assessment, scores were calculated as a percentage of the maximum points available and a weighted sum of these scores indicated the car's overall all-round performance. The testing of low and higher speed Autonomous Emergency Braking as well as Lane Support systems was added in 2014. The latest update of the Euro NCAP rating is the addition of Autonomous Emergency Braking technology for pedestrians and pedal cyclists.

Other NCAPs responded with changes to the rating systems, which sit in between the "encompass all" approach of Euro NCAP and the advisory approach of US NCAP. For example, to qualify for IIHS's Top Safety Pick, a vehicle must earn good ratings in five crashworthiness tests – small overlap front, moderate overlap front, side, roof strength, and head restraints – as well as a basic rating for front crash prevention, its low-speed Autonomous Emergency Braking technology test. To qualify for Top Safety Pick+, a vehicle must earn good ratings in the five crashworthiness tests, an advanced or superior rating for front crash prevention and a good headlight rating.

Until recently, the Australasian NCAP star rating was based on the vehicle's performance in frontal offset, side barrier, and pole crash tests, as well as pedestrian and whiplash tests. To earn five stars, it also required key features such as SBR on front and rear fixed seats, head protecting technology (curtain bags) for front and rear seat, three-point seat belts for all forward-facing seats and ESC. This scheme was extended with a "tick-box" approach, based on a menu of Safety Assist Technologies (referred to as "additional SAT"), that included many potential technologies. In 2018, Australasian NCAP aligned their tests, criteria, and rating scheme with Euro NCAP, apart from minor differences due to local regulations.

Almost all major NCAP programs have recently introduced rating changes to accommodate the testing of avoidance systems. China NCAP has begun AEB testing as part of their star rating. Other NCAPs like Korean, Japan NCAP, Latin and ASEAN NCAP have moved to an overall rating system and/or are in the process of making changes to accommodate more crash avoidance technologies. Finally, NHTSA is considering a new approach to determining a vehicle's overall five-star rating that may, for the first time, incorporate advanced crash avoidance technology features, along with ratings for crashworthiness and pedestrian protection.

Consumer Information in the Era of Automation

The idea of assisted driving, automated driving, and self-driving cars has been widely aired in technical discussions and in media coverage over the last years. The rapid development of electronic safety systems and communication over the air has made the concept possible and the first cars have come onto the market, which are able, with driver oversight, to "drive" themselves in controlled situations. The established vehicle industry is active in this field but also new players, such as Waymo, Zoox, UBER, Lyft, etc., are trialling self-driving cars. There is no doubt that greater automation will lead to a revolution in safety, putting it above all other requirements and characteristics of a car. Not only will the self-driving car have the technology to sense, avoid, and mitigate in potential crash scenarios, it will also drive in a safer manner. Besides that, the vehicle must always carry the safety elements and technologies to intervene and protect the occupants when necessary (the "backup safety").

However, as Volvo, Mercedes, Tesla, GM, and others are launching their first "auto-pilot," Highway Driving Assistant systems, it is not easy to see to what extent safety on the roads may be affected in the short term. Cars with increasing levels of automation will allow drivers to delegate control, taking their eyes of the road and engage in activities unrelated to driving. Drivers, however, must resume control in conditions not yet supported, such as adverse weather or complex traffic conditions. Drivers need enough time to regain situation awareness in order to effectively take back control, a challenge that may become more critical the longer the driver has been "out of the loop." So far, this means that drivers must always continue to monitor the vehicle drive itself and the systems can only be used safely in restricted traffic situations that represent a relatively low crash risk in the first place.

Unfortunately, the automated driving media hype is confusing consumers, as many drivers believe they can purchase a self-driving car right now. According to a study, commissioned by Thatcham Research, Euro NCAP, and Global NCAP (Thatcham Research 2019), 71% of motorists believe that they can buy a self-driving car today, while 11% would be tempted to have a brief nap while using current "Highway Assist" systems. The research was conducted throughout October 2018 and included 1567 car owners from China, France, Germany, Italy, Spain, the UK, and the USA.

Tests of cooperative driving systems such as “Highway Assist systems” by IIHS (Insurance Institute for Highway Safety 2018), Euro NCAP (Euro NCAP 2018), and others clearly demonstrate that cars on the market today can provide driver assistance, but this should not be confused with automated driving. The driver remains fully responsible for safe driving. Used correctly, this technology can help the driver to maintain a safe distance, speed, and to stay within the lane, but these systems should not be used in situations they are not designed for and should not be relied upon as an alternative to safe and controlled driving. The lack of driver training and standardized controls, symbols and names for these features, is further complicating matters for consumers. For the time being, NCAPs can play an important role in promoting realistic expectation among consumers and highlighting the need for constant driver vigilance.

The industry is working towards a safer system by adding Vehicle-to-Everything (V2X) communication, improved 360 degrees sensing capabilities, driver state monitoring, and smarter algorithms, which will further reduce driver engagement risks. Hands-free driving will open the door to completely new concepts that are offering a high degree of flexibility in design, layout, and seating arrangements. From an occupant crash protection perspective, this means that restraint systems will probably become more seat-centric and that the classic approach where belt and bags systems are validated against a limited number of load cases and occupant seating positions will need to be revisited. The continuous situation-awareness of the vehicle itself, facilitated by surround sensors and communication, and that of the occupants inside, will allow for more integrated safety functions across sensors and actuators. This, in turn, can improve pre-crash interventions and enhance the efficiency of passive safety systems.

With over 1.2 billion vehicles on the world’s roads and the average age of vehicles on the road rising to over 10 years, it is a given that automated and self-driving vehicles will have to operate in a mixed traffic environment with manually driven cars for many years to come. The accident distribution of automated cars will be notably different from today’s cars as, although they are expected to cause fewer crashes, they will still be involved in accidents with older, manually driven vehicles and other road users. Improving the level of safety of all vehicles on the road, regardless of level of automation, therefore deserves our continued attention. This remains particularly true for the vehicles sold in the most low-income countries, which do not meet minimum safety standards and trail behind the advancements made in high-income markets over the last decades.

NCAP Challenges for the Next Decade

Over the years, NCAP has offered a mechanism by which improved insight or technology can be introduced into the design of new vehicles much faster than would otherwise be possible. Gradually, the vehicle industry has come to terms with consumer ratings and has learned to use the system to its advantage in each market. This has greatly helped to democratize car safety and has improved consumer awareness around the world, important steps in achieving the Vision Zero goal to eliminate traffic casualties.

As the automotive industry is rapidly changing and new forms of mobility become available, the formal role that NCAPs traditionally had in influencing the market through consumer information will no doubt become more difficult to play in the future. One of the challenges for NCAPs will be who actually will be the consumer in the future – will private individuals still be buying cars as they do now 10 years from today? Will safety continue to sell, now that that most cars offer many systems as standard and our focus has radically shifted towards the promotion of sustainable mobility and reducing the impacts of climate change? And will consumers, even if it is just as service users, be allowed to have a say in setting minimum levels of safety for automated vehicles?

The answers to these and many other questions will need to be found the coming years. Even so, in the era of false information and differing opinions, there remains a need for truthful and transparent information, and so there will be plenty of opportunities for NCAPs to continue to make a difference.

Correlation with Real-Life Injury Risks?

For NCAP to maintain its credibility, the overall indication of the safety level that is provided by a safety rating must be a valid prediction when considering severe or fatal injuries or injurious crash involvement. On a technology level, a positive correlation between improved safety performance and the reduction of real-life injuries can often be determined, as shown by the numerous examples mentioned before, but in most cases, consistent field data only emerges several years after countermeasures have penetrated the market. An important challenge for NCAPs worldwide therefore continues to lie in the early identification of live-saving technologies, such that these organizations can effectively play their role as catalysts.

For this, a robust system for the collection, management, and analysis of regional road accident data is essential. Accurate information from before, during, and after an accident, including on the driver state, helps to determine accident causation and allows accident researchers to assess the effectiveness of countermeasures.

Furthermore, as most new safety technology is fitted as optional and, in the case of ADAS not always default on, it is important that researchers can independently verify which technology was fitted and in use on when a vehicle was involved in a crash?

On a more general level, it is more challenging to determine whether there is a correlation between star ratings and benefits in real-life impacts. Lie and Tingvall (2002) found that in car-to-car collisions, cars with three or four stars were found to be approximately 30% safer when compared with two-star cars or cars without a Euro NCAP score. The results indicated a 12% per star risk reduction for severe and fatal injuries. A few years later, these conclusions were supported by more broad international study, SARAC II (European Commission 2006); however, it was noted that significant variation remained in the measures of injury outcome in real crashes for specific vehicles within each Euro NCAP score category. Kullgren et al. (2010) again showed Euro NCAP crash tests to be highly correlated with serious crash performance, confirming their relevance for evaluating real-world crash performance. Good concordance was also found between Euro NCAP and Folksam (insurance claims based) crash and injury ratings. More recently, Kullgren et al. (2019) reviewed the developments in car crash safety in cars launched since the 1980s based on real-world data and reexamined how Euro NCAP crash test results predict the outcome in real-world crashes. It was found that Euro NCAP crash test ratings mirror real-world injury outcomes for all injury severities studied. Comparing five-star with two-star rated cars, the proportion of AIS 3+ injuries was 34% lower.

Note that the above studies focused on crashworthiness improvements and excluded active safety or driver assist technologies. To further develop rating systems that reward the overall safety of a vehicle from a self and partner protection point of view, the real-life impact of the combination of passive and active safety measures still needs to be better understood.

Vehicle Safety in Low- and Middle-Income Countries

As the Academic Expert Group for the third Global Ministerial Conference on Road Safety (Global Ministerial Conference on Road Safety 2019) points out, only 40 countries have implemented 7 or 8 of the critical safety standards identified in the 2018 Global Status Report on Road Safety, whereas 124 countries, many of them low- and middle-income nations, have implemented none or just one of these standards. Especially in developing markets, that are showing extraordinary growth in the number of vehicles in use, this is a major challenge as without such standards, manufacturers can easily cut back on safety to boost profitability.

To bring safer cars to these regions, a combined approach of legislative action and raising consumer awareness is most efficient, as has been illustrated in India recently by the efforts of Global NCAP and the Indian government (Ministry of Road Transport and Highways 2019).

Harmonization of Standards

But whereas NCAP's strength is its ability to follow closely the technology development by industry and take account of local market circumstances, it is also true that this has led to a wide variety of test conditions and inherently different rating schemes applied around the world. The criticism about the lack of harmonization is certainly justified in some instances, when different test speeds, barriers and crash dummies are used to evaluate a car's performance in what is essentially the same real-world crash scenario. On the other hand, there are many good reasons too to be different, not in the least because the cars built around the world are so diverse and must often meet local regulations.

Global NCAP provides a cooperation platform for NCAPs and similar organizations around the world to share best practice, to further exchange information, and to promote the use of consumer information to encourage the manufacture of safer cars across the global automotive market facilitates the dialog between NCAPs. Recently, more efforts have gone into cooperation between NCAP programs at the development phase as well, for instance, on the definition of a common 3D "soft" vehicle target for AEB testing (Grover et al. 2017).

Population Diversity

In most markets, new cars today are safer than they were a decade ago thanks to improved test standards, crumple zones, seatbelts, and airbags, which all help to protect occupants in a crash. While most occupant safety measures can be considered mature, more could and should be done to improve their robustness and effectiveness for the general diversity of vehicle occupants and crash scenarios.

Standard crash tests focus primarily on a limited number of sizes of occupants, namely the mid-sized male, small female, and large male. The effect of variation in age, gender, race, and corpulence must be better understood so that vehicle safety systems can work to the benefit of all. Test methods and injury criteria, especially those applied in regulation and by NCAPs, must drive more robust performance for the population of car occupants and vulnerable road users.

Encouraging ADAS

Crash avoidance systems can help prevent accidents from happening in the first place. Considering the time any new technology needs to penetrate the vehicle fleet, it is important that they are effectively deployed to address the above key accident scenarios, including those that involve other road users and commercial vehicles.

Today, the global uptake of crash avoidance technology is still developing: a large variety of systems is available, some are standard in developed markets, but only offered as optional elsewhere. As most ADAS are not mandated, the uptake of optional systems is still low and depends greatly on market incentives. The situation is likely to improve as the need for more on-board technologies to support (partial) automated driving will make crash avoidance systems cheaper and more cost-effective across the car fleet. Voluntary agreements to make equipment standard across the fleet – like those announced by US.DOT and IIHS on AEB systems in the USA (Insurance Institute for Highway Safety 2015) – help generate the momentum in the marketplace. In Europe, Euro NCAP's five-star system has helped boost the availability of ADAS across the Member States, as is shown from the share of the total cars rated with standard ADAS between 2012 and 2019 (Fig. 10). The situation is about to improve even more from 2022 onwards as the General Safety Regulation (European Parliament 2019) will come into effect, mandating, for the first time, systems like AEB, lane support, and speed assistance for passenger cars and LCVs.

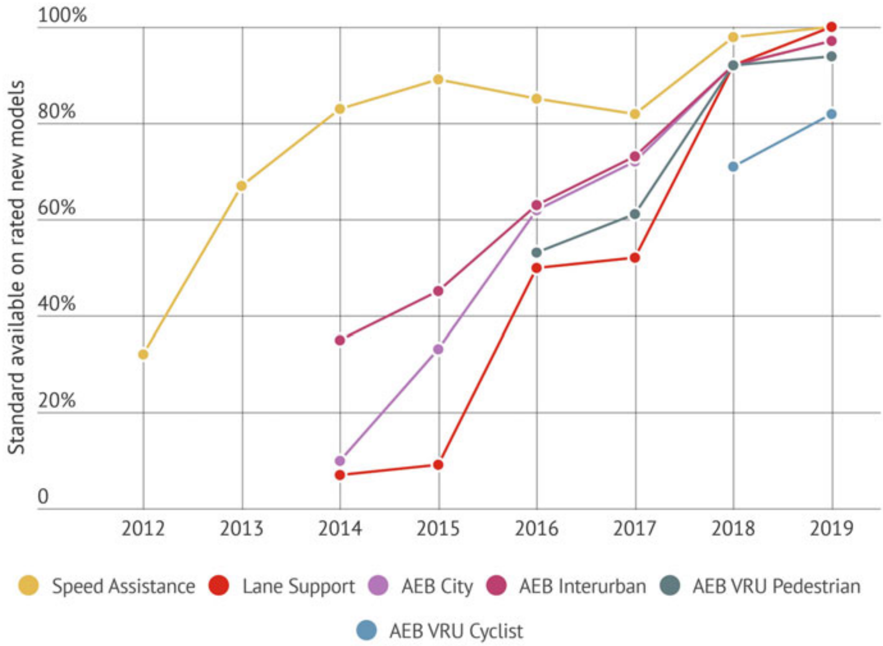

Fig. 10 Percentage of cars tested per year that is equipped with standard ADAS across the European market. Euro NCAP 2012–2019

Besides price, the acceptance and volume of advanced technologies are driven largely by how well consumers understand these features and value them. Today, when they are placed on the market, ADAS are often not yet fully mature. Together with the lack of knowledge among drivers, situations in which drivers fail to understand why the vehicle responds or indeed fails to respond in a certain way, can quickly arise. To counter this, consumer ratings must adequately evaluate the complex role of driver behavior and address inconsistencies in information, warning, and intervention strategies across the industry.

From Assisted to Autonomous and Connected Driving

As automation in cars becomes more mainstream, new crash scenarios and priorities may emerge and surveillance systems should be in place to ensure high quality data will be collected on the circumstances of a crash and the role of man and machine. There is a high expectation that vehicle automation will lead to innovations in the in-vehicle environment. This will lead to a potentially more complex loading environment for future restraint systems and will present a major challenge to NCAPs and regulators that must evaluate them.

As long as there are clear categories of crash avoidance systems that address typical accident scenarios and where the contribution of the driver is limited, the "spot testing" approach currently followed by NCAPs will remain beneficial. Verifying the performance on a system level in idealized conditions has the advantage of being able to set clear engineering targets, raise consumer awareness and effectively drive best practice and higher equipment fitment in the market. However, as safety functions become further integrated and vehicles begin to rely on connectivity with infrastructure and other road users – in other words become truly connected – it is unlikely that track testing alone will be sufficiently meaningful or conclusive to steer improvements in industry or to inform the consumer.

Conclusions

Vehicle safety has played an important role in reaching Vision Zero. Whereas regulations set minimum safety standards for motor vehicles in each region and give authorities the power to restrict sales of unfit vehicles, consumer ratings are an effective mechanism to influence the consumer preference and promote new technology entering the market.

Most consumers will have no personal experience by which to judge the crash safety of their car. Are they happy with the level of safety offered? Can they specify what level they want? Can they assess whether this objective has been met? Clearly, without objective and transparent safety information, these questions would be impossible to answer. This underlines the importance of public safety ratings and justifies why NCAPs around the world continue to develop their comparative safety tests. Moreover, it explains why consumer ratings continue to have an impact, not only with consumers but also more and more with public and private fleet managers to help them ensure that their vehicle fleet provides acceptable levels of protection to their employees.

A consumer rating system that is rooted firmly on real life experiences, but which closely follows the technological innovations in the marketplace, can deliver the most benefit for society. For this reason, links to road safety and biomechanical research as well as to the automotive industry are essential. The NCAPs together have achieved much to be proud of, but there is still important work to be done: in low- and middle-income markets to ensure that zero-star cars will be a thing of the past and, in developed markets, to ensure safety remains a priority for car manufacturers, in order to reduce road fatalities and injuries even further.

The NCAP community plans to engage in the roll out of vehicle automation as a way to dramatically improve vehicle safety and safe driving. It will continue to promote best safety practice when vehicles start to have elements fitted which support automated driving and to ensure that the vehicle manufacturer remains responsible for safe operation of the system. Consumer acceptance of these systems and objective, independent reassurance of their performance will play a key part in the transition that is ahead of us.

NCAP has shown that increasing consumer demand for safer cars, combined with exerting pressure on car manufacturers to incorporate better safety features into their vehicles, can make significant improvements to the safety of cars and bring Vision Zero one step closer.

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Saving Lives Beyond 2020: The Next Steps 26

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Foreword

Road safety has come a long way in our lifetimes, and there are steps in this progress that mark their place in history. Many of these were technical innovations, such as seat belts, electronic stability control, and geofencing for vehicle speed control. Also important, though perhaps fewer in number, were innovations in strategies to achieve change. These include the public health model of Dr. William Haddon, the introduction of Vision Zero, the World Report on Road Traffic Injury Prevention from WHO and the World Bank, and more recently, the Decade of Action 2011–2020. I am sure that the work and recommendations presented in this report will deserve their place in a "Hall of Fame" for strategic innovation in saving lives across the globe.

Our report and recommendations are based on the introduction of 2030 Agenda, often referred to as the Sustainable Development Goals (SDGs). With the establishment of these Goals in 2015, road safety was explicitly included for the first time as part of the global development agenda, and this heightened recognition gives us a new and unique opportunity to accelerate progress. This recognition puts road traffic safety on the same level of global criticality as climate, health, and equity issues and means that road safety can no longer be traded off in order to promote other needs. Inclusion among the SDGs also means that road safety is the responsibility of a wide range of stakeholders, both public and private. While some might see this as an imposition, I see it as hope and an opportunity to use our knowledge to achieve a vision of mobility without fear for our lives.

In this report, we point out that road safety is a necessity for health, climate, equity, and prosperity. If children cannot walk or bicycle to school without risking their lives, we limit their access to education, good health, and freedom and consequently our hope for the future. If we cannot transport goods across a nation or around the world in a safe and sustainable way, we limit the possibility of trade, economic development, and elimination of poverty. If our workplaces are not safe, we threaten earnings and the sustainability of families. Elimination of deaths and serious injuries in road traffic is essential to many other sustainability goals in very direct and clear ways. Road traffic safety can no longer develop in isolation.

The SDGs have been widely endorsed, and their achievement is now accepted as a central responsibility by governments, corporations, and civil society. Expectations for meaningful contributions by these organizations are driving public attitudes and even affecting investment decisions. Sustainability reporting has become a means for organizations to demonstrate their societal value, and new tools are needed to help them communicate their contributions in an accurate and transparent way. Cities and corporations can do fantastic things to protect the public and create a more livable environment with improved security, better health, and cleaner air.

I am proud to have led a group of internationally recognized road safety thought leaders to formulate the vision, strategy, and rationale underlying these recommendations. Capturing the wisdom of these leaders was among the most challenging tasks I have undertaken, but also the most rewarding. The ideas in the report were developed by consensus. Each member of the group made concessions in our personal viewpoints, but gained insight and knowledge from the others. All of us are proud to stand behind the product of our collaboration, and that is in the end what counts!

Executive Summary

The Academic Expert Group convened by the Swedish Transport Administration lent its combined experience, expertise, and understanding of global road safety issues, problems, and solutions to create a set of recommendations for a decade of activity by the public and private sectors that would lead to a reduction of worldwide road deaths by one-half by 2030. The recommendations are made in the context of a Third High-Level Conference on Global Road Safety to be held in Stockholm in February 2020 and are offered for consideration by conference participants and leaders from businesses, corporations, governments, and civil society worldwide.

The report reflects on the Decade of Action for Road Safety 2011–2020, addressing both its accomplishments and limitations. The targeted reductions in global road deaths were not achieved, and in fact the number of global road traffic deaths increased over the decade. Available data are insufficient to assess progress on serious injuries. However, there were many foundational accomplishments during the decade, including increased awareness of road safety problems and solutions among governments, corporations, businesses, and civil society; measurable and effective safety improvements in many locations; new funding; and new partnerships. Road safety needs were expressed in a new structure using five pillars, and evidence-based interventions were identified for each pillar, along with measures and targets. A significant achievement of the Decade of Action 2011–2020 was the inclusion of road safety among the Sustainable Development Goals (SDGs). Integrating a road safety target into SDG 3.6 and 11.2 was a remarkable accomplishment with far-reaching potential.

The report proposes a vision for the evolution of road safety and recommends a new target of 50% reduction in road deaths and serious injuries by 2030 based on expanded application of the five pillars, adoption of Safe System principles, and integration of road safety among the Sustainable Development Goals. The vision describes an evolution of road safety, building from the foundation of the pillars, incorporating adoption of the Safe System approach, and leading to a future comprehensive integration of road safety activity in policy-making and the daily operations of governments, businesses, and corporations through their entire value chains. The vision also stresses the need for further engagement of the public and private sectors and civil society in road safety activities and capacity-building among road safety professionals worldwide.

A set of nine recommendations are proposed to realize the vision over the coming decade:

Sustainable Practices and Reporting: including road safety interventions across sectors as part of SDG contributions	*Safe Vehicles Across the Globe*: adopting a minimum set of safety standards for motor vehicles

(continued)

Procurement: utilizing the buying power of public and private organizations across their value chains	*Zero Speeding*: protecting road users from crash forces beyond the limits of human injury tolerance
Modal Shift: moving from personal motor vehicles toward safer and more active forms of mobility	*30 km/h*: mandating a 30 km/h speed limit in urban areas to prevent serious injuries and deaths to vulnerable road users when human errors occur
Child and Youth Health: encouraging active mobility by building safer roads and walkways	*Technology*: bringing the benefits of safer vehicles and infrastructure to low- and middle-income countries
Infrastructure: realizing the value of Safe System design as quickly as possible	

Preamble

In 2018, as the Decade of Action for Road Safety 2011–2020 was nearing its conclusion, the Government of Sweden made an offer to host the Third Global Ministerial Conference on Road Safety, an event that will gather road safety experts and national delegates from around the world to reflect on the purpose, progress, and future of this global road safety movement. As a leader in both road safety theory and practice, Sweden is well-positioned to host this important gathering and provide a structure and forum where stakeholders look back at how the global effort started, take stock in how far we have come, and consider our path forward.

Recognizing the pivotal role that this conference will serve in global road safety and the range of stakeholders engaged in the movement, the Government of Sweden worked closely with UN colleagues to create an inclusive conference planning structure that engaged leaders from governments, non-government and civic organizations, academia, and businesses. Work groups were formed, research was reviewed, and perspectives on the past and future of road safety were compared in order to formulate a framework for the Third Ministerial Conference.

The work of these groups was further motivated by the Political Declaration from the Sustainable Development Goals Summit taking place on September 24–25, 2019 which reaffirmed commitment to implementing the 2030 Agenda on Sustainable Development and called for accelerated action by all stakeholders at all levels to fulfill this vision (United Nations 2019).

Among the work groups engaged in conference planning was the Academic Expert Group consisting of experienced road safety researchers, practitioners, and thought leaders from around the world. The Academic Expert Group was charged with these primary tasks:

- What are the results of the Decade of Action, and what experiences can we draw from the efforts made during the past 10 years?
- What is a challenging and usable target (or targets) for the next 10 years up to 2030 that can be integrated in the 2030 Agenda, in particular Goal 3.6?

- What processes and tools could be further developed or added to make actions even more effective, and which sectors of the society could be further stimulated to contribute to the overall results?
- How can trade, occupational safety, standards, corporate behavior, and other aspects of the modern society be linked with road safety?
- How can nations, local authorities, and governments as well as public and private enterprises, in particular major enterprises, be stimulated to contribute to road safety through their own operations?
- How can other important challenges, in particular those targeted in Agenda 2030, contribute to improved road safety, and vice versa?

This report documents the recommendations of the Academic Expert Group and provides an indication of the rationale behind their views. A list of the members of the Group is included in the appendix.

Reflections on the Decade of Action 2011–2020

Origins of the Decade

General Assembly Resolution 58/289 of April 2004 recognized the need for the UN System to support efforts to address the global road safety crisis. The Resolution invited the World Health Organization to coordinate road safety issues within the UN System, working in close cooperation with the UN Regional Commissions. The UN Road Safety Collaboration was established, bringing together international organizations, governments, non-government organizations, foundations, and private sector entities to coordinate effective responses to road safety.

The Commission for Global Road Safety formed by the FIA Foundation in 2006 issued a call for a Decade of Action for Road Safety in its 2009 report which was widely endorsed. The UN Secretary-General, in his 2009 report to the General Assembly, encouraged Member States to support efforts to establish a Decade as a means to coordinate activities in support of regional, national, and local road safety, accelerate investment in low- and middle-income nations, and rethink the relationship between roads and people.

In March 2010 the UN General Assembly proclaimed the Decade of Action for Road Safety 2011–2020 with a goal of stabilizing and then reducing the forecasted level of road fatalities and injuries around the world. The resolution requested that the World Health Organization and the UN Regional Commissions, in cooperation with partners in the UN Road Safety Collaboration and other stakeholders, prepare a global plan with the Decade as a guiding document to support the implementation of its objectives.

Major Milestones and Accomplishments

The Decade of Action raised global awareness of road safety among governments, businesses, and civil society. It brought measurable and effective safety improvements. It attracted new funding and new partnerships and brought road safety closer to the global arena of public health issues.

Target setting is now common practice across sectors of society as a means for managing progress toward ambitious goals, and in some cases the practice has developed from simple targets to complex sets of sub-targets, indicators, and action plans. However, there is room for improvement in road safety indicators to ensure an adequate link to outcomes so they can be useful in guiding policy decisions.

A significant achievement of the Decade of Action with regard to the long-term course of road safety is the inclusion of road safety among the Sustainable Development Goals (SDGs). Integrating road safety targets 3.6 and 11.2 in the SDGs was a remarkable accomplishment with far-reaching implications. The 2030 Agenda states clearly that the "17 Sustainable Development Goals with 169 associated targets are integrated and indivisible." This recognition places road safety at the same level of criticality as other global sustainability needs and clearly indicates that sustainable health and well-being cannot be achieved without substantial reductions in road deaths and serious injuries. While this integration with other SDGs has yet to be realized on a global level, the opportunity for new partnerships is now available, and the potential benefits that could come from such integration are compelling.

According to the projections for road deaths and the ambition set by the Decade of Action in 2011, deaths were expected to reach 1.9 million by 2020 if no actions were taken. The ambition was to "stabilize and then reduce deaths" by about 50% of the forecast level, or approximately 900,000 deaths, by 2020. The road safety target included in the SDGs uses different definitions and data sources and calls for an ambitious 50% reduction in the absolute number of global deaths and injuries between 2015 and 2020, or about 650,000 deaths.

The 2018 Global Status Report estimates a current level of about 1.35 million road deaths, indicating that the ambition of stabilizing the trend of global deaths has not been met. Data on injuries are insufficient to measure progress. The targeted numbers of annual deaths – neither the 900,000 proposed by the original Decade nor the 650,000 included in the later SDG – are likely to be reached by 2020 (Fig. 1).

A significant achievement was the establishment of the UN Special Envoy for Road Safety. This position, created by the UN Secretary-General in April 2015, signifies the importance of road safety among global needs and provides a focal point for promoting and coordinating road safety activities among government and non-government organizations worldwide.

A particularly visible element of the Decade are the road safety pillars. This pillar structure illustrates the scope of activities needed to achieve lasting road safety progress and has proven to be useful for identifying gaps in national programs and allocating local resources to the most critical areas for improvements. The individual interventions included under each of the five pillars have been tested and evaluated and provide an evidence-based pathway to sustainable road safety. Evaluations of these interventions has been collected in systematic reviews and meta-analyses, and their application has been facilitated by the development of calculator tools that can

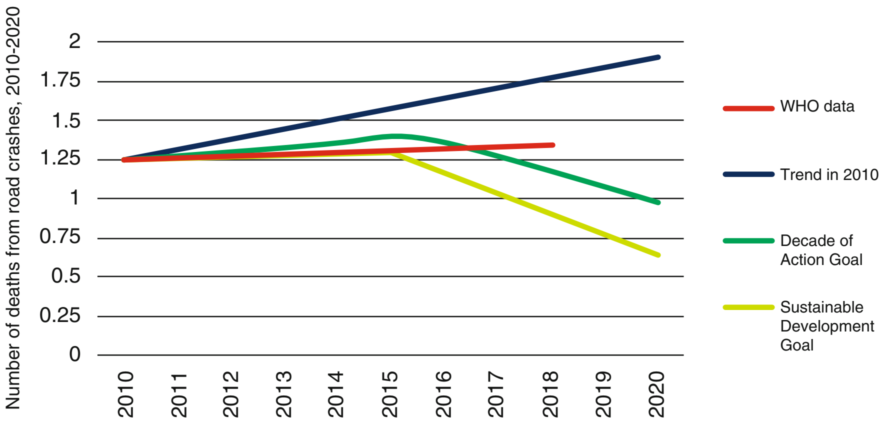

Fig. 1 Number of deaths from road crashes. (Adapted from OECD, International Transport Forum)

estimate impacts of changes and assist implementers in making strategy and investment decisions (Elvik et al. 2009; Wismans et al. 2019).

The road safety pillars are expected to remain the primary tools for improving road safety in the coming decade. The challenge is in expanding their adoption and application, building upon this achievement with the Safe System approach and integrating safety across sectors. The Sustainable Development Goals offer an opportunity to achieve these objectives.

Vision for the Second Decade

Road safety is integral to nearly every aspect of daily life around the globe. We step from our homes into a road system that leads us to work, to get our food, and to many of our daily family, health, and social needs.

The influence of the road transportation system is so pervasive that its safety – or lack of safety – affects a wide range of social needs. Road safety – mobility without risk of death or injury – affects health, poverty, equity, the environment, employment, education, gender equality, and the sustainability of communities. In fact, road safety directly or indirectly influences many of the UN Sustainable Development Goals.

Unlike other modes of transportation such as aviation, railways, or maritime, road transport has lacked an integrated and comprehensive approach towards safety. The Academic Expert Group proposes a global road safety vision that describes how existing accomplishments combined with progressive techniques can lead to a new era in which road safety is integrated in a range of other social development movements and pursued in a comprehensive manner.

The vision proposes an evolution of road safety beginning with the road safety pillars as a foundation. Nations at every level of road safety development rely on fundamental tools included among the pillars as the operational elements to achieve and maintain high levels of road safety.

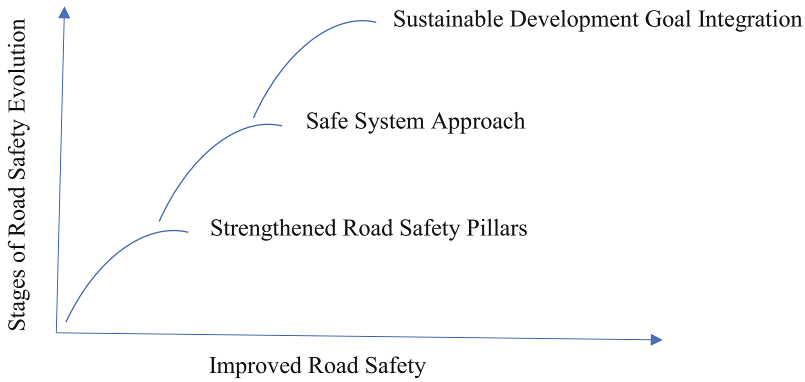

Fig. 2 The evolution of road safety

Many nations around the world have enhanced the effect of pillar interventions by applying them selectively and strategically according to Safe System principles. The Safe System approach addresses problems closer to their root cause and on a broader scale than conventional methods.

The highest level of road safety evolution has yet to be reached by any nation but promises exponential benefits. At this level, road safety is no longer an independent public health and safety initiative, but rather an integral part of a broad range of societal endeavors from commercial enterprise to humanitarian initiatives (Fig. 2).

Strengthened Road Safety Pillars

While there is still much to learn, we have the tools to vastly improve road safety around the globe. The five road safety pillars identified in the Global Plan for the Decade of Action for Road Safety 2011–2020 include a set of evidence-based interventions that can measurably improve the safety of road traffic, especially if they are applied with the Safe System approach. These road safety pillars include tools for improving road safety management and enhancing the safety of roads and mobility, vehicles, road users, and emergency response.

We have made progress in getting these tools into practice. What we need is much more progress, the sort of progress that will require a larger and more effective army of implementers. The Sustainable Development Goals – and the army of advocates who are advancing these goals around the world – can make a substantial contribution to this need.

Safe System Approach

The vision for the next decade multiplies the reach and impact of the tools within the five pillars and also extends the value of another critical component of the first decade, the Safe System approach. The vision recognizes that the tools of the five pillars will have the greatest effect on safety when they are applied alongside new tools in a strategic and pervasive manner following the proven principles of the Safe System approach. The Safe System approach – also referred to as Vision Zero – recognizes that road transport is a complex system and that humans, vehicles, and the road infrastructure must interact in a way that ensures a high level of safety. The Safe System approach (Welle et al. 2018):

1. Seeks a transportation system that anticipates and accommodates human errors and prevents consequent death or serious injury
2. Incorporates road and vehicle designs that limit crash forces to levels that are within human tolerance
3. Motivates those who design and maintain the roads, manufacture vehicles, and administer safety programs to share responsibility for safety with road users, so that when a crash occurs, remedies are sought throughout the system, rather than solely blaming the driver or other road users
4. Pursues a commitment to proactive improvement of roads and vehicles so that the entire system is made safe rather than just locations or situations where crashes last occurred
5. Adheres to the underlying premise that the transportation system should produce zero deaths or serious injuries and that safety should not be compromised for the sake of other factors such as cost or the desire for shorter transportation times

Integration of Road Safety in Sustainable Development Goals

As an independent endeavor, the road safety movement is limited in potential reach and influence. Positioned as a special interest, road safety is often subordinate to other social needs and can gain progress only where it can achieve attention by road users or those who make decisions about roads and vehicles. But if recognized as a basic necessity that can facilitate progress in meeting social needs ranging from gender equity to environmental sustainability, the potential of road safety can be greatly expanded.

Among the key achievements of the Decade of Action 2011–2020 was the inclusion of road safety in the Sustainable Development Goals. Because these Goals are defined as indivisible and mutually dependent (United Nations 2015), the explicit citation of road safety in the *Health and Well-Being* and *Sustainable Cities* goals is accompanied by implicit integration across the goals and especially in those addressing climate, equity, education, and employment.

Integrating road safety among the Sustainable Development Goals is an important step toward embedding road safety expectations and activities in the far-ranging daily processes of governments and in the operations of corporations, businesses, and civic organizations globally. Substantial levels of such widespread integration have yet to be achieved but have the potential to expand interventions to a scale where road deaths and serious injuries would be reduced to near zero.

Importance of the Vision for Low- and Middle-Income Nations

The focus of global road safety efforts needs to remain on low- and middle-income nations, the location of the great majority of the problem – 93% worldwide road traffic deaths in 2016.

The Academic Expert Group believes that the value of the road safety pillars is universal.

That is, the scope of action described by the pillars – Road Safety Management, Infrastructure, Safe Vehicles, Road User Behavior, and Post-Crash Care – is essential in any environment, and the activities outlined in the Global Plan of Action (World Health Organization 2010) for each pillar can be effective in nearly every national context.

However, the Group recognizes that implementation of these activities from the Safe System perspective in some environments can face formidable barriers. Competing priorities, the capacity of local governments to take action, and differences in geographic, geopolitical, and geodemographic situations can present serious challenges to implementing changes necessary to initiate or sustain road safety improvements. These challenges have likely contributed to the lack of reductions in road deaths over the past several years in many nations.

Despite these challenges, many nations have made progress with key road safety activities. Since 2014, 22 nations with a combined population of over 1 billion people – 14% of the world population – have amended laws on one or more key risk factors, bringing their legislation in line with best practice (World Health Organization 2018a). Credit for this progress likely goes to a range of influencers, including motivated local government or non-government leaders, actions by national or international NGOs with interest in road safety, and leadership through the UN system.

Change in low- and middle-income nations has been slower, and governments in these nations need to take a deeper look at their situation and address this issue, with help from external partners as the situation requires. While the Agenda 2030 looks to governments for lead responsibility, strong and sustained efforts from the private sector are important for the achievement of the goals and targets. Business underlies 84% of the GDP and 90% of the jobs in developing countries and, by utilizing their full value chains, can make a substantial contribution to the safety of those who are at greatest risk for a range of threats including motor vehicle crashes.

The Safe System approach is of critical importance not only for developed areas but also for developing nations and cities. The global trend toward urbanization will cause widespread expansion of cities and create new urban areas in coming decades. The UN Department of Economic and Social Affairs predicts that urban areas will grow by more than 50% over the coming 30 years, with the great majority of this expansion occurring in Africa and Asia (World Urbanization Prospects 2018). New roads and infrastructure will be necessary to accommodate the urban expansion, and this creates an opportunity to incorporate Safe System design features from the beginning.

Technological development will continue to accelerate making existing safety devices more affordable and introducing new safety potential for vehicles and the road infrastructure. Public and private sector organizations will be increasingly compelled to contribute to sustainability goals, including road safety. The vision presented here by the Academic Expert Group provides an opportunity to guide these changes in ways that can improve road safety and contribute to global sustainability.

Sustainable Development Goals

The UN 2030 Agenda for Sustainable Development, adopted by all Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. The Agenda is based on 17 Sustainable Development Goals (SDGs) and presented as an urgent call to action for both the public and private sectors in a global partnership.

The SDGs cover a range of necessities for improving and stabilizing both the human condition and the condition of our planet, recognizing the interdependence of these two objectives (Fig. 3).

The SDGs build on decades of research, deliberation, and negotiation. Transportation issues have been part of the sustainability discussion for at least 30 years, initially with a focus on reducing congestion and improving energy efficiency. However, road safety was not explicitly included among the development goals and targets until adoption of the 2030 Agenda for Sustainable Development in 2015.

Fig. 3 UN Sustainable Development Goals (World Health Organization)

Sustainable Development Goals: Integrated and Indivisible

The UN General Assembly Resolution 70/1, Transforming our World: The 2030 Agenda for Sustainable Development, defines a global vision of unprecedented scope, far beyond the previous Millennium Development Goals. It maintains a focus on priorities such as poverty eradication, health, education, and food security and nutrition, while adding critical economic, social, and environmental objectives.

The specific inclusion of road safety targets in Agenda 2030 reflects universal recognition that death and injury from road crashes are now among the most serious threats to the future of our people and planet. Article 55 of the Resolution states that the 17 Goals are "integrated and indivisible, global in nature and universally applicable." This means that road safety is no longer a need that can be compromised or traded off in order to achieve other social needs. It implies, for example, that the safety risks inherent in raising speed limits should not be tolerated in order to realize economic benefits of faster traffic and that investments necessary to improve road safety should not be diverted for other needs.

The 2030 Agenda also points out the deep interconnections among the goals and targets, beginning with the fundamental interconnection of the health of people and the health of the planet and extending to many other interdependencies (Fig. 4).

An analysis of SDG interactions at the Goal level by the International Council for Science (2017) points out the connections between Goal 3: Good Health and Well-Being, the location of the primary road safety target, and many of the other Goals.

Together, these qualities of indivisibility and connectedness among the goals and targets present an opportunity to advance road safety in new context, but they need to be pursued and acted upon by the road safety community and others. They need to be translated into actions and solutions to contribute to improving road safety and other human development issues worldwide.

Agenda 2030 compels public and private organizations of all sizes to apply their resources and influence to the widest extent possible toward achievement of SDGs. Many organizations, government and corporate, have a health or safety mandate that will lead them to apply resources directly to targets 3.6 and 11.2. A far greater range of entities have mandates that point them directly at one or more other Goals and – because of the interconnectedness and indivisibility of the Goals – will also recognize the relevance of applying their influence to advance road safety. Examples of these connections include:

- Environmental organizations contributing to efforts to reduce vehicle speeds and lower emissions and noise
- Gender equity organizations contributing to safe pedestrian, bicycle, and motor vehicle travel as a means to open opportunities for women of all ages
- Workplace safety organizations contributing to road safety as a leading cause of workplace death and injury
- Organizations pursuing eradication of poverty advancing road safety as a means for improving access to employment opportunities
- Education organizations promoting road safety to facilitate travel to local schools

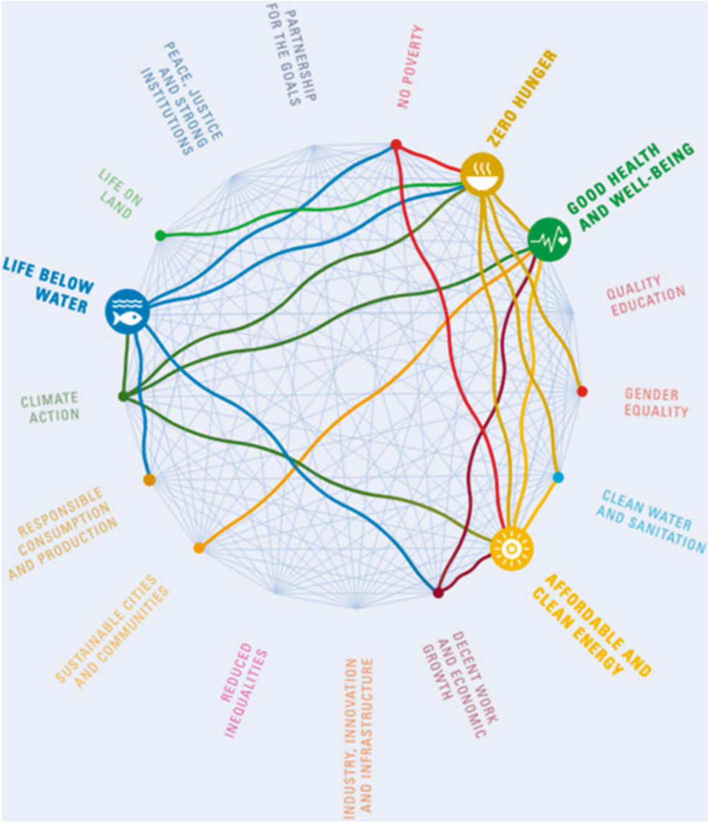

Fig. 4 Goal interactions (International Council for Science)

- Organizations seeking elimination of inequalities supporting road safety to encourage access to essential needs for individuals and under-served communities

Strategies and Tools for Achieving Sustainable Development Goals

Government and corporate organizations need guidance and direction to make meaningful contributions to a range of SDGs. Following are examples of tools and guidance available to assist organizations in focusing their efforts to make efficient and effective contributions.

In their Sustainable Development Report: 2019, Bertelsmann Stiftung and Sustainable Development Solutions Network propose a set of six transformation strategies that can be used by governments and corporations to organize their SDG contributions. These transformation strategies are structured to take advantage of synergies among the SDGs and to align with typical methods of government and corporate operations (Bertelsmann Stiftung and Sustainable Development Solutions Network 2019).

Sustainable Mobility for All is advancing sustainable mobility as a prerequisite for achieving a range of SDGs. The organization is engaging stakeholders to develop a Global Roadmap for Action to promote four mobility policy goals, Universal Access, Efficiency, Safety, and Green Mobility, and offers tools such as Mobility Data by Country, a Global Mobility Tracking Framework, and Global Transport Stakeholder Mapping (Sustainable Mobility for All 2019).

The World Business Council for Sustainable Development (WBCSD) works with cities and corporations to facilitate their effective and efficient contribution to the SDGs. WBCSD is a CEO-led global membership organization representing nearly 200 leading businesses. WBCSD enhances the business case for sustainability with tools, models, services, and experiences (World Business Council for Sustainable Development 2019).

The Sustainable Development Compass provides practical guidance for companies to align their strategies and measure their contributions to the SDGs. Developed through a partnership among GRI, the UN Global Compact, and WBCSD, the Sustainable Development Compass assists companies in understanding the SDGs, defining priorities, settings goals, integrating activities, and reporting and communicating progress (Sustainable Development Compass 2015).

Finally, while sources of guidance and tools such as those described above can help engage businesses, governments, and civil organizations in effective contributions to the SDGs, and assist them in focusing, coordinating, monitoring, and measuring their work, there are currently few such tools available to guide road safety contributions. This type of road safety guidance is urgently needed.

This guidance for corporate and government organizations needs to address where contributions can be made to road safety as well as how such actions can be taken. The ground-level activities needed to contribute to the road safety targets 3.6 and 11.2 are well understood and documented. The five pillars described in the Global Plan for the Decade of Action for Road Safety 2011–2020 include a comprehensive set of evidence-based interventions that have proven effective in some circumstances and will provide a useful basis for new road safety contributions by governments, corporations, and civil society, especially if applied according to Safe System principles (Global Plan for the Decade of Action for Road Safety 2010).

Prerequisites for Change

Expanded Engagement of Public and Private Sectors

In the coming decade, we have the potential to use the linkages between road safety and the Sustainable Development Goals to expand the reach of our tools well beyond the traditional scope of transportation, public safety, and public health. Integrating road safety among a range of Sustainable Development Goals will engage non-traditional public and private stakeholders and lead to road safety activities taking place across entire governmental and corporate value chains.

Governments, corporations, and civil society will be encouraged to use their resources and influence to contribute to the achievement of Sustainable Development Goals wherever possible. The collective power of public and private organizations around the world adopting road safety practices as part of their contributions to the Sustainable Development goals, together with their endorsement, leadership, and purchase power, is substantial. This potential multiplies the value of the road safety pillars, placing these tools in the hands of a far wider group of motivated implementers than has previously been possible.

Corporations from every sector and public authorities with a wide range of direct responsibilities can be engaged in road safety activities. These organizations will be motivated to look beyond their core tasks for efficient and effective strategies to contribute to the SDGs. If these organizations are educated concerning the need and opportunities, road safety actions could be a widespread priority.

The means for contributing to road safety by these new partners could include policies regarding vehicle fleet purchase and the manner in which these vehicles are scheduled, routed, and driven. In addition, these organizations can use their contractual and procurement power to affect road safety policies and practices of all those upstream organizations from which they purchase services and supplies and all those downstream to whom they distribute their services.

Methods to realize the full potential of corporate and government engagement in road safety have yet to be fully explored. Combinations of traditional government-corporate regulatory roles may be effective alongside government incentives and voluntary SDG-driven roles. Exploration and evaluation of such alternative combinations of governmental and corporate initiatives is a high priority.

Capacity-Building

Research shows that a strong road safety management system is correlated with good road safety performance. The World Report on the Prevention of Road Traffic Injuries (2004) points out two key elements of a strong road safety management system, an effective lead road safety agency and committed road safety leadership.

The World Report defines a lead agency as an organization with the authority and responsibility to make decisions, control resources, and coordinate efforts by all sectors of government, including those of health, transport, education, and the police. The Report describes road safety leadership as including the capacity for commitment and informed decision-making at all levels of government, the private sector, civil society, and international agencies to support the actions necessary to achieve reductions in road risks, deaths, and serious injuries.

While a top-down approach to road safety management incorporating a lead agency and good safety leadership is an important ingredient, examinations of high-performing national road safety programs also point out the need for committed and knowledgeable road safety professionals. High-performing professionals are not only good practitioners (able to design and implement effective interventions) but also are able to link themselves with top-level decision-making in order to create a positive political environment and scale up effective road safety interventions. In some countries, road safety professionals are able to influence public and political discourse on road safety, and this has paved the way for effective policies (Bliss and Breen 2009).

However, many road safety professionals lack the skills necessary to be good practitioners, and an even greater number lack the insights needed to recognize opportunities to influence top-level road safety decision-making in the public and private sectors.

This lack of capacity among road safety professionals is a major barrier to progress in many countries. These countries do not have professionals with the specialized knowledge necessary to be effective in making roads and vehicles safer, to achieve safer road user behavior, and to design and operate a well-functioning post-crash system. Further, many countries and cities do not have the expertise required to adapt Safe System principles to their own conditions, effectively collect and analyze road safety data, or carry out quality road safety research. While less information is available to generalize the adequacy of such road safety professional expertise in the private sector, it is very likely that similar deficiencies exist.

Capacity-building for road safety professionals working for the government, the private sector, civil society, and research institutions should be given top priority, not only to make them better practitioners but also to prepare them to act more effectively within their organizational and national structures. Such capacity-building could go a long way toward moving road safety higher on the political agenda and advancing the evolution of road safety programs in jurisdictions and corporations. Study of road safety capacity-building approaches should be conducted to identify effective techniques and strategies.

Recommendations

The following recommendations are offered by the Academic Expert Group for inclusion in the Stockholm Declaration and for use by political, corporate, and civil society leaders and practitioners worldwide. The recommendations are directed towards 2030 and are intended to build upon those previously established in the Moscow Declaration of 2009 and the Brasilia Declaration of 2015 as well as prior UN General Assembly and World Health Assembly resolutions. The Academic Expert Group considers these additional recommendations to be essential for achieving the goal of reducing global road fatalities and serious injuries by half by 2030. The recommendations are interrelated and intended to be considered as a set rather than as individual options. The recommendations are based on the Safe System Approach.

These recommendations are necessarily far-reaching in both scope and ambition. The Group believes that the best strategy for reaching the goal for 2030 is to maintain commitment to prior recommendations and immediately initiate action on each of these new recommendations with sufficient intensity to achieve substantial progress by the middle of the coming decade. The Group further recommends that a rigorous evaluation be conducted 5 years into their adoption to measure progress and that the findings be used subsequently to refine and adjust the strategy.

Recommended Target for 2030

The Academic Expert Group discussed the importance of target setting and recognized the action taken by the High-Level Political Forum on Sustainable Development to "maintain the integrity of the 2030 Agenda, including by ensuring ambitious and continuous action on the targets of the Sustainable Development Goals with a 2020 timeline (United Nations 2019)."

The Group recommends the following points:

> It is crucial that a specific road safety target is maintained and kept up to date within the Sustainable Development Goals.

Proposed wording for Sustainable Development Goal 3, Target 3.6:

> Between 2020 and 2030, halve the number of global deaths and serious injuries from road traffic crashes, achieving continuous progress through the application of the Safe System approach.

The Academic Expert Group further recommends that:

> Operational targets should be set by individual global regions (consistent with the ambition of 3.6, but taking into account local developments, conditions, and resources).
>
> Targets should include fatalities and serious injuries. Identifying appropriate rates of deaths and serious injuries is also desirable. However, the optimal measure of fatal and non-fatal injury rates has yet to be determined.
>
> Linkages and collaborations should be established among the constituencies associated with the range of other SDGs that are affected by and associated with road safety. These include Quality Education, Decent Work and Economic Growth, Reduced Inequalities, Sustainable Cities and Communities, Climate Action, and others. Actions should involve both the public and private sectors.

Criteria Considered in Formulating Recommendations

To identify areas of focus and specific content of the recommendations, the Academic Expert Group agreed on a number of inclusion criteria:

1. Recommendations that extend beyond Sustainable Development Goal 3.6 and establish synergies with other Goals will be prioritized.

2. Recommendations that engage non-traditional partners with potential for leadership or constituencies that could reach widespread participation will be prioritized.
3. Recommendations must reach beyond those previously established in Declarations from the First and Second Ministerial conferences and Resolutions from intervening UN General Assemblies.
4. Recommendations must have compelling evidence of potential impact in terms of intervention effectiveness, scale of the problem addressed, and efficiency of the proposed solution.
5. Recommendations must adhere to the SMART principle:
   Specific: identifiable responsibilities and actions
   Measurable: tangible and observable with objective units of scale
   Attainable: possible considering known obstacles
   Relevant: consistent with the Safe System approach
   Timebound: achievable (or capable of substantial progress) by 2030

The Academic Expert Group recommends that additional consideration be given to monitoring progress toward achievement of the recommendations. While useful measurement tools are available, such as the UN Voluntary Global Performance Targets (United Nations 2018a) and their associated indicators (United Nations 2018b), these measures do not adequately reflect implementation of the Safe System approach. More work is needed to develop targets and indicators that reflect Safe System implementation (European Commission 2019).

Recommendation #1: Sustainable Practices and Reporting

Summary

In order to ensure the sustainability of businesses and enterprises of all sizes, and contribute to the achievement of a range of Sustainable Development Goals including those concerning climate, health, and equity, we recommend that these organizations provide annual public sustainability reports including road safety disclosures and that these organizations require the highest level of road safety according to Safe System principles in their internal practices, in policies concerning the health and safety of their employees, and in the processes and policies of the full range of suppliers, distributors, and partners throughout their value chain or production and distribution system.

Rationale

The traditional assumption that road safety is solely the responsibility of governments is being challenged by several factors. First, while some governments have led substantial improvements in road safety in prior decades, relying on government leadership and regulation has not resulted in sufficient progress in recent years in most countries. This shortcoming is despite the launch and growth of a worldwide road safety movement stimulated by the UN Decade for Action for Road Safety 2011–2020 that was largely targeted at engaging and directing government action.

Second, governmental strategies to improve road safety have largely targeted the regulation of individual road user behaviors, missing the opportunity to engage organizations such corporations, businesses, civil society, and other authorities in road safety commitments.

Third, the scale and potential road safety impact of large multinational corporations is larger than that of many governments. Supply chains associated with multinational corporations account for over 80% of global trade and employ one of five workers (Thorlakson et al. 2018).

The World Economic Forum points out that a number of multinational corporations have grown to such a scale that they eclipse most national governments in gross annual revenue (World Economic Forum 2016). Other authors point out that the scope of multinational companies allows far-reaching influence. More than 30 financial institutions have consolidated revenues of more than $50 billion each – more than the gross domestic product of 2/3 of the world's countries. Beyond their economic power, multinational companies shape social conditions. In developing nations, large corporations may spend more on education than the government (Khanna 2016) (Fig. 5).

Clearly, corporations and businesses have the power and global reach to effectively contribute to the achievement of the SDGs. A number of frameworks, principles, and guidelines have been developed over the past decades to establish expectations concerning their contributions, including:

- International Labour Organization Tripartite Declaration of Principles Concerning Multinational Enterprises and Social Policy
- UN Global Compact Principles
- UN Guiding Principles on Business and Human Rights

These principles address responsibilities such as universal rights, environmental concerns, and anti-corruption standards, defining minimum expectations for

The world's biggest economic entities

Based on a ranking from Global Justice Now. Data from the Fortune 500 and CIA World Factbook. Compares government and corporate revenues

1. United States
2. China
3. Germany
4. Japan
5. France
6. United Kingdom
7. Italy
8. Brazil
9. Canada
10. Walmart

Source: Global Justice Now, CIA World Factbook and Fortune

How the 10 biggest corporations compare to economies

Based on a ranking from Global Justice Now. Compares government and corporate revenues. Overall ranking in brackets

1. Walmart (10)
2. State Grid (14)
3. China National Petroleum (15)
4. Sinopec Group (16)
5. Royal Dutch Shell (18)
6. Exxon Mobil (21)
7. Volkswagen (22)
8. Toyota Motor (23)
9. Apple (25)
10. BP (27)

Source: Global Justice Now, CIA World Factbook and Fortune

Fig. 5 World's largest economic entities (World Economic Forum) companies engaging in sustainable development activities. Other guidelines include the ISO 26000 Guidance on Social Responsibility and regional guidance such as the OECD Guidelines for Multinational Enterprises (Sustainable Development Compass 2015).

Businesses recognize the value of corporate virtue, and the SDGs provide a timely and widely endorsed opportunity for corporate engagement in sustainability. A review of business trends in the book *The Market for Virtue* concludes that corporate social responsibility has been a global phenomenon since the 1990s and that the business case for such practices is widely understood and applied. However, the author explores the extent of corporate sustainability practices and suggests that they could go much further (Vogel 2005).

An analysis performed by Oxfam in 2018 (Mhlanga et al. 2018) found mixed evidence of corporate action in responding to the SDG opportunity. An important positive finding is that more companies – especially multinational organizations – are making commitments to the SDGs in their corporate communications. This is an essential step forward; however, evidence concerning increases in corporate action were more difficult to identify.

A large body of evidence supports the benefits of sustainable practices. A review over 200 academic papers on sustainability and corporate performance found that:

- Ninety percent of the studies find that sound sustainability standards lower the cost of capital of companies,
- Eighty-eight percent of studies conclude that solid environmental, social and governance practices result in better operational performance, and
- Eighty percent of studies show that stock price performance is positively correlated with sustainability practices (Clark et al. 2015).

Increasingly, investors are looking beyond solely economic indicators before purchasing a firm's stock or providing capital. One in four dollars now invested in the USA – a total of $23 trillion/year globally – is now directed to firms after considering their environmental, social, and governance performance (Scott 2019).

Sustainability reporting is key to stimulating corporate change. Reporting that is relevant, reliable, and accessible will help businesses organize and prioritize their efforts, actuate the business case for corporate virtue by enabling meaningful external review, and stimulate the application of stakeholder pressure, both positive and negative.

Actions and Responsibilities

Sustainability reporting standards and models are available from a number of sources, including those developed by Global Reporting Initiative (GRI) who report widespread use of their standards among the world's largest corporations (GRI and Sustainability Reporting 2019).

Existing literature provides little detail on how to report on road safety in the context of the Sustainable Development Goals. Further work is needed to facilitate this reporting task. Because organizations differ in the ways they can affect sustainability, including their opportunities to improve road safety, reporting standards should be specific to the functions of the organization. For example, opportunities for sustainability contributions by a manufacturing firm that uses trucks to bring in raw materials and distribute products will be far different than a banking organization that performs its transactions electronically. Specific standards for several industrial sectors are now being developed by GRI. To fully reflect road safety sustainability actions across the range of public and private sector organizations, many more such targeted reporting standards – including standards for road safety reporting – are needed.

With regard to road safety targets 3.6 and 11.2, reporting should be internal and external and extend across the full range of the corporate value chain. A value chain is the full scope of activities – including design, production, marketing, and distribution – businesses conduct to bring a product or service from conception to delivery. For companies that produce goods, the value chain starts with accessing raw materials used to make their products and includes every other step including distribution and use by purchasers (Harrison 2018).

Author Michael Porter from Harvard Business School was the first to discuss the concept of a value chain and how it can be used to identify opportunities and focus energy to increase corporate value. Porter points out five primary activities in a corporate value chain (Porter 1998):

- ***Inbound logistics*** are the receiving, storing, and distributing of raw materials used in the production process.
- ***Operations*** is the stage at which the raw materials are turned into the final product.
- ***Outbound logistics*** are the distribution of the final product to consumers.
- ***Marketing and sales*** include advertising, promotions, sales-force organization, distribution channels, pricing, and managing the final product to ensure it is targeted to the appropriate consumer groups.
- ***Service*** refers to the activities needed to maintain the product's performance after it has been produced, including installation, training, maintenance, repair, warranty, and after-sale services.

While specific opportunities will vary, nearly every business, corporation, or government organization could contribute and report on road safety across their value chain. Using Porter's model, the following table illustrates a number of possibilities:

	Inbound logistics	Operations	Outbound logistics	Marketing and sales	Service
Vehicle manufacturer	Require component suppliers to follow a road safety management program (e.g., ISO 39001)	Advance safe design at every opportunity including speed limiters and driver impairment detection	Require distribution carriers to follow safest routes to dealerships and that professional drivers comply with safety rules	Provide vehicles with at least the UN-recommended eight minimum safety standards for every global market	Provide training on use of safety devices and free safety checkups for first and subsequent owners

(continued)

	Inbound logistics	Operations	Outbound logistics	Marketing and sales	Service
Clothing producer	Require textile and garment assembly firms to provide safe transportation to and from the factory for workers	Set expectations and monitor safety performance by contracted trucking operations	Contract only with freight carriers that use an effective safety management program	Promote active and safe mobility with clothing design and in advertising	Design bicycle helmets and offer at reduced cost to clothing customers
Local government authority	Require procured services to act safely, use safe vehicles, and have a system for safety management	Require employees to choose the safest travel options and practice safe behaviors while traveling on duty	Ensure that shipping is performed by services that comply with safety requirements	Publish safety performance and results openly	Advise citizens on safe travel options, such as safe routes to school
Insurance company	Require facilities, advertising or other service providers to follow a road safety management program	Purchase only vehicles with highest NCAP ratings for corporate fleet	Reduce unnecessary travel with electronic communications	Reward safe driving by insured using voluntary speed monitoring systems	As part of basic service, provide safety devices such as bicycle helmets and child safety seats to customers
Mobility service provider	Ensure that navigation maps are produced with boundary conditions reflecting safety and environmental needs	Use only vehicles with the highest NCAP score and minimal CO_2 and noise impact	Use geofencing to make sure delivery of services is safe and sustainable	Publish safety & environmental impact of the service	Advise citizens on safe service options, such as selection of safe routes

Beyond direct control of their value chain, large corporations and non-government organizations also have political influence. A number of authors have suggested that sustainability reporting also addresses corporate political activities that are relevant to the achievement of the SDGs. National policies and regulation are critical for driving SDG achievement, and corporate engagement in the political and legislative process is an important influence on such rules (Lyon et al. 2018; Vogel 2005).

Finally, while corporate action and reporting are vital for road safety and the full range of SDGs, the same applies to governments, who have primary responsibility for review of SDG progress and follow-up. Governments at every level can report on sustainability actions in their own operations and, through their governance practices, can influence reporting by the private and non-profit sectors. The UN High-Level Political Forum for the 2030 Agenda provides a mechanism for countries to submit Voluntary National Reviews. Conducting such reviews is an important indicator of political commitment and is also likely to influence the quantity and quality of corporate reporting.

Between 2016 and 2018, 111 of the 193 Member Nations submitted Voluntary National Reviews, with an additional 73 Reviews scheduled to be presented in 2019 and 2020. Nearly all countries with populations greater than 100 million have submitted or plan to submit a Review by 2020. Together these countries represent more than 90% of the global population and large shares of economic and trade activities.

While the UN provides guidelines for the preparation of Voluntary National Reviews, the scope and depth of those submitted vary greatly in terms of institutional mechanisms for conducting the review, participation of non-government organizations, and the use of data and statistics to measure progress (HLPF 2018). More uniform quality and consistency in these Reviews could improve their impact.

This Recommendation Is Linked to Others Including

Procurement, Modal Shift, Child and Youth Health, Zero Speeding, 30 km/h, and Technology.

Recommendation #2: Procurement

Summary

In order to achieve the Sustainable Development Goals addressing road safety, health, climate, equity, and education, we recommend that all tiers of government and the private sector prioritize road safety following the Safe System approach in all decisions, including the specification of safety in their procurement of fleet vehicles and transport services, in requirements for safety in road infrastructure investments, and in policies that incentivize safe operation of public transit and commercial vehicles.

Rationale

Corporations, businesses, and government organizations have tremendous influence on society through a range of factors, from political influence to the nature of their products and services. A substantial component of this influence is by means of their spending on the goods and services necessary for their function.

Government procurement is estimated to be 10–15% of gross domestic product on average (World Trade Organization 2019), with some analyses showing that the GDP portion of public procurement in low-income nations is slightly higher than that in high-income countries (Djankov and Saliola 2016). The World Bank reports a total global GDP of about 86 trillion US dollars in 2018 (World Bank Group 2019), with low- and middle-income nations contributing about $32 trillion of that total.

With total corporate procurement spending estimated at an average of 43% of revenues (Schannon et al. 2016) and the revenue of the 500 largest companies totaling $30 trillion (Ventura 2019), the aggregate public and private procurement sums are very large indeed. The social influence of this spending – if directed to incentivize sustainable practices and investments, including road safety – is substantial.

Both government and corporate spending is directed to a value chain – the full scope of activities to bring a product or service from conception to delivery. For companies that produce goods, the value chain starts with accessing raw materials used to make their products and includes every other step including distribution and use by purchasers. Corporate and government services have similar value chains, including the tools, materials, and contracted services needed to conduct and disseminate their function.

When a government controls the safety behaviors of individuals, the burden of enforcement is on the government, and as a result there are certain tolerance levels and inconsistencies in compliance. But when a government deals with a provider of goods or services, and road safety is an integral part of the contract, the burden of enforcement is delegated to the provider. The firm that is supplying the goods or services is motivated to keep the contract and compelled to comply with its terms. Thus, it is important that businesses contracted in public procurement demonstrate capability to comply with safety standards, including having a system to monitor and correct incidents of non-compliance. This example of governance decentralizes monitoring of road safety compliance and can lead to widespread culture change.

Actions and Responsibilities

Each expenditure across the value chain could be used to improve road safety. For example, contingencies could be placed on procurements based on suppliers' policies or performance with regard to (Bidasca and Townsend 2015):

- *Specifications for vehicle safety levels, including powered two-wheelers*, to be used in carrying out procured services. These specifications could go well beyond minimum levels required by domestic governments, to include advanced safety technologies such as speed limiters and impairment detection systems, and could also set limits on vehicle age. In some countries, vehicles owned by businesses and corporations comprise more than half of total vehicle registrations, so the reach of such contingencies could be substantial.

- *Requirements for training of drivers involved in performing procured services, including those who ride powered two-wheelers and other motorized personal mobility devices*, in addition to traffic codes and appropriate extreme condition driving skills, such training could involve education regarding fatigue, distraction, speed, impairment, and other safety factors.
- *Expectations for road safety monitoring, reporting, and performance*. These expectations could require that firms receiving contracts demonstrate higher-than-average performance across their fleet in terms of crash involvement and traffic citations.
- *Standards for scheduling* and planning procured driving operations. These could include practices to manage driver fatigue, use of low-risk roads, use of lower-risk vehicles, and improved times for travel.

Standards and recommended practices for these safety practices and for overall corporate road safety risk management are available from a number of sources including the International Organization for Standardization (ISO) (2012).

Prioritizing road safety in procurement practices of corporations and governments could have far-reaching effects. Businesses underlie 84% of the GDP and 90% of the jobs in developing countries, and, by utilizing their full value chains, they can improve the lives of those who are at greatest risk for a range of threats including motor vehicle crashes (Bertelsmann Stiftung and Sustainable Development Solutions Network 2019).

When making decisions about using procurement to improve road safety, corporations and governments should keep Safe Systems principles in mind. Contingencies placed on procurements will have the greatest long-term effects if they are designed to accommodate predictable human errors and create an environment where crash forces are limited to human injury tolerances.

Safe System principles would favor vehicle safety requirements that accommodate driver errors, such as electronic stability control and automatic emergency braking, and devices that could reduce crash forces, such as intelligent speed adaptation. Other Safe System procurement strategies could include requirements that contracted services use routes with good road design including separated pedestrian and bicycling facilities, roundabouts, road diets, and traffic calming to reduce speeds around vulnerable road users.

This Recommendation Is Linked to Others Including

Sustainable Practices and Reporting, Modal Shift, Safe Vehicles, Zero Speeding, 30 km/h, Technology, and Infrastructure.

Recommendation #3: Modal Shift

Summary

In order to achieve sustainability in global safety, health, and environment, we recommend that nations and cities use urban and transport planning along with mobility policies to shift travel toward cleaner, safer, and affordable modes incorporating higher levels of physical activity such as walking, bicycling, and use of public transit.

Rationale

Evidence points to the widespread value of decreasing dependence on personal motor vehicles for transport and increasing use of safer, cleaner, and healthier alternatives. According to the World Health Organization, insufficient physical activity is the fourth leading risk factor for global mortality and is on the rise in many countries, adding to the burden of non-communicable diseases and affecting general health worldwide (World Health Organization 2011). Active travel can help prevent many of the 3.2 million deaths from physical inactivity, 2.6 million of which are in low- and middle-income nations.

The burden of insufficient physical activity is particularly severe for the younger population. The most recent estimates indicate that 81% of adolescents aged 11–17 years do not meet the WHO's Global Recommendations on Physical Activity for Health. Physical inactivity is estimated to cost more than $50 billion US annually in increased healthcare expenditures (Ding et al. 2016) or about 2–3% of national healthcare expenditures in high-, middle-, and low-income nations (Bull et al. 2017).

A critical prerequisite to modal shifts is safe environments for walking and biking and low-speed powered two- or three-wheelers. Evidence from developed countries ranks biking and walking among the least safe modes of transportation (ETSC 2019).

In our current environment, shifting individual trips from automobiles to walking or bicycling is often considered in terms of a trade-off between safety and health. For example, a systematic review conducted by the EU-funded PASTA (Physical Activity through Sustainable Transport Approaches) Project examined 30 independent analyses of the health impact of active mobility and found that the health benefits of increased physical activity far outweighed increases in safety and health risks associated with walking or bicycling. These results were consistent across analysis methodologies and geographic areas involved (Mueller et al. 2015) (Fig. 6).

However, in the context of the Sustainable Development Goals, safety and health should not be traded off against one another. Consistent with the principle that the Sustainable Development Goals are integrated and indivisible, priority should be given to actions that will allow improvements to both safety and health. The risks associated with pedestrian and bicycle travel are correctable by redesigning walkways and bicycle pathways to separate these modes from traffic moving at greater than 30 km/h and by providing better lighting and safer street crossings (Fig. 7).

Actions and Responsibilities

The WHO Global Action Plan on Physical Activity points out that policies that promote compact urban design and prioritize access by pedestrians, cyclists, and users of public transport can reduce use of personal motorized transportation, carbon emissions, and traffic congestion as well as healthcare costs while stimulating the economy in local neighborhoods and improving health, community well-being, and

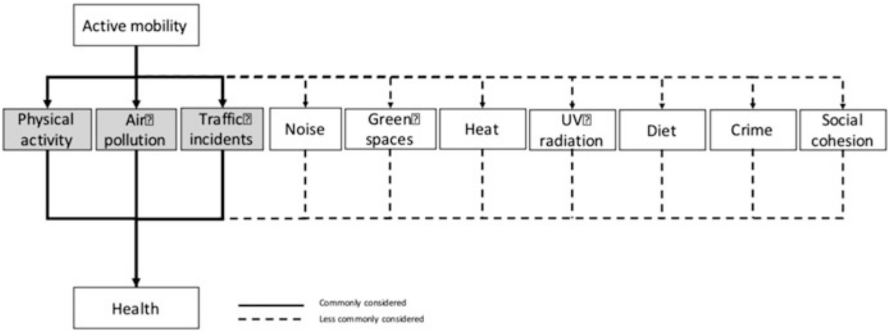

Fig. 6 Health determinant contribution to the estimated health impact of mode shift scenarios to active mobility (Mueller et al. 2015)

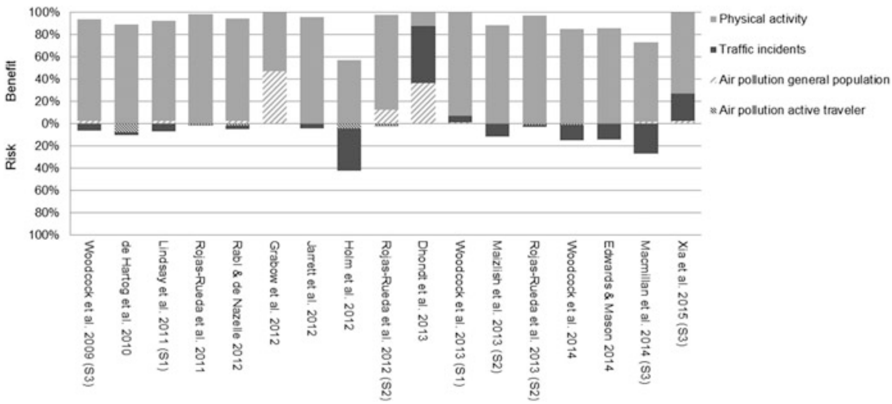

Fig. 7 Health determinants of active mobility (Rabl et al. 2012)

quality of life (World Health Organization 2018b). Improved infrastructure, both physical and digital, could improve the availability and safety of shared micro-mobility options such as e-scooters and e-boards.

In addition to eliminating risks to pedestrians and cyclists from motor vehicle traffic, crime needs to be controlled to improve perceptions of security. A number of studies have documented the association between perceived personal safety and frequency of walking or bicycling. A study of attitudes and walking habits in 8 European cities showed that the odds of occasional walking were 22% higher among women and 39% higher among men who perceived their neighborhood as being safe (Shenassa et al. 2006). Similar findings were reported from a study in Nigeria which measured frequency of physical activity and found that women were far more affected by both traffic and crime perceptions than men (Oyeyemi et al. 2012).

The Global Action Plan on Physical Activity also indicates that beyond their direct effect on road safety and health, safer walking and bicycling routes could contribute to a range of Sustainable Development Goals, including Goal 4 (Quality Education), Goal 5 (Gender Equality), Goal 9 (Industry, Innovation and Infrastructure), Goal 10 (Reduced Inequalities), Goal 11 (Sustainable Cities and Communities), Goal 13 (Climate Action), Goal 15 (Life on Land), and Goal 16 (Peace, Justice and Strong Institutions).

Infrastructure investments and policies that improve perceptions of safety, both from traffic and crime, and especially address gender safety concerns, are important prerequisites to encouraging modal shifts to active mobility. Well-maintained sidewalks, walking and bicycling paths that are separated from fast-moving traffic, adequate pedestrian crossing facilities, and effective street lighting are critical safety measures.

The iRAP star rating program for roads has been effective in stimulating investment in road safety. A star rating program specifically for pedestrian and bicycling facilities could be effective in calling attention to the need for safety improvements such as physical separation from fast-moving motorized traffic and safe crossings where necessary. Geofencing (i.e., digital infrastructure to allow only specific vehicle types and speeds in designated geographic areas) could also be effective in reducing pedestrian and bicycling risk.

Policy evaluations have compared a variety of approaches for stimulating modal shifts. A study of experience in four midsize northwest European cities concluded that the greatest modal shift results from a mix of car-constraining "push" strategies along with "pull" policies that encourage alternatives to car transportation (Dijk et al. 2018).

This Recommendation Is Linked to Others Including

Infrastructure, Zero Speeding, 30 km/h, and Child and Youth Health.

Recommendation #4: Child and Youth Health

Summary

In order to protect the lives, security, and well-being of children and youth and ensure the education and sustainability of future generations, we recommend that cities, road authorities, and citizens examine the routes frequently traveled by children to attend school and for other purposes; identify needs, including changes that encourage active modes such as walking and cycling; and incorporate Safe System principles to eliminate risks along these routes.

Rationale

Our children are our most valuable societal asset, and we cannot look into the future without special consideration for their welfare. This principle underlies the development of the UN declaration of children's rights (United Nations 1989). While mortality among children less than 5 years of age is down over the past decades (World Health

Organization 2019), the children of today are the first in history to have a predicted lifespan shorter than that of their parents (World Health Organization 2018b). Recent decreases in overall life expectancy have resulted from other factors, but motor vehicle crash deaths remain the leading cause of death globally for ages 5–29.

Another substantial risk to child health, lack of physical activity, is related to road safety in that the safety of roads affects decisions about when and where children will walk or bicycle. Both road safety and the frequency of physical activity could be improved by a few common measures. Widespread adoption of compact living centers and highly connected neighborhoods that reduce dependence on motor vehicles could facilitate both the frequency and safety of walking and bicycling for daily transportation. This type of physical activity as a regular routine is particularly beneficial to health.

However, the popularity of walking and bicycling is declining in many countries, especially in low- and middle-income nations where large numbers of people are switching from active mobility to personal motorized transport (Li et al. 2017), including scooters or mopeds, which can be driven by those as young as age 14 in many countries.

Two UN human rights conventions in the 1989 Declaration of the Rights of Children, the Right of Protection from Abuse and Neglect and the Right to Guidance from Caring Adults, have underpinned child safety legislation around the world, including child passenger safety laws. Because of widespread concern for the welfare of children, laws that protect children in traffic are often easier to enact than similar legislation addressing all ages. This has been the case with child passenger safety legislation in many countries, where such laws preceded seat belt laws or, in some locations, were among the first traffic laws of any kind.

Child safety legislation has often served as an introduction to the concept of traffic rules, and their enactment has increased the willingness of citizens and policy-makers to take further legislative steps that extend protection to the remainder of the population. Examples of child-specific safety legislation include child safety seat laws for infants and toddlers, booster seat and seat belt laws for older children, prohibitions against carrying children in cargo areas of trucks, bicycle helmet laws, bans on carrying children too small to reach footrests on powered two-wheelers, and enhanced penalties for drunk driving if children are in the vehicle.

Target 4.7 of Sustainable Development Goal 4, Quality Education, seeks to "ensure that all learners are provided with the knowledge and skills to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development." Safe routes to school can help ensure that children and youth are exposed to this type of education and that they have the opportunity to use their global citizenship to make a better world, possibly leading change for safer roads in the way that Malala Yousafzai has advocated for women's education and Greta Thunberg has championed environmental responsibility.

An important part of child and youth education is role modeling by parents and other adults. Young people are influenced by the behaviors of people they respect and admire, so it is important that adults demonstrate the types of road safety attitudes and behaviors that children need in order to be safe road users.

Actions and Responsibilities

An important reason for the shift away from walking and bicycling is the perception of a lack of safety of public spaces. Studies indicate that investment to improve sidewalks and street crossings and provide designated bicycle lanes could increase the number of people using active forms of transportation (Aziz et al. 2018). Programs such as Vision Zero for Youth promote investment in road, pedestrian, and cycling infrastructure, targeting corridors frequently used by children on their route to and from school or recreational facilities. By improving the safety and frequency of walking and bicycling by children and youth, such programs address a range of Sustainable Development Goals, and by following the Safe System approach in designing infrastructure improvements, these programs could serve an important role in introducing communities to Safe System processes.

Infrastructure design needs to accommodate the special needs of children, particularly the younger ones, who cannot be expected to understand and comply with non-intuitive rules or behaviors. Routes traveled by children should use designs such as separated pedestrian walkways to limit risk exposure and include safe crosswalks where children are likely to feel the need to cross the road. Schools have an important responsibility to analyze, propose, and support implementation of safe routes to the schools.

Countries can pay particular attention to the age at which young people are permitted to operate cars, trucks, or powered two-wheelers to ensure that drivers have adequate maturity and judgment. Graduated driver licensing is proven to be effective in facilitating learning and controlling risk exposure for young drivers.

In many countries, children are frequent passengers on powered two-wheelers. Because of the inherent risks of this mode of travel and because smaller children are at particular risk since they often situated on the vehicle in an unstable manner, the goal should be to provide safer modes for child mobility. However, when families have no choice other than a powered two-wheeler for child mobility and needed changes such as transportation planning will take substantial time, countries and local jurisdictions should consider measures that could reduce the risk for children on powered two-wheelers in the shorter term. Such measures could include helmets for children, special lower speed limits for powered two-wheelers carrying small children, or route restrictions that would prevent these vehicles from traveling on busy or higher speed roads where alternatives are available.

This Recommendation Is Linked to Others Including

Zero Speeding, 30 km/h, Modal Shift, Safe Vehicles, Infrastructure, and Procurement.

Recommendation #5: Infrastructure

Summary

In order to realize the benefits that roads designed according to the Safe System approach will bring to a broad range of Sustainable Development Goals as quickly and thoroughly as possible, we recommend that governments and all road authorities allocate sufficient resources to upgrade existing road infrastructure to incorporate Safe System principles as soon as feasible.

Rationale

Road design is critical in the Safe System approach. While each component of the system – people, vehicles, the road, and the environment – is important, road design is perhaps the most powerful means for achieving high levels of system safety. In-depth crash investigations have shown strong interactions between the roles of vehicles, road infrastructure, and road users in contributing to serious crashes and indicate that road infrastructure factors are most strongly linked to crash fatalities (Stigson et al. 2008).

Well-designed roads and roadsides encourage safe driving speeds, heighten driver attention where risks are increased by the presence of vulnerable road users, prevent the types of crashes that lead to the most serious injuries, provide segregated traffic flows, and reduce risks of serious outcomes in run-off-the-road crashes when drivers make errors. Poorly designed roads not only fail to protect road users from crashes; they also encourage behaviors that drastically increase risk such as inappropriate speeds and interactions between vehicles and crossing pedestrians.

In the Safe System, roads are designed according to their function using a range of classifications with each type having features that ensure safety for all road users. Residential or business district streets have narrower lanes and frequent lane shifts, elevation changes, or other features to maintain safe speeds, as well as visual cues to keep drivers attentive for interactions with vulnerable road users. Roads intended to carry higher speed traffic have wider lanes and longer sight distances, along with roundabouts or other intersection treatments to prevent the most serious crash types, and separation of vulnerable road users to protect them from the higher vehicle speeds. All roads should be designed to control speeds and manage the kinetic energy of moving vehicles so that when drivers or other road users make errors, they will be protected from crash forces that could cause death or serious injury.

Upgrading design standards so that new roads are built according to Safe System principles and bringing existing roads to the same standard is essential to achieving the road safety targets among the Sustainable Development Goals. The World Resources Institute analyzed changes in road deaths in 53 countries over a 20-year period and found that nations which experienced the greatest declines in road fatalities and achieved the lowest fatality rates were those that adopted the Safe System approach (Welle et al. 2018).

The benefits of safe roads go beyond reductions in serious injuries and deaths. Slower and smoother traffic flow improves air quality, reduces noise, and enhances community health and quality of life. Roads designed according to Safe System principles have a dramatic effect on the safety of vulnerable road users and, by improving the comfort of walking and bicycling, encourage healthy modal shifts for short trips.

The costs of road improvements are manageable in context. Studies indicate that as little as 1–3% of road construction budgets are needed to make road safety improvements (Welle et al. 2018) and that when the value of lives saved and serious injuries prevented are considered, the return on investment is positive.

Two additional factors contribute to the urgency of investment in safe roads, urbanization and motorization. The global trend toward urbanization will cause widespread expansion of cities and create new urban areas in the coming decades with an increasing mix of traffic users. The UN Department of Economic and Social Affairs predicts that urban areas will grow by more than 50% over the coming 30 years, with the great majority of this expansion occurring in Africa and Asia (World Urbanization Prospects 2018). New roads and infrastructure will be necessary to accommodate the urban expansion, and this creates an opportunity to incorporate Safe System design features from the beginning.

A 2014 study by RAND and the Institute for Mobility Research on the future of driving in developing countries analyzes factors affecting adoption of personal vehicles and found that, based on the experience of developed nations, car-friendly infrastructure is the second most critical factor after spatial dispersion of the population in determining eventual dependence on personal motor vehicles for mobility (Ecola et al. 2014).

The authors of the RAND study point out that the trajectory of automobile dependence is likely to be shaped during the period of motorization and that many developing nations are in this period at the current time. Investment in roads that are designed according to Safe System principles can reduce serious crash injuries, encourage active mobility, create healthier urban living spaces, and help shape sustainable communities.

Infrastructure upgrades could also include digital resources to support the availability of digital speed maps as well as road fixtures and markings that can be recognized by advanced vehicle safety systems. For example, road markings that can be read by the vehicle can enable vehicle systems to prevent unsafe lane changes and run-off-the-road crashes. Studies of such systems have shown a clear safety effect (Sternlund 2018).

Actions and Responsibilities

It is recommended that infrastructure providers apply infrastructure safety measures according to Safe System principles. A number of comprehensive references are available to guide such investments, including the compendium of knowledge published by Austroads in 2018 (Woolley et al. 2018).

This Recommendation Is Linked to Others Including

Zero Speeding, 30 km/h, Safe Vehicles, Technology, and Child and Youth Health.

Recommendation #6: Safe Vehicles Across the Globe

Summary

In order to achieve higher and more equitable levels of road safety across the globe, we recommend that vehicle manufacturers, governments, and fleet purchasers ensure

that all vehicles produced for every market be equipped with recommended levels of safety performance, that incentives for use of vehicles with enhanced safety performance be provided where possible, and that the highest possible levels of vehicle safety performance be required for vehicles used in private and public vehicle fleets.

Rationale

Vehicle safety technology has proven to be effective both in preventing crashes and in saving lives when crashes happen. Vehicle safety systems serve an important role in the Safe System approach by addressing these core principles:

Accommodating human error: Crash avoidance technologies such as automatic emergency braking systems – available in two- and four-wheeled motorized vehicles – or electronic stability control systems compensate for driver errors in vehicle control in emergency conditions.

Limiting crash forces to levels within human injury tolerance: Crashworthiness technologies, including seat belts, airbags, frontal and side impact protection, and pedestrian protection, reduce forces by extending deceleration times and managing the manner in which forces are directed to the body. Some of these technologies are also applicable to powered two-wheelers.

Pursuing a commitment to proactive improvement: Mandated safety standards apply to all specified new vehicles, ensuring that virtually all such vehicles will be equipped over a period of time.

Safety standards in place in many developed nations have been highly effective in saving lives over the past 50 years. For example, an analysis of mandated passenger car, bus, and truck safety technologies in the USA indicates that between 1960 and 2012, technologies associated with Federal motor vehicle safety standards prevented more than 600,000 crash deaths (Kahane 2015).

However, there are stark disparities around the world in the adoption of mandatory vehicle standards covering the most critical safety technologies. The 2018 Global Status Report on Road Safety identifies 8 critical safety vehicle standards and indicates that while 40 countries have implemented 7 or 8 of these standards, 124 countries worldwide have implemented none or just 1 of these requirements (World Health Organization 2018a).

Since 2011, only six nations have acceded the 1958 Agreement on Harmonized Technical Regulations for Wheeled Vehicles, Equipment, and Parts. Without such standards, manufacturers could produce vehicles for these markets without safety devices as a cost-savings measure. The countries that lack critical vehicle safety standards are mostly developing nations where 50% of new vehicles are sold and road travel is most hazardous (World Health Organization 2015).

A study of the potential benefits of adopting key safety standards in Latin America examined the improvements that could be realized if Argentina, Brazil, Chile, and Mexico adopted international standards for electronic stability control, pedestrian impact protection, and automatic emergency braking for vulnerable road users. Researchers estimated that about 14,000 lives and 290,000 serious injuries could be saved between 2020 and 2030 if these countries adopted regulations requiring these devices.

This study also examined the costs and benefits of these regulations and determined that the per-vehicle cost would be about $50 US for electronic stability control, $261 for automatic emergency braking for vulnerable road users, and $258 for pedestrian impact protection. The economic benefits resulting from the reduced crashes, serious injuries, and death these technologies would bring across the four countries over this period would total $28.9 billion. Benefits would exceed costs beginning in 2023 (Wallbank et al. 2019).

The UN vehicle standards apply to passenger cars, large trucks and buses, and motorcycles. However, such safety standards for other road transport modes like bicycles and scooters are lacking, an issue that should be addressed as soon as possible.

In addition to improvements of safety standards for new vehicles, the overall safety of vehicles in low- and middle-income nations could be improved by limiting the import of secondhand vehicles that were built to comply with older, less stringent standards. The effectiveness and economic feasibility of such import policies should be studied.

Actions and Responsibilities

Regulation can be effective in establishing minimum levels of vehicle safety. A voluntary industry agreement specifying similar levels of safety could also be effective if it were widely adopted by manufacturers. Other approaches, including consumer information and fleet purchases, can be effective in lifting safety performance beyond minimum levels.

Consumer information regarding auto safety is available through New Car Assessment Programs (NCAP) which work in conjunction with national regulatory functions to motivate consumer demand for improved vehicle safety and influence the level of safety provided by vehicle manufacturers. A number of regional, national, and domestic NCAP are active and have shown success in stimulating the market for passenger cars with crash avoidance and protection performance beyond minimum local standards. These programs serve an important educational role, using crash test results to inform users of the need for safe vehicle design and the differences in safety between specific makes and models.

NCAP have shown success in stimulating the market for safer cars, and a similar approach should be pursued to educate consumers about safety features and crash performance of trucks, buses, and powered two-wheelers. It is important to note that NCAP are not comparable among regions, which prevents the promotion of consistently safe vehicles all over the world.

All vehicle manufacturers should present information to consumers on the safety performance of their vehicles beyond minimum standards, either through NCAP testing, their own testing, or both. One such measure that should be included by every passenger car manufacturer is the ability of their vehicles to safely accommodate small children without the need for extra equipment. Another test that would further improve NCAP effectiveness is the capacity of crash avoidance technologies to identify and avoid vulnerable road users, including powered two-wheelers.

The potential for informed purchasers to shape the market for safer vehicles can be pursued at an even higher level by engaging corporate and government fleet purchase operations. Fleet purchases are an important way for governments and corporations to contribute to Sustainable Development Goals and can have far-reaching effects on overall road safety.

In some countries, two of every three new car sales are to corporate fleets (Deloitte Insights 2017). Corporate and government fleet purchasers can specify the types of vehicle purchased, the safety features required, and policies concerning driver behavior and vehicle use. Safety information from New Car Assessment Programs, together with business standards such as the Road Safety Management System Standard 39001 from the International Organization for Standardization (ISO), can help fleet purchasers make the best decisions.

An additional opportunity for improving road safety around the world is to upgrade safety technology in heavy trucks and buses. Global safety standards specify fewer advanced safety technologies for large trucks and buses than for passenger cars, and safety features such as electronic stability control, forward collision warning, lane departure warning, and blind spot detection warning have not been widely adopted in these vehicles. Factors affecting this disparity include limited information on technology effectiveness and additional complexity in fitting some systems to long or articulated vehicles (Sweatman 2017).

A study of heavy vehicle safety in Oman suggests that technology could be especially important in low- and middle-income countries where improving economies could increase heavy vehicle use and consequent safety risks (Al-Bulushi et al. 2015). New global safety regulations for heavy vehicles together with an NCAP-type consumer education approach would be effective in stimulating improvement in truck and bus safety.

The safety of powered two-wheelers could be improved by requirements for limiting speed, improving stability, and incorporating design features that would protect passengers and other vulnerable road users from injury during impacts. This should be done by both regulation and through NCAPs (Strandroth et al. 2011).

In addition, new vehicle types entering the market, such as motorized personal mobility devices, should be regulated with regard to maximum operating speed and safety performance and subjected to consumer tests.

This Recommendation Is Linked to Others Including

Sustainable Practices and Reporting, Procurement, Child and Youth Health, 30 km/h, Zero Speeding, and Technology.

Recommendation #7: Zero Speeding

Summary

In order to achieve widespread benefits to safety, health, equity, climate, and quality of life, we recommend that businesses, governments, and other fleet owners practice a zero-tolerance approach to speeding and that they collaborate with supporters of a range of Sustainable Development Goals on policies and practices to reduce speeds to levels that are consistent with Safe System principles using the full range of vehicle, infrastructure, and enforcement interventions.

Rationale

Speed management is essential to reductions in crashes, serious injuries, and fatalities. Road users from around the world report significant rates of speeding by as much as 20 km/h over the speed limit (Meesmann et al. 2008). The Safe System approach optimizes the speed of mobility while minimizing the number of road user casualties. In the Safe System, designers specify speed limits based on evidence of vehicle and road safety and the assumption that drivers and other road users will make errors. Vehicle and road design can help prevent certain errors. For example, roundabouts eliminate traffic lights, reduce speeds, and prevent drivers from red light running.

When an error happens, vehicle and road design can also help avoid a crash. For example, electronic stability control will intercede to keep a vehicle in control when a driver makes a control error. If a collision does occur, vehicle and road design can help limit the crash forces that reach the occupants to levels that will not cause serious injuries. However, speed determines the amount of energy that must be managed in a crash, and even the best vehicle and road designs have limits. When speeds exceed the ability of the road and vehicle to manage crash forces, serious injury or death may result.

Speeds in the Safe System are set so that vehicle and road design features can limit crash forces to human injury tolerance limits. For example, vehicles that meet UN or equivalent national standards are designed to limit crash forces to their occupants to survivable levels in side impacts up to collision speeds of 50 km/h. Therefore, the Safe System would limit speeds to 50 km/h or less on roads with intersections where side impacts can be expected. Standards require that vehicles limit crash forces to their occupants to survivable levels in frontal crashes up to 70 km/h. Consequently, speed limits should be set to 70 km/h or less on roads where there is no center barrier and head-on collisions are possible and where no pedestrians or other types of vulnerable road users are present. While these estimates have been developed for passenger cars, further research is needed to confirm safe travel speeds for other vehicle types in various environments (Ohlin et al. 2019). Other research estimates that lower speeds may be necessary to reduce the probability of serious injury to less than 10% (Jurewicz et al. 2016).

The relationship between speed and the probability and severity of crashes has been well researched in both theory and practice. In general, higher speeds increase both the likelihood of crashing and the severity, though the magnitude of the effect varies according to the absolute speed and environmental circumstances (Elvik 2013). Studies have shown that relatively small changes in travel speeds can result in substantial changes in death or injury in crashes (Elvik 2009). A review of empirical studies from ten countries by the International Transport Forum confirms the theoretical relationship and demonstrates that reducing travel speeds by just a few km/h can greatly reduce the risks and severity of crashes (International Traffic Safety Data and Analysis Group 2018). Conversely, a study of speed limit increases over a 25-year period in the USA published by the Insurance Institute for Highway Safety found that speed limit increases between 1993 and 2017 were responsible for 36,760 deaths (3.8% of the total), with 1900 lives (5.2%) lost in 2017 alone (Farmer 2018).

Vehicle speeds are directly linked to a number of Sustainable Development Goals, and this opens the potential for new partners to support the implementation of speed management methods. While the most direct link to speed would be the road safety targets 3.6 and 11.2, there are also strong links to Goal 5 (Gender Equality) and Goal 10 (Reduced Inequalities) due to the improved perception of safety for vulnerable road users that is associated with lower road speeds in populated areas. A higher level of perceived safety is likely to lead to greater mobility and expanded opportunities for social needs including education (Goal 4) and employment (Goal 8).

Vehicle speeds are also related to environmental noise levels. A 2017 study used a comprehensive national noise measuring campaign in the UK and a refined methodology to measure traffic noise and found that 30 km/h road speeds reduced acoustic energy levels by about half (Beuhlmann and Egger 2017). Environmental noise has been linked to sleep disorders, heart disease, stress, and, among children, decreased school performance, including decreased learning, lower reading comprehension, and concentration deficits (Hammer et al. 2014).

Actions and Responsibilities

Speed limits in the Safe System need to be determined according to the principles described above, and system owners – the officials who set the standards for road design and vehicle safety – must take responsibility for integrating effective speed management methods to ensure that vehicles remain in compliance.

A variety of methods can be used to control speeds, including:

- Appropriate speed limits determined according to the Safe System approach.
- Public education on the risks associated with speeding along with awareness of active enforcement activity.
- Road designs that cause drivers to travel at the desired speeds by constraining visual fields or introducing obstacles that are most easily negotiated at the safe speed limit.
- Vehicle technologies that detect speed limits and prevent higher speeds or provide warnings when the speed limit is exceeded.
- Businesses, governments, and other fleet owners practice a zero-tolerance approach to speeding in their own or procured transport operations.
- Effective enforcement methods and practices, along with substantial penalties for offenders.

Vehicle speed is so fundamentally related to Safe Systems and societal health that responsibility for compliance and assurance should permeate the community. There can be no tolerance limits for unsafe speeds. Incorporating speed compliance as a contractual prerequisite in public and corporate procurements is an important strategy for modeling this zero-tolerance approach. In such business relationships, providers of products or services are motivated to utilize their own speed compliance methods to avoid violating conditions of the agreement and losing the contract.

The best approaches for ensuring compliance with safe speeds will be consistent with Safe System principles. These approaches will utilize infrastructure and vehicle design to reduce opportunities for drivers to unintentionally – or intentionally – exceed speed limits. Roads can be designed so that drivers find it most comfortable to travel at safe speeds. Connected vehicle technology can be used in conjunction with speed limiters and geofencing to control speeds in specific areas.

Speed enforcement is also of importance, and the use of automated speed cameras is shown to be effective. Section control, sometimes called camera-to-camera systems, is found to be effective not only for safety but also for emissions including significant reduction in CO_2 noise levels (Thornton 2010). Section controls as part of an integrated enforcement strategy require only limited margins for error as variations in speed will be picked up by measuring the average speed rather than the point speed.

This Recommendation Is Linked to Others Including

Sustainable Practices and Reporting, Procurement, Child and Youth Health, Safe Vehicles, 30 km/h, and Technology.

Recommendation #8: 30 km/h

Summary

In order to protect vulnerable road users and achieve sustainability goals addressing livable cities, health, and security, we recommend that a maximum road travel speed limit of 30 km/h be mandated in urban areas unless strong evidence exists that higher speeds are safe.

Rationale

In the Safe System, roads and vehicles are designed to accommodate human errors without resulting in serious injury or death. Allowable vehicle speeds in the Safe System are a function of the level of safety provided by other parts of the system.

While this concept holds true for many parts of the system, dense urban areas present a special case. Safe vehicle and road design features are especially critical in urban areas where vulnerable road users, including pedestrians, bicyclists, and motorcyclists, are a constant part of the road user environment. The concentration of vulnerable road users in urban neighborhoods, together with the complexity of traffic patterns and the frequency of road user interactions, creates extraordinary crash and injury risk. In these dense urban areas, even the best road and vehicle design features are unable to adequately guarantee the safety of all road users when speeds are above the known safe level of 30 km/h.

A maximum speed limit of 30 km/h in urban areas is widely supported by researchers and safety experts to provide adequate protection for vulnerable road users (Global Road Safety Partnership 2008; Kroyer 2014; International Traffic Safety Data and Analysis Group 2018). A review of available international research on the relationships between impact velocity change, impact speeds, and probability of serious or fatal injuries suggests that the safe limit for pedestrians struck by passenger cars may be even lower. Figure 8 illustrates that the risk of serious injury begins to climb sharply at 20 km/h (Jurewicz et al. 2016). A study of bicycle crashes also shows that 30 km/h may still produce serious injuries for these vulnerable road users (Ohlin et al. 2019).

A systematic review conducted by Cairns et al. found 10 independent studies of 30 km/h or 20 mph zones or limits and concluded that these measures show convincing evidence of reductions in crashes, injuries, traffic speed, and volume. The studies also include evidence of cost-effectiveness, improved levels of perceived safety by residents, and positive community response for the speed limits (Fig. 9).

The review by Cairns et al. points to evidence of socioeconomic inequalities in crash injuries internationally, and, while none of the reviewed studies directly addressed this effect, the authors extrapolate from available evidence and suggest that 30 km/h zones or limits could be effective in reducing these inequalities (Cairns et al. 2015).

Reducing urban speeds to 30 km/h has a range of additional benefits such as noise reduction and more active mobility. A 2017 study by Buehlmann and Egger published by the Institute of Noise Control Engineering used a comprehensive national noise measuring campaign in the UK and a refined methodology to measure traffic noise and found that 30 km/h road speeds reduced acoustic energy levels by about half (Beuhlmann and Egger 2017). Environmental noise has been linked to sleep disorders, heart disease, stress, and, among children, decreased school performance, including decreased learning, lower reading comprehension, and concentration deficits (Hammer et al. 2014).

It is clear that 30 km/h urban speed limits improve the quality of urban life in a number of dimensions. In addition, 30 km/h speed limits could have a long-term effect on community mobility patterns. A 2014 study by RAND and the Institute for Mobility Research on the future of driving in developing countries analyzed factors affecting adoption of personal vehicles and found that, based on the experience of developed nations, car-friendly infrastructure is the second most critical factor after spatial dispersion of the population in determining eventual dependence on personal motor vehicles for mobility (Ecola et al. 2014).

The authors of the RAND study point out that the trajectory of automobile dependence is likely to be shaped during the period of motorization and that many developing nations are in this period at the current time. Policies that slow motorized traffic, reduce serious crash injuries, create healthier urban living spaces, and encourage active mobility can shape communities that are on a path toward realization of a range of Sustainable Development Goals as suggested under the recommendation for Modal Shift.

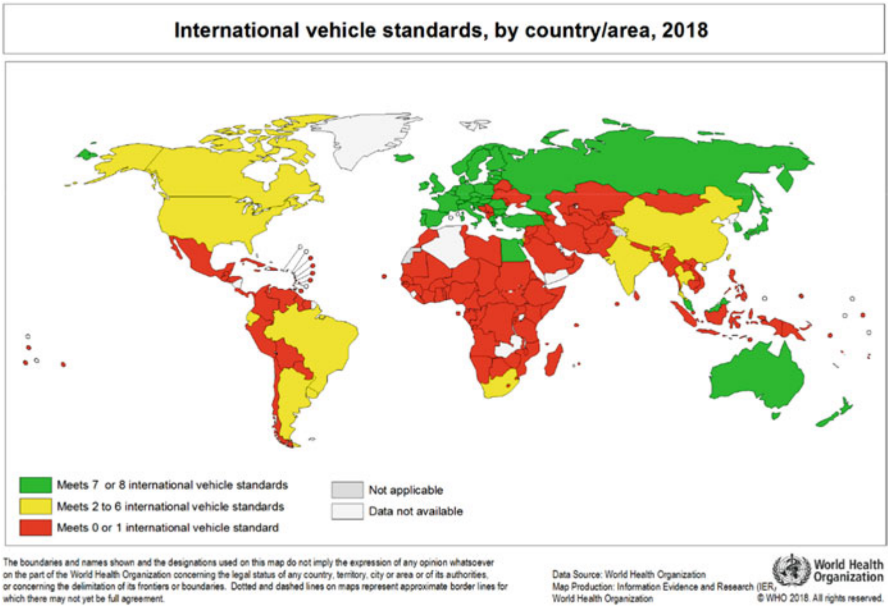

Fig. 8 Compliance with international vehicle safety standards (World Health Organization 2018a (UNECE data))

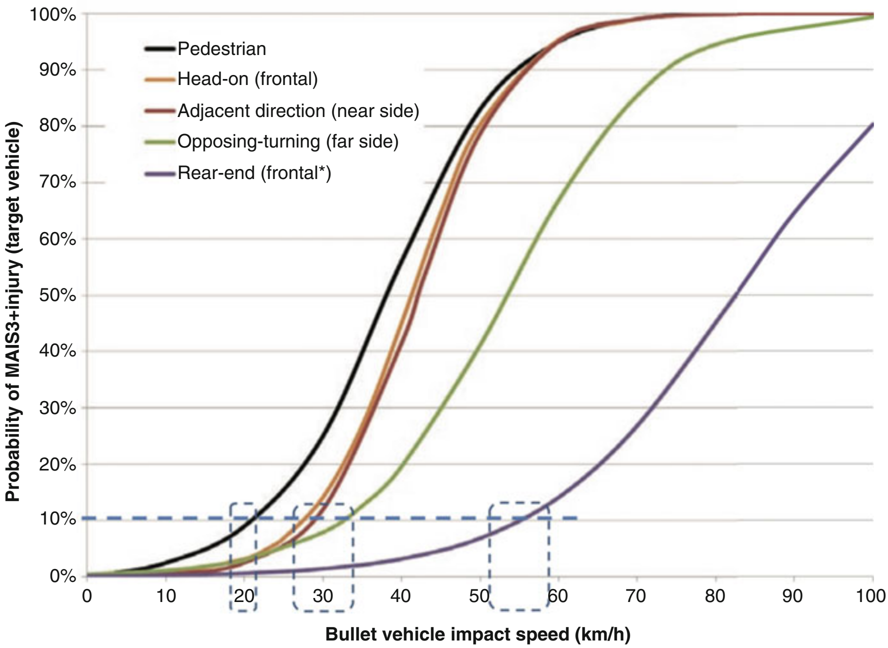

Fig. 9 Probability of severe injury when struck by a motor vehicle (Jurewicz et al. 2016)

Actions and Responsibilities

Compliance with the 30 km/h urban speed limit is best achieved through techniques that are consistent with Safe System principles and thereby reduce the opportunity for drivers to unintentionally – or intentionally – exceed the speed limit. These include infrastructure designs such as road diets, chicanes, raised intersection tables, and other road features that calm traffic by affecting the comfortable driving speed for most vehicles.

Adopting connected vehicle technology would allow vehicle speed limiters to be used together with geofencing to control speeds in designated areas. Automated speed enforcement could include section control, where the mean speed over longer distances is measured along with point camera enforcement.

This Recommendation Is Linked to Others Including

Sustainable Practices and Reporting, Infrastructure, Safe Vehicles, and Zero Speeding.

Recommendation #9: Technology

Summary

In order to quickly and equitably realize the potential benefits of emerging technologies to road safety, including, but not limited to, sensory devices, connectivity methods, and artificial intelligence, we recommend that corporations and governments incentivize the development, application, and deployment of existing and future technologies to improve all aspects of road safety from crash prevention to emergency response and trauma care, with special attention given to the safety needs and social, economic, and environmental conditions of low- and middle-income nations.

Rationale

The role of advanced technology in improving road safety in high-income countries has been well discussed in scientific, policy, and ethics literature. There is little doubt that automated vehicles will save lives over the coming decades. But opinions differ widely on questions such as how many will be saved, how soon the savings will begin, and how many deaths might be caused by imperfect technologies during the development period. Perhaps the most reasonable observation is that vehicle automation in the form of automated driving systems, including electronic stability control, lane change warnings, and automatic emergency braking, is currently saving lives in many countries (National Highway Traffic Safety Administration 2017). This development fits very well with the Safe System approach. Full self-driving technology is likely to reach and be adopted in different countries at different stages due to political, economic, technological, and infrastructural reasons.

Advanced vehicle safety technologies are among the most effective of all automotive safety devices. An early example of crash avoidance technology, electronic stability control, has been shown to be 30–50% effective in preventing fatal single vehicle passenger car crashes and 50–70% effective with sport utility vehicles (Ferguson 2007). A recent study by TRL Limited indicates that the cost of electronic stability control if adopted in Latin America would be about $50 per vehicle (Wallbank et al. 2019).

Whether Moore's Law on declining costs for computing power continues to hold true is under debate (Simonite 2016). However, history has shown that the consumer price for computer equipment dropped by 95% between 1997 and 2015 (Bureau of Labor Statistics). So it is not unreasonable to expect that the cost of the computational technology needed for electronic stability control or similar crash avoidance technologies, such as automatic emergency braking or intelligent speed adaptation, will decrease over the coming decades. This could facilitate widespread adoption in low- and middle-income nations, particularly if the domestic regulatory upgrades encouraged by the World Health Organization, Global New Car Assessment Program, and others are pursued.

The question of whether new in-vehicle technologies could be developed over the coming decades that might be suitable for use in low- and middle-income nations could almost certainly be answered in the affirmative. However, realization of that potential will require the commitment of both the public and private sectors. Automotive technology is changing at an unprecedented rate, so it seems highly likely that there will be candidate safety devices in the coming years. The availability of advanced safety technology in low- and middle-income nations could also be expanded by corporate investment in road safety through their value chains as part of their commitment to the Sustainable Development Goals. Such investment could include provision of fleet vehicles in these regions with high levels of safety equipment.

Technologies outside the vehicle could also make a difference in low- and middle-income countries. One example is post-crash care, where communications technology – perhaps built upon the near-ubiquitous mobile phone – could facilitate effective bystander care for the injured. Where ambulances are not available, technology could provide route guidance for delivering crash victims to the nearest medical facility capable of trauma care.

Another important infrastructure application for advanced technologies is speed management, including geofencing and infrastructure-to-vehicle communications. Studies of the benefits of Intelligent Speed Adaptation using such technology predict potential crash reductions of up to 33% in urban areas and reductions in CO_2 emissions of up to 5.8% on high-speed roads (Lai et al. 2012).

Vehicle-to-vehicle and vehicle-to-infrastructure communications have potential for contributing to a number of Sustainable Development Goals, including climate, energy, and economic growth, as well as road safety. These technologies can enable vehicles to detect the movement of others on the road, including vulnerable road users, and adjust speed and direction to avoid conflicts. This capability could be particularly beneficial for the safety of pedestrians, bicyclists, and powered two-wheelers. Similar technology can also permit route planning to reduce congestion, reduce emissions, and optimize safety.

Communications and logistics technologies can reduce the need for travel by connecting people electronically for business and commerce and facilitating efficient and safe shipping of products and materials. However, some analysts have shown that these technologies may actually stimulate travel when first deployed because of the new opportunities for revenue and human interaction they produce. Later stages of adoption can involve both reductions in the amount and modifications in the types of travel needed to efficiently utilize the new technology (Banister and Stead 2004).

Actions and Responsibilities

Stimulating the development of safety technology that would be appropriate for developing nations is a leadership challenge. In order to move those candidate safety technologies into large numbers of new cars destined for low- and middle-income nations, auto manufacturers will need to commit to installing the devices in the appropriate vehicles, and governments will need to create a demand by enacting necessary safety standards.

Businesses can also play a role in introducing safety technologies in low- and middle-income countries. For example, speed adaptation to local conditions using geofencing could be used by firms that operate fleets of heavy trucks in populated areas as a means to ensure safe speeds and protect vulnerable road users. Geofencing and crash avoidance technologies should be encouraged as part of micro-mobility services, such as scooters and e-bicycles, to manage speeds and prevent crashes especially where interactions with pedestrians or larger vehicles are likely.

This Recommendation Is Linked to Others Including

Sustainable Practices and Reporting, Infrastructure, Safe Vehicles, Zero Speeding, and 30 km/h.

Discussion

As we approach the end of the Decade of Action for Road Safety 2011–2020, we find ourselves with a strong foundation for change, but little progress overall in reducing the number of global road deaths and serious injuries. While it is disappointing that we were not able to bring the numbers down, the value of the foundation should not be underestimated. Substantial achievements were made in increasing awareness and recognition of the road safety crisis, gathering high-level leadership commitment, establishing a solid structure of measurement and targets, and developing a framework for action and a set of evidence-based tools.

Lessons Learned from the Decade of Action 2011–2020

Among the important accomplishments of the Decade of Action was identifying and promoting a comprehensive set of evidence-based tools for improving road safety. These tools – organized under five pillars – cover a wide range of needs from road safety management to post-crash response. Over the decade, many of these tools have been used in a variety of environments around the world. The World Health Organization's Global Status Report on Road Safety 2018 highlights examples of drink-driving legislation reducing crashes and deaths in Brazil, road improvements in school zones in sub-Saharan Africa getting an improved star rating, and new e-bike regulations in China resulting in improved motorcycle safety (World Health Organization 2018a).

While the tools included in the five pillars are generally supported by evidence of effectiveness, in many cases, this evidence was generated in high-income counties, and results could differ in other situations. More research is needed to verify the effectiveness of these interventions across the range of environments found in middle- and low-income nations.

A strong and diverse road safety movement has been active for many years. The movement was well-developed before the Decade of Action 2011–2020 and was nurtured and expanded as a result of the UN leadership during the Decade. Considering its scale relative to the enormity of the global road safety crisis, the movement has been remarkably successful. The scientific community within the movement has established a substantial understanding of the social, economic, and technical factors influencing road safety. The public policy community has disseminated effective laws and regulations, and the capacity-building community has made significant inroads in enabling local decision-makers and implementers to pursue road safety interventions. Road safety advocacy groups, especially victims' organizations, have been influential in calling attention to road safety problems and motivating enactment of stronger laws. This ongoing work is responsible for the tremendous road safety progress seen in many nations over the past decades and will remain the essential guiding core as we move into the next decade.

A central lesson learned in the Decade of Action 2011–2020 is that while our tools are effective, we need to greatly expand their utilization across the globe. Our current road safety army is making great contributions, but simply is not of sufficient scale to affect change at a global level. There is currently a lack of capacity in terms of both road safety knowledge and action among governments and private sectors across the globe.

Opportunities Beyond 2020

As we turn to the next decade, we can reflect on the evolution that has taken place in our methods to change road transportation and look forward to a further level of progress. From a prior dependence on the four E's – engineering, enforcement, education, and emergency medical services – many countries adopted the five pillars of road safety over the Decade of Action 2011–2020 and consequently developed a more comprehensive set of road safety interventions.

During the Decade of Action, other countries moved from a road safety program consisting of a set of disconnected interventions to adoption of the Safe System approach, which brought a fundamental shift in objectives and methods and resulted in more widespread and effective change. From a focus on using interventions to adapt human behavior to a complex and dangerous road and vehicle system, these countries evolved to an approach which seeks to adjust the system to accommodate the characteristics of human behavior. Many of the tools developed over the past decades as part of the four E's and five pillars of road safety remain essential in the newer context, with their application aligned with Safe System principles. Most of the countries that have adopted the Safe System approach are in the early stages of this change, and the results seen from those who are furthest along in the process are very encouraging.

Looking forward to the coming decade, we see a further evolutionary opportunity that could build upon both the tools of the five pillars and the methodology of the Safe System approach and result in widespread and sustainable change. This next level will involve integration of road safety in activities contributing to the Sustainable Development Goals and in the daily operations of a far-ranging collection of public and private sector organizations.

The specific inclusion of road safety targets in the 2030 Agenda for Sustainable Development reflects universal recognition that death and injury from road crashes are now among the most serious threats to the future of our people and planet. Moreover, the explicit characterization of the 17 Goals as "integrated and indivisible, global in nature and universally applicable" means that road safety is no longer a need that can be compromised or traded off in order to achieve other social needs. Further, the 2030 Agenda points out the deep interconnections among the Goals and targets, beginning with the fundamental interconnection of the health of people and the health of the planet and extending to many other interdependencies.

Together, these factors motivate a broad range of businesses, corporations, and government units to seek new opportunities to contribute in measurable ways to the Sustainable Development Goals, and whether their primary mission concerns the environment, social welfare, or human rights, road safety can be a relevant and viable element of that entity's contribution.

Governments, through their lead road safety and public health agencies, are a cornerstone of the road safety movement. They have the responsibility to address the full range of human needs for their citizens, including safe mobility, and serve the lead role in achievement of the Sustainable Development Goals. We have learned that governments cannot carry this burden alone and are compelled to use the opportunity of the Sustainable Development Goals to engage support from the business and corporate sectors.

Recommendations from the Academic Expert Group

The Academic Expert Group, convened by the Swedish Transport Administration to advise on priority directions for road safety following the first Decade of Action, offers nine recommendations. Two of these, *Sustainable Practices and Reporting* and *Procurement*, concern corporate or governmental contributions to the Sustainable Development Goals. Three recommendations, *Modal Shift*, *Infrastructure*, and *Technology*, focus on the design of our future transportation system. Four others, *30 km/h*, *Zero Speeding*, *Safe Vehicles Across the Globe*, and *Child and Youth Health*, highlight specific interventions that are among the existing pillars, but so critical to progress that they warrant special attention.

The recommendations are interrelated and intended to be considered as a set rather than individually. For example, the potential of *Procurement* will be best realized if organizations are motivated to pursue *Sustainable Practices and Reporting*. Likewise, both *Procurement* and *Infrastructure* will facilitate achievement of *30 km/h* speed limits in urban areas, *Zero Tolerance for Speeding*, and *Modal Shifts*.

Next Steps for Progress

Realizing the potential of these recommendations will require effective engagement – and meaningful contributions – of additional stakeholders and sectors of society in road safety activities. Even though compelled to contribute to the Sustainable Development Goals, these new partners – both public and private sectors – are not likely to spontaneously focus on road safety and launch effective interventions. They will need guidance, tools, and policy models.

To take advantage of this opportunity and engage new sectors in road safety interventions, we need to articulate a compelling case for their involvement; disseminate this message among leaders across the business, corporate, and public sectors; and create tools to assist these new partners in identifying how they can use their influence and their value chains to improve road safety. New measures will also be needed to track progress in engaging new sectors and assessing the outputs and outcomes of their road safety activities.

Engaging new sectors in road safety work will require significant preparation, leadership, and persistence from within the existing road safety community. Perhaps the greatest challenge as we move into the next decade will be to realize the potential of this new opportunity without detracting from our ongoing road safety work or neglecting the potential of the existing road safety community.

Capacity-building both among the public and private sector professionals already engaged in road safety activities and among new partners will be essential, and our current cadre of road safety technical experts will be urgently needed to design and conduct educational courses and programs. Many road safety professionals around the world currently lack the knowledge and skills necessary to develop and implement components of the Safe System. Knowledge of the Sustainable Development Goals is also critical, including an awareness of the full range of Goals, how road safety relates to these other needs, and how road safety could be incorporated in activities related to those Goals.

As we pursue this essential path, it is critically important that governments increase their efforts, both in direct response to road safety problems in their jurisdictions and also to engage active support of their Sustainable Development Goal partners. Through the combined efforts of governments, all those engaged in the road safety movement, and our new Sustainable Development Goal partners, achievement of the target of reducing road deaths and serious injuries by half by 2030 is feasible.

The Sustainable Development Goals offer tremendous hope and opportunity for the future of our people and our planet. The recommendations in this report reflect the combined experience, wisdom, and insight of the Academic Expert Group and point to transformative processes and tools that, if fully utilized, could achieve the road safety targets while contributing to other human, social, and environmental goals. We look forward to seeing national, sub-national, and city governments, businesses and corporations, and civil society consider these recommendations as they plan, implement, and report on their contributions to the full range of Sustainable Development Goals including road safety.

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Miscommunications Based on Different Meanings of "Safe" and Their Implications for the Meaning of Safe System

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Contents

Abstract

While many countries are apparently adopting "Safe System" for road safety, the failure to deliver the vision of zero deaths and serious injuries continues in part due to the lack of a rigorous and agreed definition of "safe" in road safety. Multiple authoritative definitions of the adjective "safe" exist which may be categorized as probabilistic and absolute. While apparently similar, these definitions are in a fundamental sense inconsistent with each other. The probabilistic definition involves degrees of safety, through probabilities that harm is not likely or unlikely, or that there is little risk. The absolute definition presents safety as free from harm or not involving any risk or protected from danger. Road safety is currently communicated as though there is an agreed meaning of safe, but the vital conversation around what is meant by safe is not undertaken because the difference in usage of the term safe is not appreciated. For example, in road design and engineering, road design standards are generally developed to achieve this probabilistic definition of safety and not absolute safety: the road can be

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described as safe because it by itself (with perfect use) will not cause a crash, even though people still die on it. Based on the absolute definition of safe, such roads are not safe as unambiguously demonstrated by people dying on them. Calls for roads to be made safe employing the absolute definition are often met with the response that they are already safe (in the probabilistic sense), having been built to "accepted" design guidelines. The acceptance of the probabilistic definition of safe for Safe System hinders progress toward its fundamental aims of zero deaths and serious injuries. In order to achieve zero deaths and serious injuries, uniform understanding and acceptance of "safe" adopting the absolute definition is needed.

Keywords

Safe · Vision zero · Shared responsibility · Safe system · Absolute · Probabilistic

Introduction

Deaths and injuries from road crashes remain an enormous burden worldwide. Each year, 1.35 million people are killed in road traffic crashes globally (World Health Organization 2018). Deaths and injuries from road crashes involve a violent event, life-changing grief and psychological suffering in injured victims and families left behind, reduced household income, living with permanent disability, and fighting for justice (Global Alliance of NGOs for Road Safety, 2020). Deaths and injuries also generate enormous costs to national economies and retard national economic growth (World Bank, 2017; Wambulwa & Job, 2019).

In 1997, the Riksdag, the Swedish Parliament, adopted Vision Zero as a new goal and strategy for road safety in Sweden (Swedish Government, 1997). Vision Zero as an overall public road safety policy differs from a more traditional road safety in how it defines a road safety problem and its causes, the long-term goal of road safety, how responsibility is shared between individuals and system providers (Job et al., 2022) and what the most appropriate strategies are to create a safe system (Belin et al., 2012). In the more than 20 years since the Vision Zero policy was adopted, it has spread internationally as a model of a public road safety policy (ITF/OECD, 2008, 2016; World Health Organization, 2017; World Bank, 2013, 2020; Job, 2017). It is not only in the transport sector that Vision Zero has attracted interest, but it has also spread and continues to spread to other sectors of Swedish society such as fire safety, patient safety, occupational accidents, and suicide (Kristianssen et al., 2018).

The Vision Zero approach began formally with adoption by the Swedish Parliament in 1997. In this approach, as adopted elsewhere, the Safe System is the state of the road transport system required to deliver the vision of zero deaths, acknowledging the need to provide a system which protects road users by accommodating the inevitability of human error and the vulnerability of the human body to physical force in crashes. A similarly system-based approach was also developed in the Netherlands with the name Sustainable Safety, and the Safe System approach has spread gradually to many countries. One of the first countries after Sweden to adopt the approach was Australia, most likely for two visible reasons. First, Claes Tingvall, a leading architect of Safe System in Sweden, moved to Australia for over 2 years and advocated for Safe System from his role leading road safety in the state of Victoria. Second, this advocacy fell on fertile ground ready for change: A push already existed for the system to be addressed rather than just the road user (for example, the assertion that road crashes are a political issue in the 1980s: Job et al., 1989), and Australia (especially including the states of Victoria and New South Wales) had reached highly effective levels of behavior change including high levels of safety-belt usage and powerful drink-driving enforcement through random breath testing resulting in large reduction in deaths (Job et al., 1997), yet leaving large numbers of people being killed or seriously injured. An improved approach was needed, and the broad road system was already the recognized target. Many countries representing all global regions have followed, including New Zealand, Canada, Qatar, Nigeria, and the countries of the European Union, and more recently the United States has adopted toward zero deaths. Globally influential organizations advocate for Safe System including the OECD, GRSF, the World Bank, World Health Organization, the United Nations Road Safety Collaboration which made Safe System a centerpiece of the *Global Plan for the Decade of Action on Road Safety 2011–2020* (UN Road Safety Collaboration, 2011), and most recently the "Stockholm Declaration" of the third Global Ministerial Conference on Road Safety 2020 (Government Offices of Sweden, 2020) as well as the United Nations General Assembly resolution on road safety included Safe System (General Assembly of the United Nations, 2020).

There are well-established evidence-based solutions which have proven to be effective in greatly reducing deaths and injuries (Welle et al., 2018) especially as related to speed management (Job & Sakashita, 2016a). Speed managing interventions deliver strong yet often underappreciated benefit-cost ratios (Yannis et al., 2008; SafetyNet, 2009; Elvik et al., 2009). It would seem justified to expect that a full suite of interventions comprehensively adopted would have the potential to eliminate road trauma, although no country has yet fully adopted the required interventions.

Comprehensive solutions and legislated requirements to ensure safety are adopted for other areas of human activity, such as workplace health and safety, yet oddly exclude road crashes generally. For example, in many high-income countries (HICs), companies are required to ensure the safety of their employees at work in offices as well as high-risk situations such as construction. While many countries are apparently adopting "Safe System" for road safety, the way it is commonly described, defined, and promoted in road safety hinders delivery of the zero deaths and serious injuries target which forms part of the Safe System Approach (Job et al., 2022; Belin, 2016).

This chapter argues that this failure to comprehensively address road safety is in part due to the lack of a rigorous and agreed definition of "safe" in road safety, presents an analysis of the meaning of "safe," and offers a rigorous definition of "Safe System" necessary to achieve elimination of deaths and serious injuries from road crashes.

The Meaning of the Adjective "Safe"

Multiple authoritative definitions of the adjective "safe" exist. Various dictionaries (with the exception of the Oxford English Dictionary) offer slightly differently worded versions of what are clearly two different definitions of safe: probabilistic and absolute (as summarized in Table 1). While apparently similar, these definitions are in a fundamental sense inconsistent with each other. The first type of definition (see examples in Table 1, Probabilistic Definitions) involves degrees of safety, through probabilities with definitions including that harm is not likely or unlikely, or that there is little risk. The second class of definitions presents safety as absolute with definitions which include free from harm or not involving any risk or protected from danger (see examples in Table 1, Absolute Definitions). These two inherently inconsistent conceptualizations of "safe" in terms of absolute versus relative are also highlighted in previous literature (Hansson, 2012).

Another way to conceptualize the different uses of the term safe is to consider their perceived opposites. The probabilistic definitions of safe can be conceptualized as being the opposite of dangerous: A hungry great white shark is dangerous to anyone in the water near it, whereas the water without a shark is relatively safe (i.e., safe under the probabilistic definition). The absolute definition presents safe as the opposite of any risk. Thus, the water is not safe because people can make mistakes in the water such as swimming out too far from shore, swimming while impaired by alcohol, or not detecting and avoiding a rip (current) on a surf beach or in a river with consequent deaths. The vast majority of human deaths in water are due to drowning not sharks, yet the media and the generation of fear (perception of risk) are more focused on the remote risk of a shark attack (reflecting the sometimes significant gap between perceived and actual risk). The solutions typically offered for drownings emphasize swimmer responsibility with swimming lessons, as well as teaching water skills and awareness. Globally per year, there are around 320,000 drownings *(World Health Organization,* 2020*)* indicating that current approaches are not delivering real safety, compared with just over 100 provoked and unprovoked shark attacks combined, with most not being fatal (Florida Museum of Natural History, 2017).

Paralleling the contrast of sharks and drownings, road safety too often demonstrates a focus on emphasizing road user responsibility via training, awareness, and other elements of behavior change with similar failures to deliver absolute safety. Claims of safety are commonly based on the absence of danger in the sense that the road will not **cause** a crash, the parallel of sharks. The road causing a crash would be, for example, where the signage and the environment do not match, such as a curve advisory speed warning of 80kph for a curve which requires a speed of 30mph to be negotiated, or a junction where the signage and lines (or lack of them) indicate to drivers on all approaches that they have right of way. These are quite rare instances, and thus, fixing them as the criterion for safe results in little road safety value (Job & Sakashita, 2016b). The large majority of crash deaths (parallel to drownings) remain demonstrably ineffectively addressed with this approach to safety – with over 51 million failures each year globally (1.35 million deaths and up to 50 million

Table 1 Definitions of "safe" in various dictionaries

Source	Probabilistic definition	Absolute definition	Other definitions not as relevant to road safety
Cambridge Dictionary https://dictionary.cambridge.org/dictionary/english/safe	Not in danger or likely to be harmed Not dangerous or likely to cause harm	Not harmed or damaged Used to refer to things that do not involve any risk	(of a place) Where something is not likely to be lost or stolen Used to say that you like and approve of someone or something
Collins Dictionary https://www.collinsdictionary.com/dictionary/english/safe	A safe place is one where it is unlikely that any harm, damage, or unpleasant things will happen to the people or things that are there	Something that is safe does not cause physical harm or danger If a person or thing is safe from something, they cannot be harmed or damaged by it If you are safe, you have not been harmed If people or things have a safe journey, they reach their destination without harm, damage, or unpleasant things happening to them If you are at a safe distance from something or someone, you are far enough away from them to avoid any danger, harm, or unpleasant effects	If something you have or expect to obtain is safe, you cannot lose it or be prevented from having it A safe course of action is one in which there is very little risk of loss or failure If you disapprove of something because you think it is not very exciting or original, you can describe it as safe [disapproval] If it is safe to say or assume something, you can say it with very little risk of being wrong If you say to someone that their secret is safe with you, you are promising not to tell it to anyone
Oxford English Dictionary https://www.oed.com/viewdictionaryentry/Entry/169673	(The Oxford English is the only dictionary identified as not presenting an applicable probabilistic definition of safe)	Presenting no risk of physical harm; posing no threat, not dangerous Unhurt, uninjured, unharmed; having escaped or been preserved from some real or apprehended danger	In sound health, well; healed, cured, restored to health Mentally or morally sound or sane Affording security from theft, loss, escape, etc.

(continued)

Table 1 (continued)

Source	Probabilistic definition	Absolute definition	Other definitions not as relevant to road safety
		Made without harm to the traveler	Affording guaranteed immunity from arrest, capture, attack, etc. Certain to happen or be the case Sure in procedure Excessively cautious; unadventurous, unimaginative; bland, boring Free from errors or flaws Not likely to be wrong
Dictionary.com https://www.dictionary.com/browse/safe?s=t	Involving little or no risk of mishap, error, etc.	Free from hurt, injury, danger, or risk	
Lexico.com https://www.lexico.com/definition/safe	Not likely to be harmed or lost Not likely to cause or lead to harm or injury; not involving danger or risk	Protected from or not exposed to danger or risk Uninjured; with no harm done	(of a place) Affording security or protection (derogatory) Cautious and unenterprising Based on good reasons or evidence and not likely to be proved wrong
Merriam Webster https://www.merriam-webster.com/dictionary/safe	Not threatening danger Not likely to take risks	Free from harm or risk Secure from threat of danger, harm, or loss	Successful at getting to a base in baseball without being put out *Obsolete, of mental or moral faculties* Unlikely to produce controversy or contradiction Trustworthy, reliable
Oxford Learner's Dictionary https://www.oxfordlearnersdictionaries.com/definition/english/safe_1?q=safe	Not likely to lead to any physical harm or danger Where somebody/something is not likely to be in danger or to be lost	Protected from any danger, harm, or loss Not harmed, damaged, lost, etc. Not involving any risk	Not likely to be wrong or to upset somebody Doing an activity in a careful way Based on good evidence

(continued)

Table 1 (continued)

Source	Probabilistic definition	Absolute definition	Other definitions not as relevant to road safety
	Not involving much risk		Used by young people to show that they approve of somebody/ something Used by young people as a way of accepting something that is offered

Table 2 Two meanings of safe (probabilistic or relative vs absolute) and their implications in safety management

Context	Degrees of safety			
	Danger of death	Moderate risk of death	Low risk of death	Zero risk of death
Water safety	Great white shark close by	No sharks but few other effective safety actions	Swimming lessons, promotion of safety, enforcement, and some limits on water access	Lifejackets, access restricted to safe swimming locations with lifeguards and monitoring systems
Road safety	Roads cause fatal crashes	Roads do not cause fatalities but few other effective safety actions	Driving lessons, promotion of safety, enforcement, and some limits on road access	Crash barriers, protective vehicles, and speeds constrained to survivable impact forces in crashes
Safe system	NA	NA	Probabilistic safety (but not Safe System)	Absolute safety (Safe System)

injuries: World Health Organization 2015, 2018) almost all not involving a crash caused by the road (as described above). These contrasting definitions of “safe” are visually represented in Table 2. Applying the absolute definition of safe to the road transport system would require that the system does not allow deaths and injuries to occur – the Vision Zero Safe System goal.

Confounded Use of “Safe” in Safe System

Appreciating the uses of these distinct meanings of safe in road safety is vital to resolving existing miscommunications. Road safety is a multidisciplinary field with different disciplines employing different meanings of the term safe while communicating as though there is an agreed meaning. In road design and engineering, safe generally takes the probabilistic form: The road is designed not to cause a crash and to guide the user to reduce errors. Thus, the road can be described as safe because it by itself (with perfect use) will not create danger, even though people still die on it. Road design standards are developed to achieve this probabilistic definition of safety not absolute safety. In most countries, road design standards are the equivalent of ensuring that we do not build swimming pools with sharks in them, and audits as commonly applied in many countries are the equivalent of removing sharks from swimming pools, while still allowing people to drown/die in crashes. This approach is facilitated by a continuing powerful culture of victim blaming, allowing the road to be presented as safe while those who crash are blamed for their unsafe behavior (Deborah, 2007; Job, 2020) or the unsafe behavior of a road user other than the victim. In the eyes of genuine Safe System advocates, such roads are not safe (as unambiguously demonstrated by people dying on them) because the absolute definition of safe is being employed. Vital miscommunications arise in this context. Calls for roads to be made safe by Safe System advocates are often met with the response that they are already safe, having been built to "accepted" design guidelines. The vital conversation around what is meant by safe is not undertaken because the difference in usage of the term safe is not appreciated. Highlighting this difference to the community may also increase broad appreciation of Safe System, the deeper (absolute) safety it offers, and the responsibility of governments and system operators for safety instead of being allowed to avoid this responsibility through victim blaming. Community understanding and demand could be a key driver of more genuine development of safe road systems.

A deeper problem in Safe System is also revealed by the visibility of the different meanings of safe: The Safe System concept fundamentally includes vision zero, and thus the names are interchangeable, though they emphasize different elements of the approach: Safe System is that which is required to deliver Vision Zero, whereas the name Vision Zero highlights the final objective. Vision Zero is the logical outcome of aiming for, and ultimate achieving, absolute safety: no risk and no danger, not low risk or little danger. However, Safe System itself has fallen victim to the use of probabilistic definitions of safe in various applications of Safe System. Two examples are apparent.

First, shared responsibility with road users is commonly articulated explicitly as a Safe System principle both in global guidance documents and in national strategies adopting Safe System, with only slight variations of description which retain the responsibility of road users for their safety (shared with system owners and operators). Examples abound: the classic *World Report* (World Health Organization and World Bank, 2004) asserted as part of safe system that "At the same time, the road user has an obligation to comply with the basic rules of road safety"; the *United Nations Global Plan for the Decade of Action on Road Safety* (UN Road Safety Collaboration, 2011) included "The individual road users have the responsibility to abide by laws and regulations"; the *Road Safety Strategy for South Australia* (Government of South Australia, 2011) and the *National Strategy for Ireland* (Road Safety Authority [Ireland], 2013) both included shared responsibility, described identically as: "Shared responsibility – everyone has a responsibility to use the road safely with organisations, businesses and communities taking responsibility for designing, managing and encouraging safe use of the road transport system.” The Canadian Road Safety Strategy (Canadian Council of Motor Transport Administrators, 2016) and the United States road safety vision, *Towards Zero Deaths* (Towards Zero Deaths, 2014), similarly still include road user responsibility for their own safety.

While this is how safe system is commonly described and defined in many recent policy documents, this is not in line with the original ideas adopted by the Swedish parliament in October 1997. According to the decision, the responsibility for safety is split between the road users and the system designers (i.e., infrastructure builders and administrators, the vehicle industry, the haulage sector, taxi companies, and all the organizations that use the road transport system professionally), on the basis of the principles that:

- The system designers have ultimate responsibility for the design, upkeep, and use of the road transport system and are thus responsible for the safety level of the entire system.
- As before, the road users are still responsible for showing consideration, judgment, and responsibility in traffic and for following the traffic regulations.
- If the road users do not take their share of the responsibility (for example due to a lack of knowledge or competence) and personal injuries occur or other risky situations occur, the system designers must take further measures to prevent people from being killed or seriously injured.

The latter point is now pervasively omitted in policy positions.

Though this understanding of shared responsibility may not have been the original intention of Safe System in Sweden (While this is how safe system is commonly described and defined in many recent policy documents, this is not in line with the original ideas adopted by the Swedish parliament in October 1997. According to the decision, the responsibility for safety is split between the road users and the system designers (i.e., infrastructure builders and administrators, the vehicle industry, the haulage sector, taxi companies, and all the organizations that use the road transport system professionally), on the basis of the principles that: The system designers have ultimate responsibility for the design, upkeep, and use of the road transport system and are thus responsible for the safety level of the entire system. As before, the road users are still responsible for showing consideration, judgment, and responsibility in traffic and for following the traffic regulations. If the road users do not take their share of the responsibility (for example, due to a lack of knowledge or competence) and personal injuries occur or other risky situations occur, the system designers must take further measures to prevent people from being killed or seriously injured. The latter point is now pervasively omitted in policy positions), the subsequent descriptions of shared responsibility with road users under the banner of or in association with Safe System implicate the probabilistic definition of safe. With human fallibility acknowledged as a fundamental principle of Safe System, making (fallible) road users responsible for their own safety means that errors with fatal consequence are inevitable. This subtle acceptance of probabilistic definition of safe for Safe System hinders progress toward its fundamental aims of zero deaths and serious injuries.

Second, increasingly over time various documents refer to “Safe System Speed Limits” (e.g., ETSC, 2008; Government of South Australia, 2011; Ministry of Transport [New Zealand], 2010; Road Safety Authority [Ireland], 2013). The risk curve indicating the risks of deaths for different levels of speed – 30kmh where vulnerable road users are present, 50kmh where side impact crashes are possible, and 70kmh where head-on crashes are possible –has been (mis)employed to define what constitutes a “safe” speed limit, supposedly adhering to Safe System principles. Subtly merged “Safe System” limits are almost universally agreed, promoted (e.g., OECD, 2006; Sustainable Mobility for All, 2019; Tingvall and Haworth, 1999), and ubiquitously expressed in Safe System road safety strategies and plans even though those limits still carry a 10% probability of death in crashes. This 10% death risk generally presented as a part of Safe System clearly reflects the adoption of a probabilistic definition of safe not an absolute definition of safe. This subtly accepts a 10% death rate in crashes at these speeds as low risk (safe in a probabilistic sense) in addition to the many serious injuries which will occur at these speeds. This transformation of the use of “Safe System” moves away from its fundamental aims for zero deaths and zero serious injuries. Therefore, setting speed limits according to tolerance against kinetic energy needs to be seen as a step in the right direction rather than absolute safe speed limits. We still need more research to clarify appropriate operating speeds and speed limits from a safe system perspective (Belin and Vadeby, 2022).

Conclusions: The Necessary Meaning of Safe System Including Vision Zero in Road Safety

In order to achieve zero deaths and serious injuries, the definition of “safe” in Safe System must be rigorously the absolute definition. Thus, a Safe System is a road system “***in which road users cannot be killed or seriously injured regardless of their behaviour or the behaviour of other road users***” (Job et al., 2022). This definition accurately encapsulates the absolute meaning of “safe” in terms of “protected/free from hurt, injury, danger, harm, damage or risk.” A Safe System must *protect* users and not *rely* on (fallible) users to protect themselves by behaving in a particular (safe, legal, and responsible) way. A system is not safe if the behavior of a user could cause death of that user or another person. In a Safe System, whether anyone suffers a death or a serious injury cannot be left to be dependent on the behaviors of human road users even as a share of responsibility. Once it is agreed that humans inevitably make mistakes and that the human body is frail and will not survive certain forces, the system must literally protect us from dangerous forces even in the event of error or when breaking the law intentionally or unintentionally. A uniform understanding of “safe” in road safety as the full accommodation of inherent human flaws and full protection with no serious harm under any circumstance is vital in order to facilitate a better understanding of Safe System and thus deliver Vision Zero on deaths and serious injuries.

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Part IV

Tools and Technologies for Vision Zero

Road Safety Analysis

28

Matteo Rizzi and Johan Strandroth

Contents

Abstract

Road safety analysis can be used to understand what has been successful in the past and what needs to be changed in order to be successful to reduce severe road trauma going forward and ultimately what's needed to achieve zero. This chapter covers some of the tools used to retrospectively evaluate real-life benefits of road safety measures and methods used to predict the combined effects of interventions in a road safety action plan as well as to estimate if they are sufficient to achieve targets near-term and long-term. Included are also a brief overview of methods to develop boundary conditions on what constitutes a Safe System for different road users. Further to that, the chapter lists some arguments for the need

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of high-quality mass and in-depth data to ensure confidence in the results and conclusions from road safety analysis. Finally, a few key messages are summarized.

Keywords

In-depth data · Real-life evaluation · Boundary conditions · Combined benefits · Safety gaps · Target setting

Introduction: Why Is Road Safety Analysis Necessary?

Road safety analysis is an area of profound importance in Vision Zero planning and implementation. It has commonly been used to understand the real-life benefits of road safety measures, to guide future implementation of interventions and to facilitate the development of action plans and strategies. Road safety analysis could be said to include more specifically in the context of Vision Zero – gaining detailed insights into crash and injury mechanisms, investigate boundary conditions for what constitutes a safe system and building confidence in innovative solutions by setting up quality management systems and evaluation frameworks. Going forward, road safety analysis is essential to understand future trauma residuals and what it might take to ultimately eliminate fatalities and serious injuries. Road safety analysis is also an important ingredient in target management as it can be used to inform what constitutes ambitious but achievable long-term and near-term targets, both in terms of trauma targets and targets for system transformation, namely Safety Performance Indicators (SPI).

In summary, road safety analysis can be used to understand what has been successful in the past and what needs to be changed in order to be successful to reduce severe road trauma going forward and ultimately what's needed to achieve zero.

Road safety analysis is made up from numerous elements of data of crashes and injuries, information of the system state as road assets, vehicle and driver characteristics, statistical methods and models, in-depth investigations as well as other analytical tools. As with all analytics, the quality of the outputs and the confidence in the results are products of the input data, the approach used when generating hypothesis and the methods adopted when testing them. Over the past decades, road safety analysis has benefited from increased data quality and coverage as well as new and improved methods for evaluation, forecasting, and scenario development.

This chapter will cover some of the tools used to retrospectively evaluate real-life benefits of road safety countermeasures and methods used to predict the combined effects of interventions in a road safety action plan as well as to estimate if they are sufficient to achieve targets near-term and long-term. Included are also a brief overview of methods to develop boundary conditions on what constitutes a Safe System for different road users. Further to that, the chapter will also list some arguments for the need of high-quality mass and in-depth data to ensure confidence in the results and conclusions from road safety analysis. Finally, a few key messages are summarized.

Retrospective Analysis

Real-Life Evaluation of Road Safety Countermeasures

With the Vision Zero approach it is imperative to constantly evaluate implemented countermeasures in real-life conditions, thus providing valuable feedback to the designers of the road transport system. The basic idea is to compare two different crash populations:

- The treated population, that is, one involving the countermeasure to be evaluated
- The untreated population, that is, one without the countermeasure

An example could be the evaluation of newly installed median barriers on a road. In its simplest form, the analysis would compare the number of crashes occurring on the new roads with median barriers with the number of crashes on the same road, before it was rebuilt. Such an approach is normally called before-and-after study. In other words, the treated and untreated crash populations come from the same road, in different time periods. However, such a simple approach would not handle possible confounders. For instance, it is conceivable that during the studied period there may be seasonable or even long-term variation in traffic volumes, or other changes in driving patterns due to weather, roadworks, or increased police enforcement, that would reasonably affect the overall crash rates on the analyzed road. In order to handle this issue, it is recommended to use the "before-and-after" approach with at least one so-called control group, that is, an untreated crash population from another road during the same time period. Clearly, several control groups can be used, as done by Transport for London (2007).

Further, even more advanced approaches could be used, that is, empirical Bayes (EB) methods, which also account for abnormal crash rates in short study periods by shrinking such estimates toward the mean, depending on the amount of data available. It should be noted, however, that EB require a certain level of statistical tools. While explaining such tools goes beyond the aim of this chapter, further details can be found in Hauer (1997), Elvik (2013), and OECD/ITF (2018).

Regardless of study design, it is important to understand that it is possible to perform real-life evaluations with limited data, as long as the data have a sufficient degree of detail and are analyzed with robust methods. A few recommendations are outlined below.

The first critical step in evaluating a countermeasure is matching the treated and untreated crash populations. Ideally, these should be as similar as possible and only differentiate on the variable under study. However, this may not always be possible, therefore it may be necessary to make assumptions or simplifications. With regard to optional vehicle safety technologies, for instance, it would be preferable to compare the same car models with and without the technology.

The second critical step is to obtain the exposure. Indirect methods are often used, that is, the exposure is derived from the actual crash data (i.e., induced exposure). With this approach, the key point is to identify at least one crash type or situation in which the countermeasure under analysis can be reasonably assumed (or known) not to be effective. Then, the relation between crashes with and without the countermeasure in a non-affected situation would be considered as the true exposure relation. For further reading, please see Evans (1998), Lie et al. (2006), or Strandroth et al. (2012). While sometimes it may be possible to use data based on real exposure (Teoh 2013; HLDI 2013), this may be difficult to obtain and could also include confounding factors. The most obvious advantage of indirect methods is that the analysis can be performed based on crash data only, without any need of other sources. Secondly, the issue of confounding factors may be easier to handle. To elaborate further, an example regarding the evaluation of optional autonomous emergency braking (AEB) on passenger cars is illustrated below.

As long as AEB is not standard equipment in all cars on the roads, it could be argued that drivers choosing AEB are probably more concerned about their safety in the first place, which could naturally lead to a lower crash involvement (i.e., selective recruitment). Further differences between the crash populations could also confound the results, for instance age, gender and use of protective equipment, etc. If crash rates are calculated based on real exposure (i.e., number of crashes divided by number of registered vehicle, or vehicle mileage), it is essential to control for possible confounders, for instance driver age or seat belt use rate, as done in Teoh (2011). However, adopting an induced exposure approach would normally address this issue, as the result is given by the relative differences within the AEB and non-AEB crash populations. Basically, even though a variable is known to affect the overall crash or injury risk (say driver age), the same variable can only confound the induced exposure results by deviating from the overall sensitive/nonsensitive ratio. If this is found to be the case, the treated crash population can be stratified into different subgroups for further analysis. The induced exposure calculations can be adjusted for confounders, as suggested by Schlesselman (1982), for instance by calculating the weighted average of the individual odds ratios.

Nonetheless, it is important to stress that the induced exposure approach is also based on a number of assumptions and limitations. First of all, it should be clear that the basic idea with this method is to calculate the number of crashes that should be included in the data, if the countermeasure under analysis had no effect at all. This approach may be considered as calculating the "missing" crashes in the dataset. Therefore, it is evident that a certain reduction in police reported crashes, for instance, does not necessarily mean that no crashes had occurred at all, or that no slight injuries were sustained in a minor crash that was not reported to the police.

An attempt to address this issue, that is, distinguishing between crash avoidance and reduced crash severity, has been presented in Rizzi et al. (2015). However, it should be noted that this approach is difficult to apply to police-reported crashes, as it requires injury data with good resolution (i.e., hospital records including full diagnoses), which may not be available in all regions of the world.

It is important to stress that the most critical assumption with the induced exposure approach is to determine the nonsensitive crash type. While the main method for selecting nonsensitive crashes is a priori analysis of in-depth studies, as done in previous research (Sferco et al. 2001), the distribution of crash types within the analyzed data may also provide insights into the non-sensitivity of certain crash types. However, it is very important that such assumptions are based on an actual hypothesis, rather than "trial and error" in the analysis steps (Lie et al. 2006). A further reflection is that evaluations of safety countermeasures based on real-life crashes may imply several factors affecting each other, that is, these may not be based on the principle "everything else is constant." An example is the fitment of "safety packages" on cars, that is, a number of safety features such as low-speed AEB, high-speed AEB, Lane Keeping Assist, and Blind Spot Detection are offered as optional fitments together. It is therefore important to keep this issue in mind in order to differentiate between explanatory variables and confounding variables. If confounders are present as variables that differ between cases and controls, they might be picked up by the effect variable. When selecting possible confounders, it is important that they are based on a hypothesis, and not just invented. If included without any hypothesis, they may pick a variation that is not real. In other words, it is important to distinguish between possible correlation and causation.

Risk Factors and Boundary Conditions

Road safety research has traditionally had a significant focus on identifying risk factors which could be explained as factors correlating with increased crash or injury risk (Stigson 2009). Certainly, in some areas of road safety it is crucial to gain insight into risk factors. The development of driver support systems is one area where an understanding of driver distraction and impairment are important when selecting treatment strategies (Tivesten 2014). However, it has been found repeatedly that severe injuries and fatalities can be prevented without deep knowledge of the specific crash causation. Median barriers, speed reduction, airbags, and restraint systems are all interventions that act independently from driver-related errors. Despite the fact that they do not prevent crashes they are nonetheless effective in preventing injuries or mitigating injury outcomes.

In designing a safe transport system there is a need for a holistic approach, and current safety policies are therefore focusing more on defining safety criteria, or boundary conditions, rather than identifying risk factors (OECD 2008). The development of risk curves is the first step in creating that holistic understanding of what would constitute a safe system.

Injury Risk Curves

Injury risk curves are another essential part of the Vision Zero approach. As mentioned in other chapters, according to Vision Zero the road transport system should be adapted to the limitations of the road users, by anticipating and allowing for human error. The primary aim is not to totally eliminate the number of crashes but to align the crash severity with the potential to protect from bodily harm. In order to do that, detailed knowledge on the human tolerance to blunt force is needed.

Different injury risk curves have been developed for passenger car occupants, pedestrians (see, e.g., Kullgren 2008); Gabauer and Gabler 2006; Rosen and Sander 2009; Niebuhr et al. 2016) and motorcyclists (Ding et al. 2019). Other studies have also identified age as critical factor affecting the injury outcome for a given crash severity. For instance, with regard to car-pedestrian collisions, Kullgren and Stigson (2010) reported that at 40 km/h the risk of sustaining a MAIS 3+ injury is almost twice as high for elderly 60+, compared to all pedestrians in general Fig. 1.

Injury risk curves can be inherently affected by different types of different measurement errors, especially if based on crash reconstructions. As pointed out by Kullgren and Stigson (2010), impact speeds in crash reconstructions can include measurement errors in the 20% magnitude, which greatly affects the injury risk functions, especially at higher impact speeds. As shown in Fig. 2, the injury risk function would become more flat with increasing measurement error. This issue implies that injury risks are underestimated at higher impact speeds, which has significant practical implications for setting safe speed limits. As illustrated below, setting the threshold for acceptable risk is set at 10% based on data including 25% measurement error would result in a more than twice as high risk based on the original data.

It is important to point out that it is difficult to compensate the influence of measurement errors, or poor data quality in general, by increasing the data size. On the contrary, data sources with greater precision, that is, data based on EDR (Event Data Recorders), should be used whenever possible, even if the number of available cases is limited.

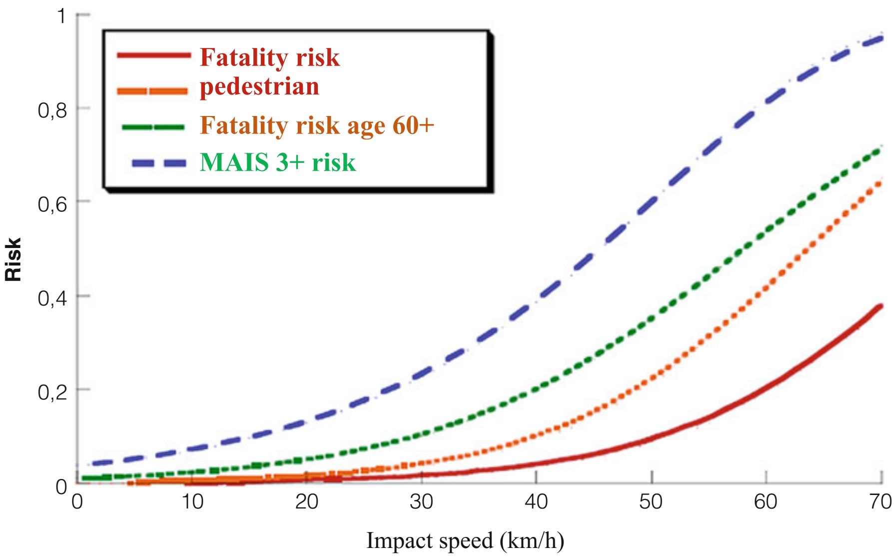

Fig. 1 Injury risk curves for pedestrians hit by cars. (Source: Kullgren and Stigson (2010))

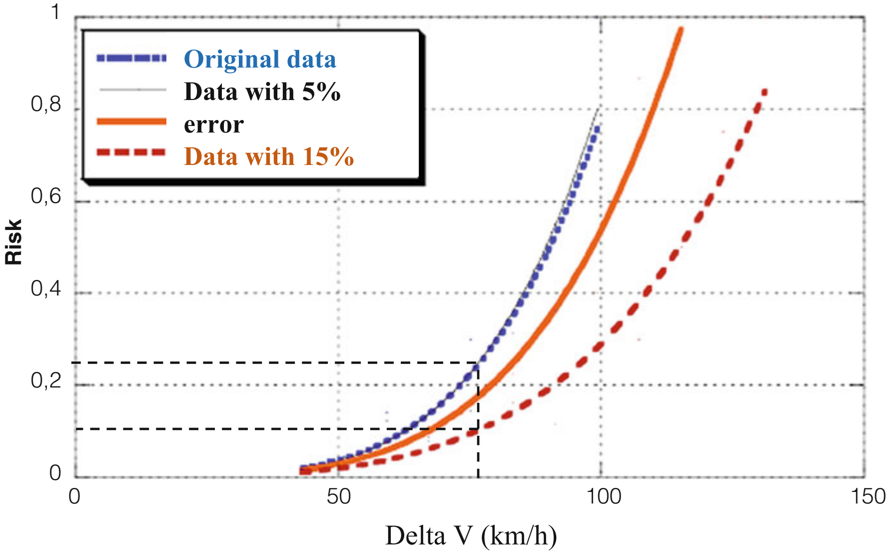

Fig. 2 Estimated effect of measurement errors on injury risk curves. (Source: Kullgren and Stigson (2010))

Model for Safe Traffic

A natural extension of risk curves, which outlines boundary conditions for specific crash configurations and road users, is to define system boundary conditions. System boundary conditions could be described as a combination of system element characteristics such as road infrastructure, vehicles, roads use, and speed such that they provide a safe system. Linnskog (2007) suggested a model as Fig. 3 where the combination of safe roads, safe vehicles, safe road use, and safe speed would produce safe traffic. For the model to be useful in different road environments, a dynamic approach was suggested where if one element failed it would need to be compensated by strengthening another. A typical example would be to adapt the speed limit to the function and safety quality of road infrastructure. Thereby a safe system can be created not only by heavy infrastructure investments but rather by a conscious decision of safe and appropriate speed in combination with infrastructure investment based on a road's strategic movement function. It is also important to note that the model criteria need constant review in relation to vehicle fleet turnover and as more advanced vehicle safety technologies enter the market.

Linnskog (2007) suggested a model for safe traffic for passenger car occupants with criteria being a Euro NCAP 5-star car, an iRAP 4-star road and a road user using seatbelt, being sober and complying with the speed limit. Stigson (2009) validated this model with the use of in-depth analysis of fatalities and serious injuries and found it to valid with a few exceptions, such as collisions with heavy goods vehicles. Also, Stigson (2009) further developed the model by suggesting that some of the road user requirements as seatbelt wearing, speed limit compliance, and unimpaired

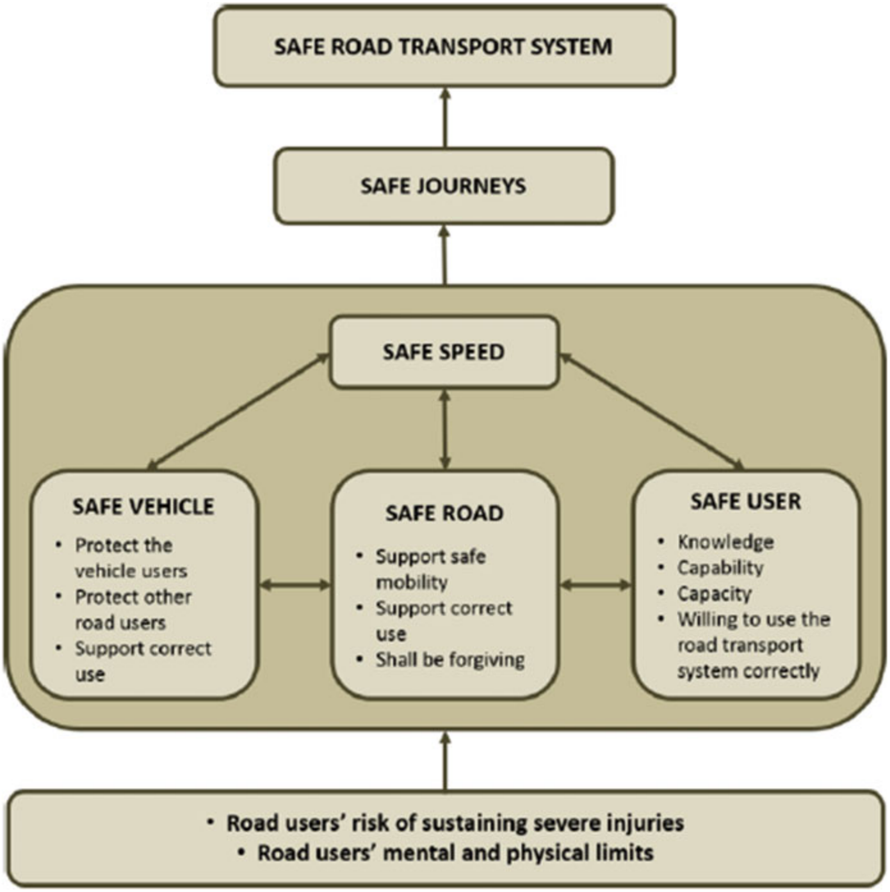

Fig. 3 The model for safe traffic adopted by the Swedish Transport Administration. (Adapted from Linnskog (2007))

driving should be guaranteed by the implementation of vehicle technology rather than being road user dependent.

In a similar matter, but with a more future focus, a model for safe traffic in 2050 is being developed and validated in Victoria (Australia) with the purpose to understand infrastructure requirements to achieve zero road trauma by 2050 when a new the national long-term target of zero by 2050 was set (Strandroth et al. 2019). Based on the in-depth investigation of fatal crashes, the implementation of road cross-sections as outlined in Fig. 4 is investigated, in combination with a 5-star vehicle model year 2025 with safety technologies as outlined in the Euro NCAP roadmap (Euro NCAP 2017).

Even though this example is limited to passenger cars on midblock sections of high-speed rural roads, it illustrates the value safe system models. These models enable a back-casting approach where a future desired state can be compared with the current system state resulting in a gap-analysis useful for future planning.

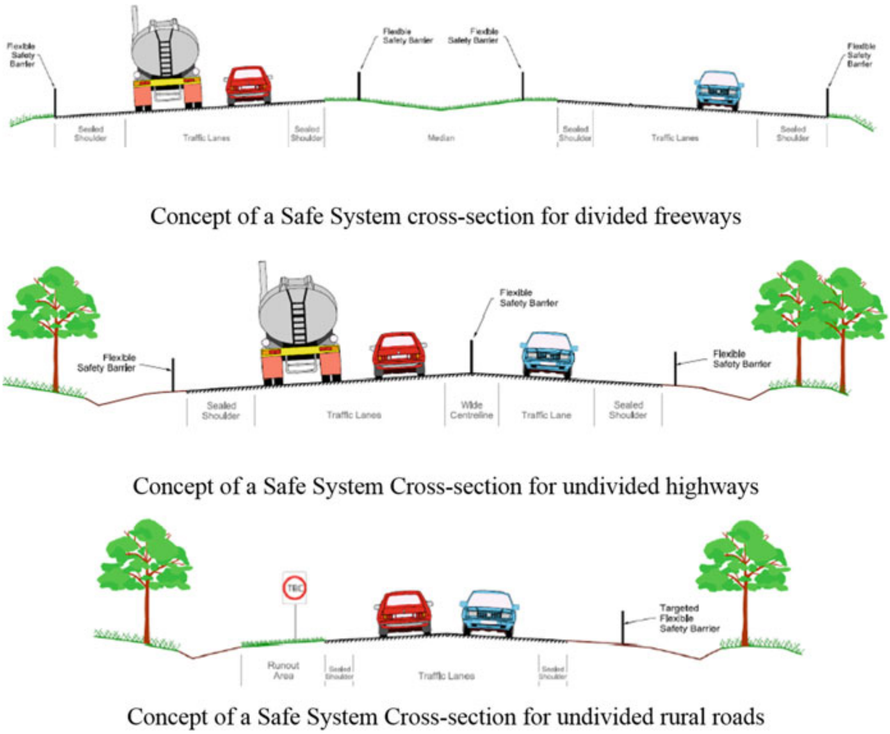

Fig. 4 Concepts of cross-sections for different road types. (Source: Strandroth et al. (2019))

By doing this, one can identify additional programs and innovation needed to achieve zero and understand how to optimize the pathway to zero.

From a Vision Zero perspective it is thereby essential to develop and validate models for safe system for all road users in all situations, as it forms the basis for Vision Zero planning and implementation.

In-Depth Analysis of Crashes and Injuries

In road safety, as for other areas of epidemiology, a commonly used approach is case studies – where in-depth investigations of uncommon events are used to gain deep insight. This is one of the key prerequisites for road safety analysis with Vision Zero. Basically, macro analyses based on mass data need to be complemented with in-depth knowledge on crashes. It is also important to acknowledge that the road transport system is far from static – it is an intrinsically ever-moving entity that needs to be constantly monitored and studied. Therefore, having up-to-date in-depth studies of crashes makes it possible to follow up the current performance of the road transport system, to identify new deficiencies, as well as to test new hypotheses on future countermeasures.

A concrete example on median barriers is presented below. Using police-reported crashes matched with road data, Carlsson (2009) reported an 80% reduction of fatalities on newly built 2+1 roads. Clearly, this is an important result that strongly supports the further implementation of 2+1 roads as soon as possible. However, on the path toward zero it is essential to truly understand the circumstances of the remaining 20% fatalities that were not addressed by mid-barriers. This could be referred to as “getting the magnifying glass and zooming in on the leakage from a treatment,” which would be very difficult task to perform using mass data. The more effective a treatment is found to be, the more important it becomes to understand the leakage. This is where detailed knowledge through case studies can support quick action by road authorities by detecting non-conformities and supporting adjustments of existing countermeasures or even the development of new countermeasures to address them. Theoretically, even one single case involving a new non-conformity could be enough to require action on the whole road transport system. Again, it becomes evident that data quantity can never replace quality.

In-depth studies are also often used to find potential benefits, especially for pre-production vehicle technologies. While the analysis of in-depth cases naturally has to deal with challenges regarding subjectivity and reliability, a number of studies have shown that it is possible to minimize this issue by setting logical decision-trees and having redundant analyses. Anti-lock Brakes, Electronic Stability Control, Autonomous Emergency Braking, Lane Keeping Assist, Barrier treatments, and Audio Tactile Line Markings are all examples of vehicle safety systems and road safety treatments which future benefits are assessed using a case-by-case approach (Sternlund 2017; Rizzi et al. 2009; Sferco et al. 2001; Swedish Transport Administration 2012a, Doecke et al. 2016).

Analysis of Future Safety Gaps

When aiming for a society free from serious road traffic injuries, it has been common practice in many countries and organizations to set up time-limited and quantified targets for the reduction of fatalities and injuries (OECD 2008). In setting these targets, the EU and other organizations recognize the importance of monitoring and predicting the development toward the target as well as the efficiency of road safety policies and interventions (EU 2010). Predicting the future status of the road transport system is, however, important not only with respect to target monitoring. According to Tingvall et al. (2010), it also plays an important role in the process of operational planning and in the prioritization of future actions.

Typical questions that arise as organizations, cities, regions, jurisdictions, and countries target zero are: How close to zero will our current strategies take us? What crashes and injuries remains in the future when all the treatments in our current toolbox are implemented and what further innovations are needed to ultimately eliminate road trauma? These are some of the questions that this chapter seeks to answer in order to facilitate Vision Zero planning.

The Challenges with Using of Retrospective Accident Data

The nature of the road transport system in many regions of the world has changed rapidly over the last decade as safety improvements in road infrastructure, vehicle fleet, and speed management have changed the characteristics of the system components. Not only has the condition state of the transport system changed, the characteristics of the crashes have also changed. For instance, Sweden has had a large reduction in car occupant fatalities since the beginning of the twenty-first century; however, the reduction is most evident in head-on crashes in contrary to single vehicle crashes. Strandroth (2015) has shown that this reduction was the result of systematic improvements, such as the installation of median barriers on roads with high traffic volume and/or vehicle improvements like the fitment of ESC and improved crashworthiness. Hence, as the road transport system continues to evolve it is quite reasonable to believe that the crashes of the future will differ a lot from the crashes of today and the past. Especially keeping in mind a future where cars can drive autonomously and the consequences of driver errors may be prevented, however, other challenges connected to automated vehicles may possibly arise (Lie 2014; Eugensson et al. 2013). Micro-mobility may also present the same possibilities and challenges.

Often when benefit assessments are made, retrospective data are used to describe accident scenarios that the technology is assumed to address (eValue 2011; Kuehn et al. 2009; Fach and Ockel 2009). The benefit estimations of a technology that will be introduced on new cars in a couple of years will then be based on accident data that may be several years old. Strandroth (2015) showed that the maximum benefit of a vehicle technology can be delayed for 10 or even 20 years. Hence, there can be a large time distance between maximum benefit and the time from which the accident data was collected and utilized in the benefit assessment. This fact can make retrospective analysis of crash data invalid when trying to predict the future impact of new or existing safety measures.

Naturally, accident data will always be intrinsically retrospective. However, the validity of the crash data need to be controlled by taking into account the evolution of the transport system when estimating benefits of future technologies.

Methods to estimate future benefits of road safety interventions based on the development of a combination of countermeasures can according to the Transportation Research Board be classified as statistical or structural (TRB 2013). TRB recognize statistical methods as an essential engineering tool for "formulating an initial, preliminary understanding of the relationship between variables" (TRB 2013). As a complement to statistical analysis, structural analysis has been proposed as an approach to identify why crashes occur and to explain causal relationships in road safety. A structural model is described by Davis (2004) as a model that "consist of deterministic mechanisms that draw on background knowledge concerning how the driver–vehicle–road system behaves. . .First, the relevant mechanisms for a specific type of crash are identified. Then, they are used to quantify the causal effect of the treatment on each mechanism. Finally, the frequencies of the mechanisms are aggregated for the facility of interest."

Methods for prediction with a structural approach have been introduced and used in, for example, Sweden and Australia. In Sweden, a model suggested by the Institute of Transport Economics in Norway was used to forecast the number of lives saved by different road safety interventions introduced in 2007 and beyond (Swedish Road Administration 2008). This was done to facilitate the decision on an interim road safety target in Sweden. The effect of the individual interventions was calculated as the exposure multiplied by the effectiveness. The number of lives saved from all interventions was then estimated by the total sum multiplied by a factor of 0.6 to adjust for double counting (Swedish Road Administration 2008).

In South Australia, a model was developed for the South Australian Government by Anderson and Ponte (2013) which aimed to quantify the benefit from a number of safety improvements until 2020. The model took implementation rate and time into account and related every intervention to its relevant target population. In this study, the target population was defined as the group of fatalities prevented by a specific intervention. Other external factors such as traffic growth and changes in the vehicle fleet were also taken into consideration. A model developed by Vulcan and Corben (1998) was numerically implemented by Corben et al. (2009) in Western Australia and used the same approach. The overall benefit from all interventions (I1, I2, . . ., In) in the Australian model was calculated as 1-(1- I1) · (1- I2) · . . . · (1- In). Hence, the interventions were treated as independent.

Correlation, Independence, Overlapping Variables, Non-Linearity, and System Effects

Although the assumption of an independent relationship could sometimes be true and applied in retrospective evaluations, it has been shown in some cases to be invalid and therefore not appropriate to describe the future. Tingvall et al. (2010) identified at least two major challenges that are linked to the dependent relationship between different SPIs and the nonlinearity between an increase of an SPI and the final outcome. Regarding the relationship between SPIs, earlier studies have shown some possible alternatives that are all based on the fact the SPIs do not act alone, but are rather interacting components in a complex system.

In some cases it is clear that SPIs are correlated. This is the case with seat belt use and impaired drivers, since the probability for impaired drivers to be unrestrained in fatal crashes have been found to be larger than for sober drivers (Tingvall et al. 2010). Also, Nilsson (2004) found correlations between alcohol, seat belt use, and speed limit compliance in studies with self-reported data. One other possible interaction between SPIs could occur where a combination of two or more SPIs is conditional, in the sense that the effect of one factor is dependent on, or enhanced by, another factor, for example, system effects.

Strandroth et al. (2011) illustrated an example of system effects by showing that the injury reducing effect of more pedestrian-friendly car fronts depends on the speed limit where the pedestrians are struck by the car. In that study, hospital records were used to calculate the mean risk of impairing or fatal consequences. The results showed a significantly lower mean risk of fatal or impairing injuries for cars with a higher Euro NCAP pedestrian score. Interestingly, the risk difference in 30 km/h speed zones was 42%, while in 50 km/h speed zones the difference was 25%; and in 70 km/h no risk differences could be found (Fig. 5).

Broughton et al. (2000) assumed this relationship when evaluating the past benefit of vehicle safety, interventions against drink-driving and road engineering. But also in an attempt to forecast the benefit of these interventions, the same study based the calculation on the theory of independence. If the SPIs are treated as independent or simply additive without interaction, double counting becomes a risk if the populations addressed are in fact overlapping. However, if system effects are introduced with a combination of SPIs, there is a risk of underestimating the combined effect by just adding them. Elvik (2009) stated that many studies earlier have overestimated the combined effects of SPIs, and suggested a more conservative approach described as the method of dominant common residuals. In that method it is assumed that the introduction of one road safety measure makes another measure entirely ineffective.

Another way of dealing with the combined effects is to simply summarize the effects and then use a multiplying factor lower than 1 in order to compensate for the correlation (Swedish Road Administration 2008). Furthermore, even if a valid and reliable number of casualties could be foreseen, it is still just a number and insufficient to describe qualitatively and to identify safety gaps.

The other challenge to predicting a final outcome from the combination of several improvements is the fact that there is not always a linear relationship between the development of an SPI in traffic and the final outcome. In-depth studies from fatal

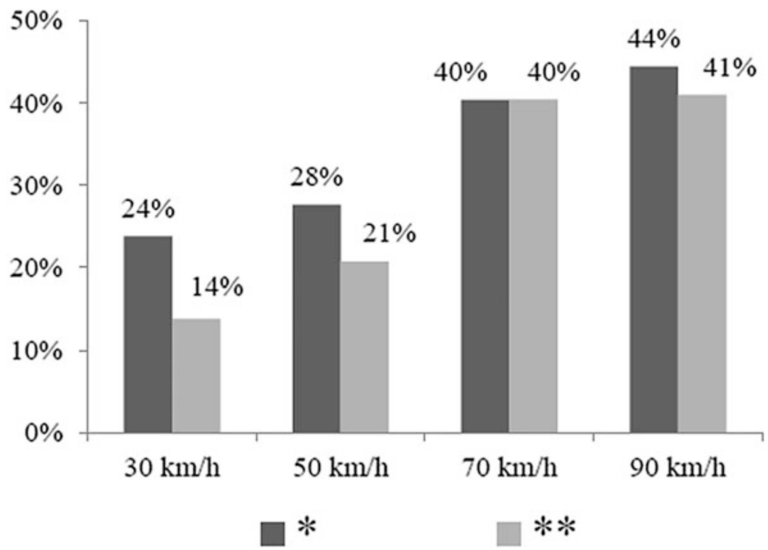

Fig. 5 System effects illustrated by comparison of mean risk for fatal or impairing injuries in one and two star cars Euro NCAP rated in different speed limits. (Source Strandroth et al. (2011))

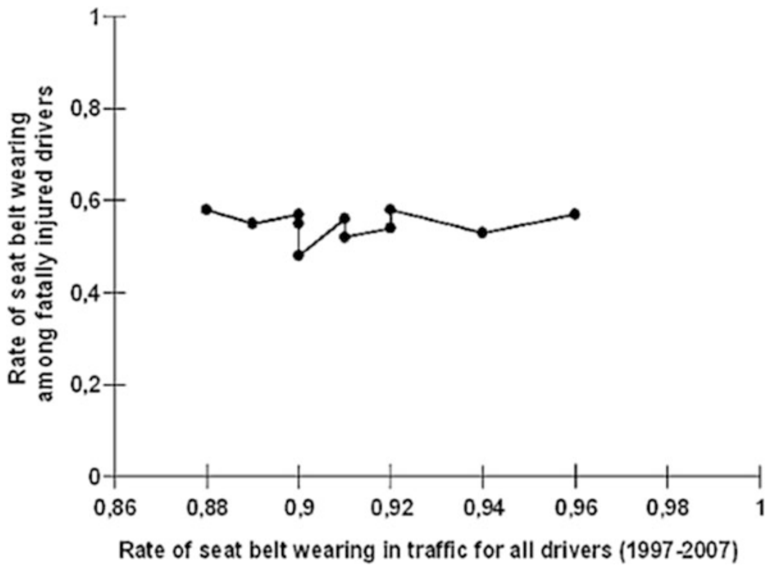

Fig. 6 Rate of seat belt wearing in traffic for all passenger car drivers vs. seat belt wearing for fatally injured drivers, from 1997 to 2007. (Source: Tingvall et al. (2010))

crashes combined with measurement on a whole population indicate that an increase of a safety factor among the whole population might not lead to an improvement in the final outcome. Tingvall et al. (2010) relate this to the fact that the improvement could address another part of the population than the one involved in severe crashes. Figure 6 shows an example where the increase in seat belt rate for all drivers does not increase the seat belt rate in fatal crashes.

Another explanation for the nonlinearity could be the slow turnover of vehicles in a vehicle fleet, and that the distribution of vehicle mileage over vehicle age is not linear with the proportion of fatal and severe crashes. Figure 7 shows that when a cohort of cars has driven 80% of their lifetime mileage, they have only been involved in 50% of their fatal and severe crashes (STA 2012c). Hence, older cars are in general over-represented in severe crashes, and as new safety technologies penetrate the market it could take many years before the technologies reach the target population. Often this nonlinearity is ignored in benefit assessments.

An Analytical Approach in Vision Zero Planning and Target Setting

To overcome issues with nonlinearity, double counting and invalid old crash data, Strandroth et al. (2015) suggested a new approach to understand the future impact of road safety interventions by combining knowledge from system improvements with in-depth crash data. Figure 8 gives a basic overview of the analytical approach in Vision Zero planning. While each step is described separately, please see Strandroth (2015a) for further reading.

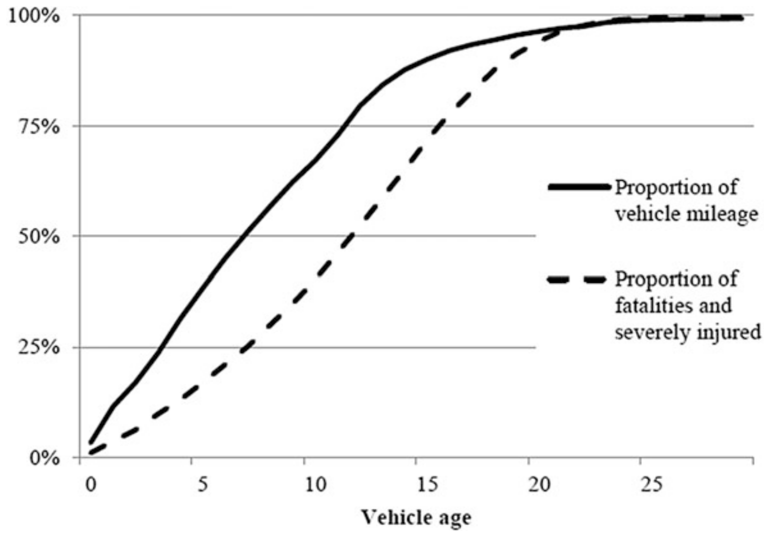

Fig. 7 Accumulated passenger car mileage and involvement in fatal and severe crashes over passenger car age. (Source: STA (2012c))

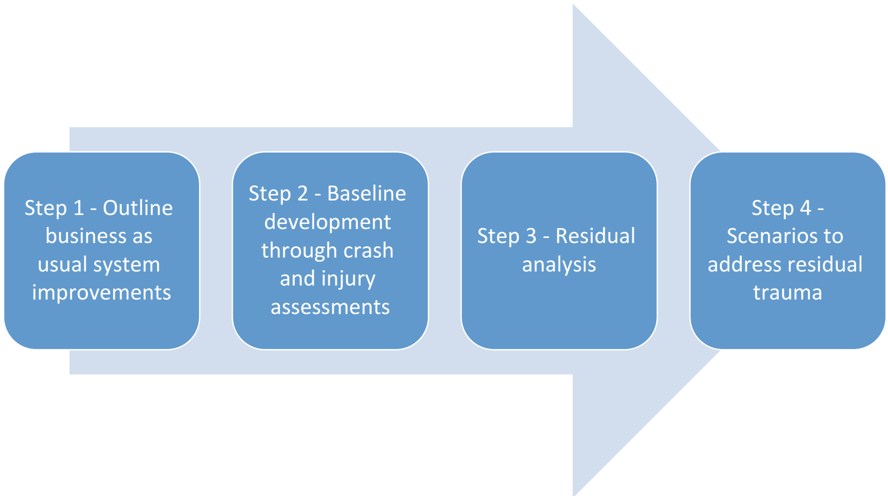

Fig. 8 Basic overview of the analytical approach in Vision Zero planning

Step 1: Outline Business as Usual System Improvements

The first three steps are about developing a baseline business as usual scenario which aims to illustrate a baseline development of fatalities and injuries. In this context, a baseline can be defined as the projection of today's fatalities and current risk levels affected by already planned system improvements. This includes infrastructure treatments in the current delivery pipeline but also vehicle safety improvements due to vehicle fleet turnover. It could also be more general factors such as travel speed changes or changes in general deterrence levels.

To consider the future impact of the baseline safety improvements, they all need associated business rules around implementation timeline, target crash pools, and effectiveness. Business rules are essential to make the modeling repeatable and scientifically sound. They cover in detail which crashes, involving who and in which situations that would be prevented by certain treatments. The business rules also need to capture every inclusion and exclusion criterion in the target crash pools, that is, extreme violations, excessive speeding.

Crash data format and quality would determine the method of modeling. In-depth crash data enables case-by-case analysis of crashes that allows detailed understanding and engagement and deals with double counting when estimating future treatment effectiveness. However, the resource intensity of case-by-case analysis limits the number of crashes that can be modeled to hundreds instead of thousands in contrast to a statistical approach using mass data. In reality, it is rarely the case that in-depth analysis of thousands of crashes is needed to understand the systematic risks in a jurisdiction, why a random sample could be selected for this specific purpose. However, in some cases, such as when analyzing big data, a similar structural model, however with a statistical approach, could be used in the analysis of serious injuries which are vast in numbers. For further reading see Strandroth et al. (2016).

Independent of the crash data format, information on the roads, vehicles, and people involved in the crashes must be linked to unit-records on the same level of detail as the crash data as well as future treatments with their associated business rules and the target years. The greater the quality of this meta-data, the more transparent and repeatable is the method.

Step 2: Baseline Development Through Crash and Injury Assessment

Crash and injury assessment by application of business rules to crash data would be different between mass data and case-by-case data. In a case-by-case analysis, every crash needs to be carefully examined to understand whether the crash outcome would be the same in a future target year given future system improvements. Each fatality is assessed according to the business rules to decide whether it is likely to be prevented or not in a specific year. Firstly, the prevailing crash type associated with each fatality is considered against the target crash pools to identify relevant treatments and vehicle safety systems. Secondly, the effectiveness business rules is applied to see whether the crash circumstances are such that the fatality would be expected to be prevented or not. Finally, implementation time is taken into account to understand in what year the fatality is expected to be prevented (if relevant). If the fatality is considered to be prevented by any of the agreed road safety improvement measures, it can be removed from the residual.

As an example case, let us assume that a passenger car with model year (MY) 2007 was involved in a single vehicle loss-of-control scenario in 2018. The crash occurred on a main national road with median barriers but without roadside barriers. When leaving the lane on the right side of the road, the driver over-corrected, lost control, and rolled over resulting in the driver being killed. The crash would sort into the target crash pool relevant to ESC, roadside ATLM, and road-side barriers. In this case we assume the circumstances do not exclude the crash from the effective envelope of ESC and barriers; however, ATLM where not assumed to be effective. The car was not equipped with ESC which, in this hypothetical example, became standard in this region of the world in 2012. Based on the five-year difference between 2007 and 2012 the crash would be expected to be prevented five years after the original crash in 2018, thus prevented and removed from the residual in 2023. In this way, not only the age of the vehicle fleet is taken into account when projecting the benefit of fleet renewal but more importantly the age of each vehicle involved in fatal crashes. This process is then repeated if the crash belongs to more than one crash pool to understand what else might have prevented the fatality. In this hypothetical case, there are no specific projects planned on this road but since it is a main national road it is expected to be fitted with barriers to 2030. In summary, ESC and the fitment of roadside barriers are expected to prevent the crash in 2023 and 2030, respectively. However, every crash is only removed once from the residual to avoid double counting of treatment benefits. Thus, this particular crash would be removed from the residual only once in 2023.

After the initial application of system improvements, general improvements that are not necessarily associated with individual crash pools can be applied (e.g., travel speed changes, enforcement elasticities). One has to be careful though not to add general factors to the degree that they represent the majority of future benefits as issues with double counting might come to effect. And in some cases, also general improvement could be associated with specific crash pools to avoid double counting. That is the case for example with crashworthiness which is a more general improvement over time while at the same time specific to only car occupant injuries. External factors like risk exposure increase due to population growth or demographic changes could also be included at this stage.

Step 3: Residual Analysis

Following the establishment of a baseline, not only is it possible to estimate the level of future residual trauma but also to investigate the characteristics of this trauma. As previously mentioned, typical questions are: How close to zero will our current strategies take us? What are the characteristics of crashes and injuries remaining in the future when all the treatments in our current toolbox are implemented and what further innovations are needed to ultimately eliminate road trauma? Other questions might be: Are interim targets estimated to be achieved? What road users are favored in the delivery of safety improvements under the "business as usual" scenario? When and where will the majority of trauma reduction benefits from safer and more advanced vehicles be realized?

The investigation of future residuals can then guide the development of future treatments and interventions to close the gap between the baseline and future targets, both near-term and long-term. Of particular interest is to understand why future crashes are estimated to not be prevented. In this context, at least three basic reasons can be mentioned. First, residual due to implementation delays – when the relevant interventions exist but are not implemented in time. Naturally this residual would be diminishing over time. Second, residual being outside the effective envelope – when relevant treatments exist and are expected to be implemented in time, but the circumstances of the crash are such that the injury outcome are not avoided or mitigated sufficiently. Third, there is no relevant intervention – when there is no intervention in the pipeline (or maybe none at all) to address the crash outcome.

Step 4: Scenarios to Address Residual Trauma

As described in Steps 1–3, a logical reduction of future trauma based on the implementation of planned interventions can be used to make informed decisions on ambitious, achievable, and empirically derived interim targets. The natural next step is to recognize potential for additional improvements and trauma reductions by comparing the baseline with scenarios based on the implementation of additional countermeasure. Alternatively, the benefits of a more rapid implementation of treatments could be investigated as the example in Fig. 9 which illustrates the benefit of a more rapid uptake of vehicle safety technology. Normally in road safety

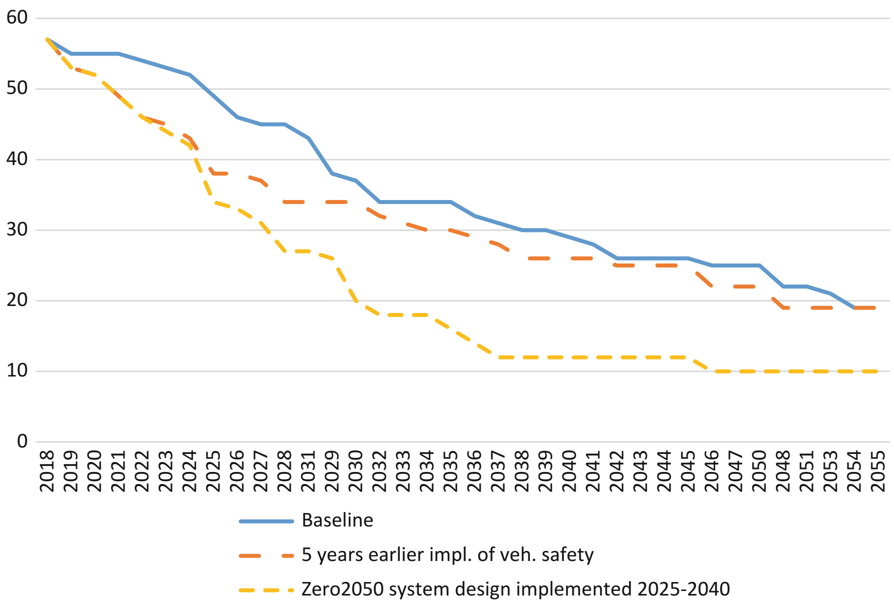

Fig. 9 An example of different scenarios

management and strategy development it is seldom valuable to reflect on the single impact of one intervention. Instead, the combined benefits of several interventions are of interest when interim road safety targets are to be set. The third line in Fig. 9 illustrates the combined effect of accelerated implementation of vehicle safety and increased efforts in infrastructure improvements.

The last but not least important step in this approach in the method would involve using the baseline modeling to develop Safety Performance Indicators and associated targets to enable system transformation monitoring. For further reading please see STA (2012b).

Methodological Considerations

One relevant question is whether prediction models in general should aim for a higher complexity by including as many variables as possible in order to reflect reality in the best possible way. Or, if methods to describe the future should be kept simple to preserve transparency and repeatability. Of course, it could always be argued that the more variables that are included in a model, the closer the model will represent real life. However, if more and more variables are included it could become harder to establish the causal relationship needed to understand the output of the model.

For instance, Broughton et al. (2000) states that even if statistical forecasting can be a powerful tool it has some weaknesses and often the modelers have no theory to guide their choice of model. Therefore, the current practice is to use a few alternative ones and choose the one that fits the existing data best. With no theory to guide the choice of model, functions could be formatted poorly and be problematic such as having correlated independent variables or induce nonexistent correlations (Hauer 2005). The challenge relating to multivariate models is that they are either additive or multiplicative. However, it has been shown in Strandroth (2015a) and in previous research that SPIs are not only additive or multiplicative. When simply added together, double counting becomes an issue, and with a multiplicative approach it is ignored that SPIs can also be conditional (where the effect of one improvement is dependent on another). Hence, when dealing with combined interventions, a deterministic logic approach is preferable as it could be more transparent and able to tackle double counting and conditional improvements, even though it is hard to image any method that would completely eliminate these issues.

Summary and Key Messages

Road safety analysis is an essential element in Vision Zero planning practices as it is used to provide guidance on what has been successful in treating past trauma problems, how to treat current risks in the road transport system and how to design a future safe system. As with all analytics, road safety analysis is reliant on good quality data in order to provide valid and reliable guidance. However, more data is not always the solution and data quantity should never be seen as a substitute of quality. On the contrary, small datasets can be very valuable if analyzed with robust methods. This is especially the case when sample sizes would naturally decrease due to road safety interventions (i.e., close to zero). The closer to zero we get, the more important is the analysis of outliers and nonconformities. And this type of quality management of the road transport system is only possible with in-depth data.

Defining future interventions and strategies in an accurate way requires in-depth knowledge of crashes and injuries, robust methods, and clear hypotheses. In order to design a Safe System, it is essential to understand the effective envelope of system interventions, that is, which crashes and injuries are prevented, what is not prevented and why. From an analytical prospective this requires a clear hypothesis of the cause and effect and not only correlation. And when selecting possible confounders, it is important that they are based on a hypothesis, and not just invented. If included without any hypothesis, they may pick a variation that is not real. In other words, it is important to distinguish between possible correlation and causation.

Another aspect of understanding the benefits of future interventions is that the road system is constantly changing, affected by everyday improvements like the renewal of the vehicle fleet, hence making retrospective data unsuited to describe the problems ahead. Naturally, crash data will always be retrospective in nature. However, the validity of the crash data needs to be ensured by taking into account the evolution of the transport system when estimating benefits of future interventions.

Road safety analysis is also about providing an analytical framework for the vision to become tangible and implemented in the day-to-day operation of road safety stakeholders. Some basic analytical steps for Vision Zero target management are presented in this chapter as follows:

1. Outline a baseline scenario with “business-as-usual” safety improvements
2. Baseline development through crash and injury assessment
3. Analyze the residual to identify future safety gaps
4. Develop scenarios to address residual trauma, set ambitious but achievable trauma targets and define Safety Performance Indicators for system transformation and set their long term and interim targets

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Speed-Limits in Local Streets: Lessons from a 30 km/h Trial in Victoria, Australia

29

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Abstract

Fatal and Severe Injuries (FSI) to vulnerable road users is a major road safety problem internationally. Recent resolutions by the Global Ministerial Conference on Road Safety called for a blanket 30 km/h speed limit in urban areas to address this problem. A project undertaken in Melbourne, Australia, set out to evaluate the effectiveness and benefits of a lower speed limit in a local residential area in the City of Yarra. The intervention comprised replacing 40 km/h speed limit signs in the treated area with 30 km/h signs with an adjacent untreated control area. A before and after study was employed with speed, resident surveys, and estimated safety benefits as measures of its success. Modest reductions in mean speed were observed in the after-phase of the study while benefits were impressive for vehicles travelling at higher speed levels where the risk of severe injury or death is greater. These findings represent an estimated 4% reduction in the risk of severe injury for pedestrians in the event of a collision. Questionnaire responses showed an increased degree of support for the 30 km/h speed limit in local streets in the trial area. The implication of these findings for road safety is discussed, along with the challenges and potential hurdles. Lower speed limits in local streets and municipalities is one important measure to help address vulnerable road users in residential local streets.

Keywords

Road safety · Speed limits · Local streets · Vulnerable road users · Severe Injury

Introduction

Lowering speed limits in local streets addresses two of the five pillars on which the Global Plan for the United Nations (UN) Decade of Action for Road Safety is founded. These are Pillar 1 – building road safety management capacity; and Pillar 4 – safer road user behavior and the issue of speed control (WHO 2005). The UN also note the importance of speed management as a key element in adopting a safe system approach to road safety. Other publications by WHO (2004), Corben et al. (2006), and TAC (2018) identify speed as a key risk factor in road traffic collisions, with pedestrians and cyclists at increased risk of a severe or fatal injury given a road crash.

Vehicle speeds in residential areas has long been associated with the risk of a serious injury and death to Vulnerable Road Users (VRU) specifically pedestrians and cyclists. There is a breadth of literature describing the relationship between the risk of injury and vehicle speed (e.g., Davis 2001; Rosen et al. 2011; Logan et al. 2019). Figure 1 shows an example of this relationship.

The World Health Organization (2018) recently reported that the number of traffic deaths reached a high of 1.35 million in 2016 and that globally, more than half of

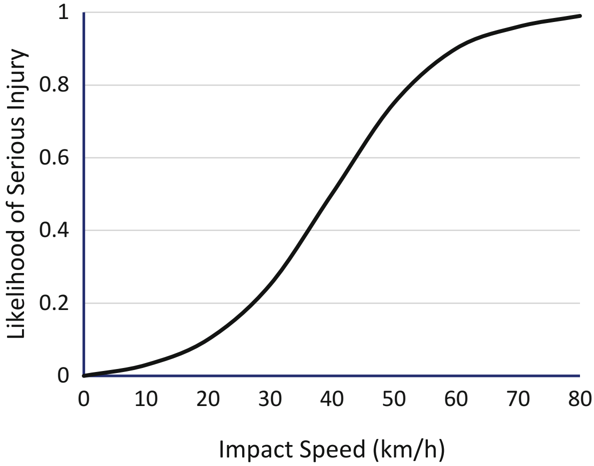

Fig. 1 Severe injury risk curve for pedestrians. (Source: Logan et al. (2019))

these were among pedestrians, cyclists, and motorcyclists (Vulnerable Road Users). They further pointed out that road traffic injuries are the leading cause of death among children and young adults, aged 5–29 years. The Transport Accident Commission of Victoria, the statutory insurer of personal liability for road accidents in this state, further reported that from 2009 to 2018, more than 400 pedestrians lost their lives on Victorian roads of which one third of those were aged 70 years or older, and that most died in the metropolitan area of Melbourne (TAC Victoria 2018).

Speed Limits in Local Urban Streets

A 30 km/h (20 mph) speed limit is commonly adopted in many European, UK, and USA municipalities, given these are predominant residential precincts. ETSC (2015) noted that many European countries such as Austria, Brussels, France, Germany, Italy, Netherlands, Spain, Sweden, and Switzerland have implemented 30 km/h speed zones in many of their regions. In addition, several states in the USA such as New York, Wisconsin, Oregon, and Boston, too, have also implemented 20 mph limits on low volume local streets, work zones, and schools (Small 2019). Finally, Auckland city in New Zealand, also recently announced they had cut speed limits in the CBD to 30 and 40 km/h on other major roads (NZ Herald 2019). These countries have recognized the safety benefits of lower speed limits in urban areas with frequent and planned interactions between VRU and cars.

Global Mandate for 30 km/h Speed Limits

Global Ministerial Conference

In February 2020, the third Global Ministerial Conference on Road Safety was held in Stockholm, Sweden, and one outcome of the conference was the release of a formal statement related to road safety objectives up until 2030 (Trafikverket 2020).

The report from this meeting proposes a vision for the evolution of road safety and recommends a new target of 50% reduction in road deaths and serious injuries by 2030 based on expanded application of the five pillars, adoption of Safe System principles, and integration of road safety among Sustainable Development Goals.

A set of ***nine*** recommendations were proposed from the meeting to realize the vision over the coming decade. One resolution of this declaration (Recommendation 8) was for countries to mandate a maximum road travel speed of 30 km/h in urban areas where there is a mix of vulnerable road users and vehicles. It noted that a speed limit in urban areas commensurate with this maximum travel speed was necessary to prevent serious injuries and deaths to vulnerable people when human errors occur.

A Safe System Approach

The Safe System methodology has become a preferred philosophical approach to achieving greater improvements in road safety around the world. It calls for the adoption of a systemic view of road safety involving safe vehicles, safe human behavior, safe roads and road infrastructure, and importantly, safe speeds, when examining road safety improvements.

It is no longer acceptable to simply blame the driver as the main cause of road crashes, but rather one element in a much wider view of causal factors in road crashes. While crashes will inevitably continue to occur, it is important that the kinetic energy imparted to the car occupants in a crash should be less than what they are able to tolerate resulting in severe injury or death.

Tingvall and Haworth (1999) first listed these values dependent of the type of collision, vehicle design, and full use of the vehicle's restraint system. Mooren et al. (2014) subsequently published these figures dependent on the type of infrastructure and traffic as shown in Table 1.

Many countries including Australia and New Zealand have adopted these values when setting speed limits in urban and rural settings. Unfortunately, the degree to which they are adhered to is variable across various states and territories. An OECD guidance document on the Safe System approach emphasizes the need for very low speed limits – no greater than 30 km/h – where conflicts with pedestrians are possible (OECD 2008).

Table 1 Safe System maximum vehicle speeds. (Source: Mooren et al. (2014))

Type of infrastructure & traffic	Possible traffic speed (km/h)
Locations with possible conflicts between pedestrians and cars	30
Intersections with possible side impacts between cars	50
Roads with possible frontal impacts between cars	70
Roads with no possibility of a side or frontal impact (only impact with the infrastructure)	100+

The Benefits of Lower Speed Zones

Grundy et al. (2009) set out to estimate the benefit of 20 mph (32 km/h) traffic speed zones on traffic collisions, injuries, and fatalities in London, using an observational study of geographically coded police data on road casualties between 1986 and 2006. They examined changes in road casualties, estimating the effect of introducing 20 mph zones on casualties on a range of existing speed zones, based on these crashes.

They reported that the introduction of 20 mph speed limits was associated with a 42% reduction in casualties, when accounting for changes in casualty rates on adjacent roads. They also reported that reductions were greater for young children and the elderly, and for the more serious injury outcomes. They concluded that 20 mph speed zones would be effective measures for reducing serious injuries and death among pedestrians involved in car crashes.

Ingamells and Raffle (2012) and Steeve Davies Gleeve (2014) further claimed that a 20 mph speed limit is the right policy on the grounds of safety, sociability, and ensuring a healthy population. While the focus of this Chapter is on the safety benefits in terms of fewer fatal and severe injuries, they noted other benefits for the residents include street calmness, incentives for more walking and cycling, reduced pollution and noise, improved mobility and independence, and physical and mental wellness.

20s Plenty for Us

The “*20s Plenty for Us*” in the United Kingdom is a non-profit organization formed in the UK early this century by Rod King MBE, Founder and Campaign Director. He noted that the objective of the campaign is for 20 mph (32 km/h) to become the default speed limit on residential and urban streets in the UK. Goodyear (2015) reported that by 2015, there were more than 15 million people in the United Kingdom living in communities where the speed limit is 20 mph (a figure of around 23% of the UK population). Goodyear claimed that this was achieved without the need for any additional physical calming on most streets while allowing for some streets to have a higher limit on particular roads when justified. She stressed, however, that any limit above 20 mph should only be after a considered decision based on local circumstances.

The Nottingham City Council is a member of the *“20’s Plenty for Us”* program. In 2012, the Council conducted a survey of its residents in Sherwood (of Robin Hood fame) and found that 63% of respondents supported the introduction of a 20 mph (32 km/h) speed limit on their street and 52% of them would like to see 20 mph speed limits extended to other parts of the City. From a before-and-after trial of lower speed limits on local streets in Sherwood, they found a speed reduction of 1.0 mph (1.6 km/h) average speed in the trial region with a 3.0 mph (4.8 km/h) reduction in the 85th percentile speed limit. They claimed these reductions include reductions in crashes and injuries to VRU, in these streets (Fildes et al. 2017).

Community Acceptance

The Global Road Safety Partnership (Silcock et al. 2008) noted that crash risk for Vulnerable Road Users is a special problem in most countries that warrants special attention. In setting local speed limits, however, they claimed it is important to know what the public is likely to accept first before committing to lower speed limits. They stress the need for community surveys to be undertaken to indicate the level of public support for these lower limits.

More recently, the ETSC (2015) pointed out that opinion polls in several countries have repeatedly shown majority public support for lower speed limits in urban areas. In a response to the EU's Urban Mobility Package last year, they called on the EU to encourage all member states to adopt speed limits of maximum 30 km/h in residential areas and zones where there are large numbers of VRUs.

Speed Limits in Urban Victoria

The current default urban speed limit in Victoria, Australia, is 50 km/h (31.3 mph) although speed limits on major urban arterial roads are typically posted up to 60 km/h (37.5 mph). On heavily congested roads and in school zones, though, limits have also dropped to 40 km/h (25 mph).

Among other Local Government Areas in the state, the City of Yarra, an inner urban Local Government Authority in Melbourne, recently adopted a blanket speed limit on local roads across its municipality of 40 km/h (25 mph) as part of its commitment to the Towards Zero program, widely adopted in Australasia. We understand that while there have been a few examples of the introduction of 30 km/h speed limits in select regions in Australia with a high mix of vulnerable road users and vehicles, none of these have ever been evaluated in terms of their safety benefits (Fig. 2).

Fig. 2 Typical streetscape in Fitzroy municipality in the City of Yarra

The City of Yarra

The City of Yarra is an inner urban metropolitan municipality in Melbourne, Victoria, Australia. It has a population of around 100,000 residents over 2000 ha and includes 12 inner suburbs. It is located on the fringe of the Central Melbourne Business District and is one of the older Melbourne metropolitan municipalities. Its age profile shows it is over-represented in young (<20 years) residents and those aged more than 30 years. It also has twice the proportion of older (65+ years) residents than the rest of Victoria. Given its location adjacent and within comfortable cycling and walking distance to the CBD, it typically has a high number of pedestrians and cyclists, and Council is concerned that 40 km/h is too fast in its residential areas (Fildes et al. 2017).

The 30 km/h Trial

Motivation Behind Trial

The City of Yarra Council is motivated to enhance the safety of vulnerable road users and move toward their vision of zero travel-related deaths and serious injuries within the municipality. The trial was seen as an opportunity to offer a demonstration of the challenges and benefits of lowering speed limits in an urban setting without substantive changes to the road infrastructure, as they relate to speed and community acceptance. It was also seen as an avenue to raise public awareness of the relationship between speed, safety, and local amenity. Public awareness campaigns were not limited to the community within the trial area but communicated throughout the whole municipality.

Key decisions related to the trial were passed through formally constituted Council meetings, and this included identifying an area within the municipality that would be amenable to a trial. A key consideration here was to identify an area without planned modifications to the road or built environment that would meaningfully show the trial outcomes. Moreover, it was also an area that was modest in size with demarcated clear boundaries. It is important to note that the trial area was not identified based on classic road safety selection criteria, such as addressing a poor crash history or speeding concern.

Two adjacent traffic management zones (or local area places) in the suburbs of Fitzroy and Collingwood were identified as candidates, and these were combined as the trial area. Two additional adjacent traffic management zones in the same suburbs were endorsed as a control area, for the purpose of providing exposure measures for observations made in the trial area.

Study Methodology

Study Design

In June 2017, the council approached the Monash University Accident Research Centre (MUARC) to assist in implementing a 30 km/h trial in a selected region of

Fig. 3 Regions selected for the treated and untreated regions in the City of Yarra trial

Fitzroy and Collingwood with an associated untreated adjacent control region. MUARC's role was also to oversee the implementation of the trial and evaluate the outcome from a safety perspective.

The study design aimed to assess differences in travel speed before and after implementation of the 30 km/h speed limit with an adjacent untreated control region still set at 40 km/h. Figure 3 shows the area in the City of Yarra selected for the lower speed limit trial. The trial ran for 12 months from September 2018.

Speed Observations

Speeds were measured from 91 sites located across both the treated and untreated regions covering both collector and one-way streets and cul-de-sacs. Speed data were collected 24/7 across both weekdays and weekends using road tubes installed at specified sites by contracted traffic surveyors.

Attitudes

It was also important to assess residents' attitudes to these changes as a measure of likely acceptability. Two online community surveys were conducted during the before and after phases. Invitations were mailed to a random selection of property addresses in the treatment area ($n = 2000$) and in the non-treatment area ($n = 2000$). The approach was the same for the baseline and the 12-month after samples. The questionnaire comprised 24 questions focused on their demographics, a range of questions related to their attitudes to the trial, and other associated local issues. Respondents were asked to complete an online questionnaire and sampling rates were 484 (24%) at baseline and 548 (27%) on completion of the trial.

Safety

Given the size of the trial, it was not possible to expect enough data on crashes that occurred during the study period. However, it was possible to compute the likely injury benefits in terms of Killed and Severe Injuries (KSI) from the observed speed changes, both before and after the trial. In addition, the speed distributions for those travelling above the speed limits before and after the trial as well as those travelling above the Safe System recommended speed categories.

The Findings

Speed Reductions

Average Speed

The average and 85th percentile speeds observed before and after the 30 km/h trial in the treated and untreated (control) locations are shown in Table 2 below.

The average and 85th percentile speed reductions were modest in both regions (median values were similar to the mean values and trends). The reductions in speeds in the control regions were unexpected, and interpreted as a carry-over effect, given that the control region was immediately adjacent and marketing for the trial did not clearly separate the two regions. Nevertheless, it did have a negative impact for the analysis, discussed further below.

Speed Categories

Importantly though were the speed findings above the speed limit, shown in Table 3. The three values were chosen based on the speed limit and Safe System values for these localities. The average percent speed reductions for the three-selected speed categories shows significant larger speed reductions for the 40 and 50 km/h

Table 2 Mean and 85th percentile speed, before and after the 30 km/h trial

Measures	Before (km/h)	After (km/h)	Reduction (%)
Treated – average speed	27.6	27.3	−1.1
Treated – 85thile speed	36.0	35.0	−2.8
Control – average speed	29.4	28.6	−2.7
Control – 85thile speed	38.0	37.0	−2.6

Table 3 Observations exceeding speed categories, before and after the 30 km/h trial

Measures	Before (%)	After (%)	Reduction (%)
Treated – 30 km/h	36.71	34.42	6.24
Treated – 40 km/h	5.38	3.89	27.73
Treated – 50 km/h	0.41	0.25	38.69
Control – 30 km/h	46.76	42.68	8.72
Control – 40 km/h	7.95	6.43	19.15
Control – 50 km/h	0.63	0.51	18.44

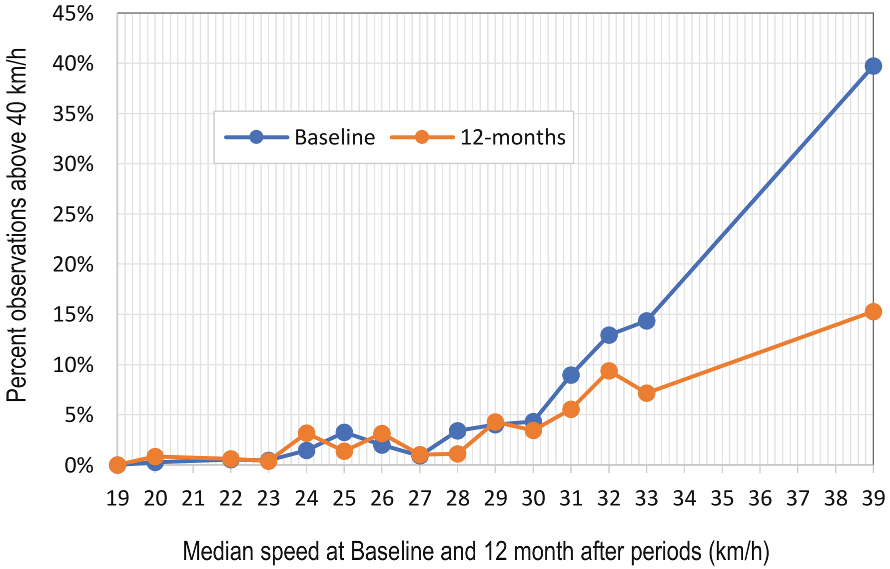

Fig. 4 Percent exceeding 40 km/h by mean speed at baseline

categories at the treated sites and at the controls. These equate to significant reductions in the likelihood of severe injury at the treated sites with the 30 km/h speed limit, compared with the untreated control sites.

Speed Trends: Before and After

The relationship between the median speed at baseline and at 12 months by speed category is a further indicator of speed changes at the various sites and/or traffic conditions where the lower speed limit had its greatest impact. Figure 4 shows the percent of observations at the treated sites exceeding 40 km/h before and after treatment. As the mean speed increased, the percent of observations also increased but noticeably less after the treatment than before. It further confirms that the speed attributed to the lower speed limit had its greater impact on sites with higher initial speeds.

Table 4 Overall treatment effect of the 30 km/h trial in speed reduction benefits

Measure	Odds ratio	CI (95%)		Significance
Exceeding 30 km/h	1.07	–	–	$P > 0.05$
Exceeding 40 km/h	0.89(−11%)	0.87	0.92	$P < 0.001$
Exceeding 50 km/h	0.75(−25%)	0.67	0.84	$P < 0.001$

Treatment Effect

The final speed analysis assessed the overall "treatment effect" of the trial used a modelling approach that adjusted for the difference between the treated and control speed reductions, that is, what was the real effect of the 30 km/h trial (see Table 4). The treatment effect was assessed against the odds of a speed observation exceeding 30, 40, and 50 km/h, in the treatment area, minus the reductions observed at the control sites.

Thus, the real treatment effect of the 30 km/h trial after adjustment was a reduction in the odds of a vehicle speed exceeding 40 km/h by around 11% and exceeding 50 km/h by 25% in the after phase. The treatment was found to not reduce the odds of a speed observation exceeding 30 km/h.

Thus, it can be concluded that the expected overall benefit of the City of Yarra 30 km/h trial in terms of speed reductions was achieved. While there was little difference in average speed before and after the trial, the main benefits were among the higher speeders where greater benefits in terms of fewer severe injuries were likely in a crash.

Community Survey

The community survey key question asked during the trial was whether the respondent would support the introduction of a 30 km/h speed limit on the street in which I live/work/own in the City of Yarra (Lawrence et al. 2017). Their responses to this question are shown in Fig. 5.

Interestingly, the yes responses to that question went from 42.7% before to 50.3% after, that is, an 18% increase in support for the trial and an associated decrease in non-support. While many of the other question responses showed little difference before and after, there was an increase in support of 10% that the reduced speed limit will not impact on travel time, another 4% that it will be safer for children and the elderly, and 3% that lower speed limits will reduce injury severity in a crash.

Safety Benefits

The final analysis was to estimate what the likely percent reduction in severe injuries would be given the speed reductions above. This estimate was based on modelling the association between the speed reductions of the treatment effect, given the severe injury risk curve for pedestrians, shown earlier. The modelling approach is illustrated in Fig. 6 below.

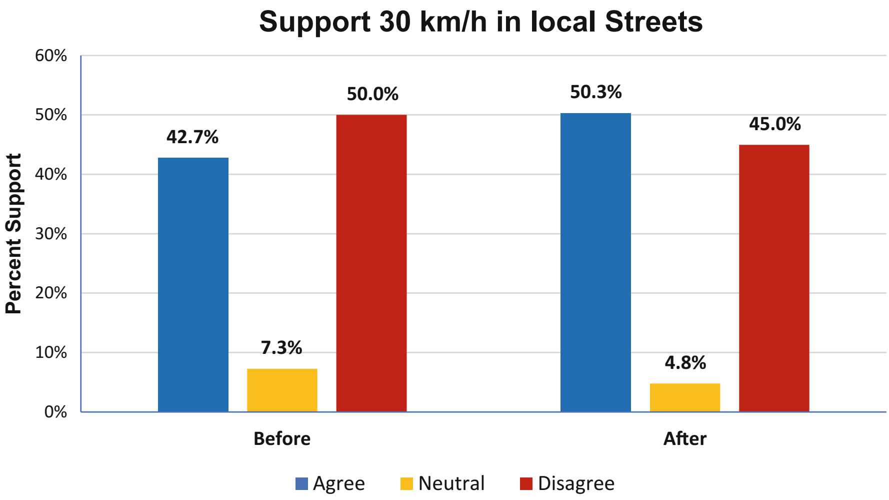

Fig. 5 Residents' support for a 30 km/h speed limit where they lived, worked, or owned

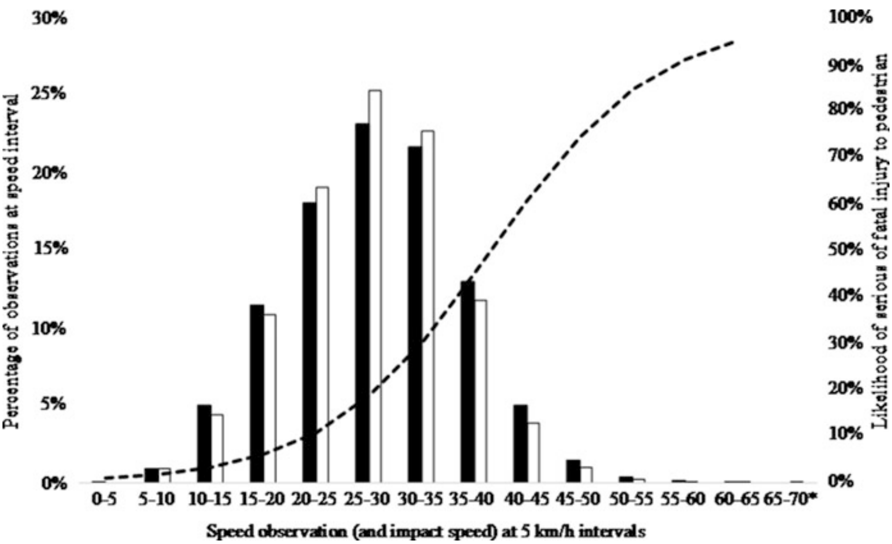

Fig. 6 Crash distributions before and after by the injury risk curve shown earlier in Fig. 1

The potential injury savings from the 30 km/h speed-limit trial over the previous 40 km/h speed-limit, were estimated by identifying the difference in the relative risk of injury, before and after the intervention, using the Davis (2001) risk curve.

The findings showed that the risk of sustaining a serious or fatal injury, given collision involvement, reduced from 24% before, to 23% after treatment. This represents a 4% reduction in the risk of sustaining a severe injury, should a collision occur between a motor-vehicle and a pedestrian. While this might sound like a relatively small improvement, it does represent a sizeable number of vehicles (between 200,000 and 300,000 annually) that will travel at excessive speeds likely to cause severe injuries to vulnerable road users. This analysis does not account for any reductions in the risk of a collision on account of the reduced speed, although this may also occur due to the lower speed limit (WHO 2004).

Crash Reductions

The risk of having or not having a collision given the speed reductions noted above was beyond the scope of this trial. Nevertheless, there are physical relationships between speed and the distance it takes to stop, reported in studies by Anderson et al. (1997) and Corben et al. (2006). Factors that affect stopping distance include initial travel speed, driver reaction time, braking capability of the vehicle, and the coefficient of friction between the tyres and the road surface. Corben et al. (2006) estimated that for a reduced travel speed from 40 to 30 km/h, the stopping distance reduces from 22 to 15 m (a 32% reduction), leading to a potential added saving in injury from total preventing the crash thereby adding additional safety benefits from those noted above (Fig. 7).

Summary of Results

In summary, there were modest reductions in average and 85th percentile speeds in both the trial and control areas, although larger reductions were observed at higher

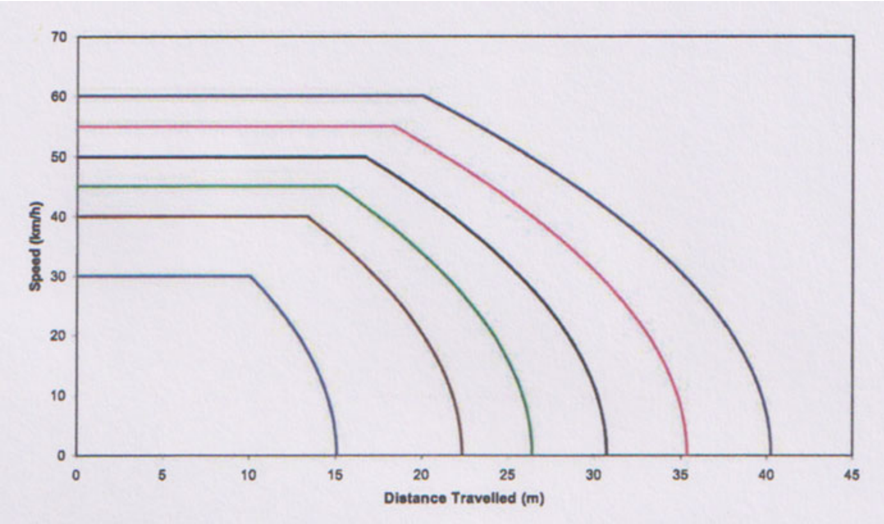

Fig. 7 Stopping distance by travel speed (Corben et al. 2006)

speed levels above 40 and 50 km/h in both regions. After adjusting the trial findings for the unexpected speed differences in the control region, there was still a significantly "treatment effect" attributed to the 30 km/h trial with a 4% reduction in likelihood of a fatal and serious injury. These reductions are likely to led to a reduction in risk of a pedestrian and other VRUs sustaining a fatal or serious injury in a crash.

Residents' positive attitudes to a 30 km/h lower speed limit increased significantly by 17% at the conclusion of the trial with a sizeable reduction in opposition. There was also a 10% increase in the belief that the 30 km/h trial would have little effect on travel time in these local streets. Small increases were observed in the agreement that the 30 km/h speed limit was safer for children and elderly pedestrians and that lower speed limits are likely to reduce injury severity in a crash. No support was observed, however, for reducing the speed limits in the neighboring main feeder streets.

Implications from the Trial

As noted earlier, this was the first evaluated trial of a 30 km/h speed limit in a residential environment in Victoria, Australia. The trial was expected to achieve reductions in area-wide travel speeds and community acceptance, and this was observed after a 12-month introductory period, especially among the higher speeders in the region. A 4% reduction in the risk of a severe or fatal crash injuries to pedestrians and an increase in community acceptance were also anticipated. A 4% increase in safety for vulnerable road users in Victoria is a worthwhile improvement for pedestrians and bicyclists in residential areas and likely to help address their over-involvement in crashes in these regions.

The findings from the trial support previous published benefits on the effectiveness of adopting a lower 30 km/h speed limits in urban areas (Grundy et al. 2009; Fildes et al. 2017a) and in current best practice in many international countries. It is consistent also in line with the recent call from the Global Ministerial Conference on Road Safety for countries to mandate a maximum road travel speed of 30 km/h in urban areas where there is a mix of vulnerable road users (Trafikverket 2020). It also supports the recommendation from adopting a Safe System approach toward speeds in residential areas (Tingvall and Haworth 1999; Mooren et al. 2014).

It must be stressed though, that 30 km/h speed limits in local streets is not a particularly new finding internationally for protecting pedestrians and cyclists in residential areas. As noted earlier, 30 km/h (20 mph) speed limits are relatively common in areas with high volumes of vehicles and vulnerable road users in many countries around the world. The World Health Organization (2018) noted that Vulnerable Road Users (pedestrians, cyclists, and motorcyclists) are disproportionately impacted globally, accounting for half of all road deaths in 2018. Further, the Global Road Safety Partnership (GRSP 2008) pointed out that in some regions, speed limits on local urban streets need to consider a variety of functions in these regions (school zones, shopping precincts and purely residential areas) and that for some of these zones, limits as low as 20 km/h may be appropriate.

Enforcement

There was a deliberate decision taken at the outset of the City of Yarra trial not to compound the findings of the trial with any police enforcement effects. The Victorian police agreed to this request and while they oversaw the conduct of the study, did not perform any speed enforcement in the area. Thus, the findings reported above are purely based on the motorists' behavior. It is anticipated, though that with time, speed enforcement in the area will be needed to maintain the speed benefits observed.

The Nottingham police reported that, the 20 mph speed limit is enforceable in the Nottingham trial where the limit is clearly marked, and that offenders may be prosecuted. They noted that the primary infringement means is by using speed cameras in 20 mph zones. They claim that this technology is more important than the use of speed humps. Afukaar (2003), however, noted that while active enforcement (e.g., speed cameras and police presence) should be the primary "weapon" used against speeding motorists, supplementary engineering treatments such as rumble strips and speed humps are also effective for speed controls in low speed environments.

From an extensive inquiry conducted by the Auditor General of the Victorian Parliament following a review of the "*Arrive Alive*" camera enforcement program (VicParl. 2006), they concluded that the enforcement program had reduced speeding by up to 20% with no evidence that the program was focused on raising revenue. While most of the speeding reductions were focused on speeds above 60 km/h, they also reported there had been significant reductions in pedestrian trauma and severity of serious injuries during the program: measures sensitive to changes in lower travel speeds.

It is important when speed changes are introduced that it is accompanied with on-going speed enforcement, mass media, public education programs and possibly infrastructure improvements. The Transport Accident Commission stress the need for public acceptance, show the risk of detection is real and the use of the latest enforcement technologies (TAC 2020).

Speed Technology

In addition to police enforcement, there are other technologies available and under investigation to help address police enforcement. Intelligent Speed Adaptation devices can be fitted to vehicles that alert the driver to the fact that he/she is travelling above the speed limit, with and without pedal activation. In a study in Belgium by Vlassenroot et al. (2007), they found large differences between drivers using the technology. While there was evidence of some drivers slowing down and driving at the speed limit, others speeds even increases despite activation of the system. Frequent speeders tend to accelerate quickly up to the speed limit causing average speeds to increase.

Fig. 8 Photo of a Geofence bus trial in Sweden. (Source: Tom Stone (2018))

More recently in Sweden, Payne (2020) reported on a new concept for speed control where vehicle speeds are digitized. The technology is known as Geo-fencing and is currently undergoing city bus and truck trials in Sweden and Norway to evaluate its potential to end speeding in these countries. Using GPS or cellular technologies, the system creates a virtual fence around the vehicle that triggers a pre-programmed action, keeping vehicles under 30 km/h as it enters the trial area (Fig. 8). The author notes that geo-fencing "*has the potential to change the way traffic infrastructure is developed and how different vehicles use the roadway.*"

Finally, in future, Connected and Autonomous Vehicles (CAVs) in use are expected to sense the legalized speed limit in the area they travel at by software using either sign-recognition or GPS interaction and then maintain the appropriate speed autonomously, ensuring the vehicle does not exceed beyond the legal speed for the region. These vehicles are still some time away from widespread use but may well be the ultimate solution, taking the choice of what speed to travel at away from the human occupants of the vehicle.

Challenges and Potential Hurdles

Community Acceptance

As noted above, there is considerable evidence showing that lowering a posted speed limit will increase safety and decrease the number of crashes (Afukaar 2003; WHO 2004; VicParl 2006;). Nevertheless, the greatest challenge in introducing a new (lower) speed limit is always gaining community acceptance of any such change.

As pointed out by Mooren et al. (2014) and others (Lahausse et al. 2009; McGuffie and Span 2009; Soole et al. 2013), part of the problem for governments when introducing safe speed limits is the amount of vocal opposition to lowering the limits. Typically, there is always enthusiasm (positive and negative) when new safety measures are introduced, but it is likely to take significant effort over a long period of time to ensure it becomes commonplace in local streets.

When mandatory wearing of seat belts was first introduced in Australia in the 1970s, more than 90% wearing rates were achieved quickly and maintained through ongoing speed enforcement. Ultimately, behavioral change occurred from early and continual enforcement (Robinson 2011) as well as in marketing programs over a constant prolonged period.

Government Support

Government support is also important which sometimes is not always forthcoming for changing speed limits, given the potential political consequences. Svensson et al. (2013), for instance, noted that in most European countries, the process of setting and implementing speed limits is often delegated to local and regional administrators. They examined the perspectives and priorities of administrators and elected officials in setting speed limits and identified two groups with different philosophies, namely, (i) those who support a mobility perspective (e.g., traffic planners for example), and (ii) those who share a traffic safety perspective (e.g., committed to improve traffic safety through lower speed limits). Further, they noted that in general, municipal politicians, officials in the regional development council, and planners share a strong commitment to regional development and economic growth, but often fail to recognize that these goals may be at the expense of a higher rate of road accidents (and injuries).

Societal Lethargy

There is also a degree of lethargy or resistance within the system generally that needs to be overcome when adopting new systems and procedures. Best evidence for adoption of a lower speed limit can be overlooked for reasons of fear or change to the status quo. In an interesting article by Paul Lawrence in the Harvard Business Review Paul Lawrence in the Harvard Business Review as far back as January 1969, he noted that one of the most baffling and recalcitrant problems that business executives face is gaining employee resistance to change. He noted many reasons for this and identified five principle causes for this challenge. These can include the following:

1. Lack of strong leadership and effective collaboration in making the change.
2. Failure to understand that sometimes, resistance may not be technical but social change.

3. Resistance by certain blind spots and attitudes which staff have because of their preoccupation with the technical aspects of new ideas.
4. Management need to take concrete steps to deal constructively with these staff attitudes.
5. Top executives also need to make greater positive efforts and be more effective at meetings of staff where change is being discussed.

He concluded, however, that once people see that the change is of benefit to them, they acquiesce and often champion the change. This would be expected to occur with the introduction of a lower speed limit in local streets once the benefits are realized and accepted.

Added Costs

To reduce speed limits to 30 km/h, there will be some associated costs in signage and possibly a need for some additional road treatments and maintenance to overcome any local hazards. However, the ratio of benefit to cost is likely to be very positive, given the potential benefits in terms of reduced serious injuries and death to Vulnerable Road Users. As noted earlier, severe injuries to this group is on the rise and it is essentially an inner urban problem.

Furthermore, WHO (2004) maintained that reductions in travel speeds, even at lower speeds, can still result in a meaningful reduction in deaths and serious injuries to VRU in the event of a collision with a motor vehicle.

Conclusion

If Vision Zero's new target of a 50% reduction by 2030 is to be achieved, then reducing travel speed to a level within the human biomechanical tolerance needs to be a priority. As noted earlier, the European Commission noted recently that while the number of crashes has become significantly safer for most road users, the same cannot be said for pedestrians, cyclists, and motorcyclists, who are rapidly becoming the most killed and injured group on their roads and especially in urban areas. The TAC (2018) noted that in the last 10 years, more than 400 pedestrians lost their lives on Victorian roads, with one third of the fatalities to people aged 70 years or over. Around three-quarters of these happened in Metropolitan Melbourne. Similar trends have also been reported by Transport for NSW.

There is a burgeoning problem worldwide among Vulnerable Road Users and speeding in urban streets is seen as a major cause of many of these injuries. Lower speed limits in areas where people live offer some promise to help in the push toward Zero. The third Global Ministerial Conference on road safety in Sweden called for countries to *"mandate a maximum road travel speed of 30 km/h in areas where vulnerable road users and vehicles mix in a frequent and planned manner."* This will certainly require some serious attempts to address all road users, and those more vulnerable. Lower speed limits in local streets and municipalities are important measures to help reduce severe injuries to vulnerable road users in residential local streets.

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Urban Road Design and Keeping Down Speed

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Abstract

This chapter examines the opportunities available to a range of professions that directly or indirectly influence urban settings, to achieve Vision Zero safety outcomes. Starting with how we want our urban areas to be, the chapter examines options to eliminate the systemic risk of deaths and serious injuries on urban roads from three separate but related viewpoints; managing the threats to life and health posed by the energy embedded within the road transport system, the potential for crashes to occur and the exposure of those who use the system to severe injury risk from crashes. In urban settings, it is sometimes possible to eliminate or minimize vehicular traffic on selected roads and streets but, in general, it is either impractical or undesirable to do so. By physically separating vehicles from other vehicles, and from highly vulnerable road users, we risk creating the types of cities and towns that do not support our high level aspirations of highly liveable and healthy societies, with sustainable and equitable urban transport systems. Where physical separation is not viable, it becomes necessary to manage transport system energy to ensure risk remains below the levels we set for Vision Zero outcomes – no one being killed or seriously injured. The main focus of this chapter therefore is on the means by which we can manage kinetic energy, primarily through compatible combinations of infrastructure design and speed limit setting, to protect all who use urban roads. Vehicle technology and structural design are important considerations for system performance as a whole.

Keywords

Active transport · Crash types · Cyclists · Infrastructure · Injury risk · Kinetic energy · Pedestrians · Roundabouts · Safe System · Speed limit · Sustainable Development Goals (or UN SDGs) · Systemic risks · Traffic signals · Urban areas · Vision Zero

Introduction

While references to significant publications are provided at selected places throughout this chapter, these references should not be regarded as providing comprehensive coverage of the literature. Rather, these references should be viewed as sources for further reading, which will often lead to more comprehensive coverage of publications in the field of relevance.

The starting point for considering how to achieve Vision Zero conditions in urban areas is to contemplate what kinds of cities and towns we want for our future, and for the futures of young and coming generations.

Much of what defines our future aspirations is captured in the United Nations Sustainable Development Goals (reference: https://www.globalgoals.org/). "In 2015, world leaders agreed to 17 goals for a better world by 2030. These goals have the power to end poverty, fight inequality and stop climate change. Guided by

Fig. 1 Representation of the global goals for sustainable development

the goals, it is now up to all of us, governments, businesses, civil society and the general public to work together to build a better future for everyone."

Of the 17 goals depicted in Fig. 1, the following are most directly relevant to traffic safety and to Vision Zero:

Goal 3: Good health and well-being
Goal 11: Sustainable cities and communities
Goal 13: Climate actions

If we think about the types of cities and towns that we want for the future, liveability, equality, personal security, sustainability, and environmental-responsibility are high priorities. They align with and promote healthy living, free of avoidable threats to life and health. Creating cities and towns that do not tolerate today's ongoing loss of life and long-term health, while contributing to sustainable, liveable, and economically prosperous urban areas presents a challenge for present-day urban planners and designers, and their counterparts in transport planning and design.

Regarding relationships between population health and well-being, and the transport system, it is well-established (e.g., Mueller et al. 2015; World Health Organization 2013b, 2018; Hammer et al. 2014; Tranter 2010; Catford 2003) that:

- Walking and cycling, known as the active forms of transport, promote both physical and mental well-being.
- Traffic noise diminishes general health, causes loss of hearing, and interferes with the abilities of students to learn.

- Road transport is a source of harmful emissions that contribute to respiratory illness, global warming, and, ultimately, climate change.
- Traffic can restrict people, especially those with mobility impairments and other health issues, in their abilities to interact fully with society and local communities. Social isolation and diminished mental health often result.

Within this broad context, consideration is now given to how an urban road transport system can be designed and operated to be free of road deaths and severe injury, while supporting the higher-order societal goals of achieving sustainable, secure, healthy, liveable, equitable, and environmentally responsible cities and towns.

Eliminating Severe Road Trauma in Cities and Towns

This section addresses the challenge of defining what is required under the Vision Zero goal of eliminating deaths and serious injuries in traffic. It is acknowledged that an agenda of eliminating the risks of severe road trauma is not of high priority among all individuals and stakeholders. However, governments are in unique and privileged positions of having a clear moral responsibility to act in the best interests of society, especially when the individuals comprising society may not be fully informed and/or intuitively motivated to act for the greater good. That is, action by governments is needed, above and beyond what individuals can achieve operating independently, and with limited information and understanding of the systemic nature of our road safety problems and the potential for lasting solutions.

The Safe System

In the early 2000s, the Safe System strategic approach to preventing deaths and severe injury on roads was formulated. The Safe System is regarded as international best practice by many countries, including the Netherlands and Sweden, both of which have consistently led the world in reducing and sustaining reductions in death and serious injury. Global organizations such as the United Nations, the World Health Organisation, the European Union, the European Transport Safety Council, and the Organisation for Economic Co-operation and Development (OECD) also strongly endorse the Safe System approach. The Safe System has been interpreted by individual jurisdictions with varying emphasis but, in essence, it differs from historical approaches to road safety in the following respects:

- It strives to eliminate deaths and serious injuries, rather than simply to reduce them. That is, the Safe System aspires to eliminate severe harm.
- It is accepted that human error cannot be completely eliminated and, therefore, crashes will continue to occur.

- The kinetic energy involved in crashes must be managed more effectively to ensure that the energy levels experienced during a crash do not exceed the human threshold for severe injury or death.
- The road designer and system operator must design and operate the road transport system to accommodate human error in all foreseeable crash types. This professional duty of care builds on the assumption that road users will comply with key rules, such as not speeding, wearing seat belts/restraints and helmets, as applicable, and not driving while impaired by alcohol, drugs, fatigue, or distraction. Where adequate compliance is not being achieved, the designer must take further steps to safely accommodate foreseeable human error.
- There are five pillars defining the Safe System:
  – Safe Roads and Roadsides
  – Safe Vehicles
  – Safe Humans
  – Safe Speeds
  – Post-crash response and care

Road and roadside design must be undertaken as part of a total system, in which vehicle and human capabilities, and vehicle travel speeds interact with the physical environment in a way that avoids severe harm to system users. While a vital element of the Safe System, the post-crash response and care pillar is not covered in this chapter.

Systemic Risk vs. Crash History

World-leading countries are in a state of transition from "chasing fatal and serious injury crashes" around the network to addressing systemic risk. Chasing crashes has been a partially successful approach, at least as far back as the 1970s (i.e., accident black spot programs) but once the locations with clear and reliable high crash concentrations have been identified and treated, identifying high-risk locations and road sections/segments, using historical crash records, becomes less reliable. Instead, it has become essential to focus on systemic risk.

In practical terms, focusing on systemic risk means addressing foreseeable risks in all parts of the system, rather than the isolated treatment of risks that have eventually been revealed through a recent history of crashes. When moving from being reactive to being proactive to safety problems, the emphasis naturally shifts to the prevention of severe harm, drawing on a knowledge of, and insights into, the circumstances that elevate crash risk, but more importantly, the risk of severe injury.

Traditionally, a history of multiple crashes has been required at a location or over a short section of road to give confidence to traffic authorities that there is actually a problem. However, the precise locations of past crashes are not reliable indicators of the locations of future crashes. By definition, systemic risk involves a recurring pattern of crashes with like-characteristics that occur in foreseeable circumstances, rather than necessarily at predictable locations. Spatial mapping of historical crash locations reveals that crashes are highly dispersed, with only minimal spatial clustering evident.

Much care has been exercised globally in writing and refining legislation to make it legally clear what road users must and must not do; however, this is not fully effective in achieving perfectly performing humans on our roads. Focusing on systemic risk makes it clear that design philosophies based on geometric parameters alone are insufficient to prevent severe road trauma. When it is acknowledged that humans are imperfect and that the loss of life or long-term health is an unacceptable consequence of everyday errors, new opportunities based on vehicle kinematics and kinetic energy management begin to reveal themselves. These new opportunities can progressively be integrated into existing design philosophies to ensure the process of building unsafe infrastructure can be disrupted, thereby bringing an end to the need to retro-fit safety, at high cost to life, health, and public finances, in the years ahead.

In urban areas, there are several forms of systemic risk to road users (an example from Australasia is included in Turner et al. 2016). While the relative frequency of each form of risk is dependent on local conditions, such as traffic volumes, transport mode profiles, vehicle fleet characteristics, speed environments, population age (and health) profiles, and the form of physical infrastructure, the main systemic crash types can be summarized as follows.

Vehicle to Vehicle Collisions at Intersections

Most commonly, these involve:

- Side-impact crashes
- Turn-against oncoming traffic crashes

Pedestrian Collisions

These are usually more severe and involve pedestrians being struck while negotiating intersections or crossing roads between intersections. Also of concern is the problem of pedestrians suffering injuries, even death, without the involvement of a vehicle. Pedestrian falls in public spaces are common and often go unreported in the official records of traffic collisions. However, hospital and other medical records have shown that the problem can be large, severe, and costly. Older people and people with mobility limitations are at particular risk, especially where footpaths and roadways act as tripping hazards and are not well-maintained (e.g., ITF 2011; World Health Organization 2013a). While not causing immediate death, falls among older pedestrians may result in bone fractures, which can be a catalyst for serious health problems, eventually leading to death, sometimes beyond the standard period for such events to be recorded as traffic-related fatalities.

Cyclist and Motorcyclist Collisions

It is common for motorists to fail to give way to cyclists and motorcyclists at intersections, especially motorists who are turning across the path of riders. Cyclists and motorcyclists can also be involved in rear-end, lane-changing and side-swipe crashes, where all road users are generally heading in the same direction.

As noted above for pedestrians, single-cyclists and single-motorcyclists falling from their two-wheelers is more common than indicated by official traffic crash records. Such events may be found in hospital and other medical records, or go unreported and, therefore, overlooked as a problem. Poorly maintained surfaces, which may include loose material on roads and paths, contribute to risks for the riders of two-wheelers (Dozza and Werneke 2014). The Swedish Transport Administration promotes good maintenance of cycle (and pedestrian) paths by road operators to reduce cyclist injuries, using its Management by Objectives program to drive the Vision Zero agenda for cyclists (Trafikverket 2019). The presence of poor surfaces, in combination with directional changes, for example, around curves or distinct turns, causes instability for two-wheelers. The presence of hard surfaces and sharp or rigid structures nearby (e.g., trees, rigid poles, sign posts and guardrails) can increase the severity of subsequent falls involving these inherently vulnerable road users.

Single-Vehicle Crashes Within the Roadside

Crashes involving a single-vehicle are common in both urban and rural settings, even though speeds tend to be lower in cities and towns. When a driver or rider leaves the road in an urban setting, there is considerable potential for a collision with a roadside tree or service/utility pole. Such impacts typically produce severe injuries, even at legal speeds in modern vehicles, largely because of the tendency for narrow, rigid objects (trees and poles) to intrude into the passenger compartments of the striking vehicle.

Rear-End Collisions at and Between Intersections

Because of the greater tendency for interrupted flow of vehicles along busy urban roads, there is an increased risk of rear-end collisions. Often, these types of crash are related to the presence of intersections, especially where traffic signals operate. Stopping motorists from potentially high speeds, in response to a red signal every 1–2 min, establishes conditions for motorists to collide with the rear of vehicles they are following.

The Need for Innovation

These key systemic crash types may vary in proportionate terms between cities and towns but, when viewed over an extended period, remain the most prevalent sources of severe trauma. The preponderance of systemic crash types will change little while the design and operational practices that created them continue to be widely used. The following quote, attributed to Albert Einstein, underscores this important point: “We can’t solve problems using the same kind of thinking we used when we created them.” Without innovation, we will continue to create the same systemic risks of past decades. We must learn from our experiences and strive for continuous improvement. Failing to innovate has high financial and economic consequences, but the real losses are to human life and health, and the traumatic stress exacted on families, friends, and first-responders and medical teams in the post-crash phase.

Eliminating Crash and Injury Risk

A number of conceptual models, aligned with the Safe System, have been developed to represent the management of kinetic energy in various key crash types that too often lead to death and serious injury (Corben et al. 2005; Logan et al. 2019; Turner et al. 2016). Within these models, there are three main options for contributing to the elimination of systemic risk of death or serious injury:

- Reduction in exposure to crash potential
- Reduction in crash likelihood
- Reduction in injury risk, in the event of a crash

Each is now discussed in greater detail.

Exposure to Crash Risk

Exposure to crash risk is measured by the numbers of road users passing through an intersection, along a particular route or through an area or region. The more road users, the more opportunities exist for road crashes to occur. The numbers of opportunities for crashes do not necessarily change in direct proportion to the numbers of road users; interactive effects and the differing nature of road user types that characterize urban areas result in complex relationships. Logically, shifting road users to non-road-based public transport (e.g., trains, air, and ferries) will reduce exposure to crash possibilities compared with road-based modes, such as the use of private car, trucks, cycling, or motorcycling. In fact, the recommendations of the Academic Expert Group (AEG) formed for the Third Global Ministerial Road Safety Conference in Stockholm in February 2020 (Swedish Transport Administration 2019) recommended as follows "In order to achieve sustainability in global safety, health and environment, we recommend that nations and cities use urban and transport planning along with mobility policies to shift travel toward cleaner, safer and affordable modes incorporating higher levels of physical activity such as walking, bicycling and use of public transit."

While substantial mode shift is a vitally important policy option, reducing exposure to such an extent as to eliminate deaths and serious injuries from urban roads is believed unrealistic in the foreseeable future. As the world's populations and urbanization grow (ITF 2016), a high and growing exposure to road crash possibilities is expected into the long-term future, but the adverse effects on safety, sustainability, and liveability can be moderated through policies directed at supporting public transport and the other active modes.

Crash Risk

The traditional focus of last century's approach to road safety has been on preventing crashes, primarily by trying to create the perfectly performing human. This has been, and continues to be, attempted through initiatives such as regulation, education, training, and enforcement. The focus on behavior change has resulted in sizeable reductions in deaths and serious injuries in countries that have lead with these measures over the past 50 or so years, but a large and severe residual problem remains, indicating that a more comprehensive approach is needed. Much of today's problems of deaths and serious injuries on all road classes can be traced to risk-taking behavior, simple human errors, and predictable lapses in road user performance (ITF 2016). This, however, does not mean that the most effective solution continues to require consistently perfect performance.

Roman philosopher Marcus Tullius Cicero is quoted as saying "It is the nature of every person to error, but only the fool perseveres in error" (https://www.brainyquote.com/quotes/marcus_tullius_cicero_156305). Unsurprisingly, the many professional disciplines involved in road safety have been only partially successful in eliminating human error. Indeed, human error is strongly evident in virtually every other aspect of life, including among our most highly skilled and intensively trained sportswomen and men. Even the very best are unable to sustain high performance when competing. Fatigue, stress, overconfidence, anxiety, and misjudgment can cause occasional failures.

When human error occurs in the road transport system, and the impact speeds are beyond the human tolerance to energy exchange in any specific crash type, severe injuries, even death, are likely. Often, legal travel speeds produce impact speeds that exceed the critical values for survivable outcomes. Allowing foreseeable loss of life and health to continue, as a consequence of systemic flaws in design and operation, is in conflict with professional obligations. It is contended that, while crash risk and/or exposure continue to be substantial, all decision-makers and professions must continually strive to eliminate injury risk.

When the means to eliminate human error have been created, today's levels of kinetic energy may become acceptable but, for the coming years (potentially decades), exposure and crash likelihood will remain unacceptably high.

Injury Risk

Vision Zero seeks to address injury risk, given our inability as a profession to reduce today's unacceptably high levels of exposure and crash risk. Addressing injury risk successfully requires the effective management of kinetic energy of individual road users and, hence, of the system as a whole, in order to avoid severe injuries when crashes inevitably occur. More specifically, the kinetic energy of vehicles involved in crashes must be kept below the levels known to threaten the survivability of the most vulnerable road users in any given crash scenario. These levels are referred to here as the Vision Zero boundary conditions and exist for each of the main systemic crash types (ECMT 2006; ITF 2016).

Because speed is the primary determinant of kinetic energy, and vehicle mass of secondary importance, speed management is critical to success. Energy can be managed in two main ways: first by minimizing the amount of energy at impact and, secondly, by managing the transfer and dissipation of energy during impact (Corben 2005).

The primary and most effective means for minimizing kinetic energy at impact is to minimize speed. Because kinetic energy (KE) is proportional to the second power of speed ($KE = \frac{1}{2} mv^2$, where m is the mass of the vehicle and v its velocity), even a small reduction in speed delivers a disproportionately larger reduction in energy. That is, reducing speed by 10% reduces kinetic energy by 19%. Smaller mass vehicles also result in less kinetic energy; however, a 10% reduction in mass leads to a 10% reduction in energy.

Figure 2 shows the relationship between kinetic energy and travel speed, for a vehicle of approximately 1250 kg. The increasing gradient of the kinetic energy curve with increasing speed highlights the second-power relationship between kinetic energy and speed. Compared with a travel speed of 50 km/h, the same vehicle traveling at 60 km/h (20% faster) has 44% more kinetic energy. This disproportionate increase in kinetic energy, which is intrinsic to the movement of all objects on Earth, presents a serious challenge to those responsible for the safe operation of the road transport system.

Reducing vehicle mass, while contributing to a reduction in the threat to life and health of the occupants of a struck vehicle, has other practical effects, including a

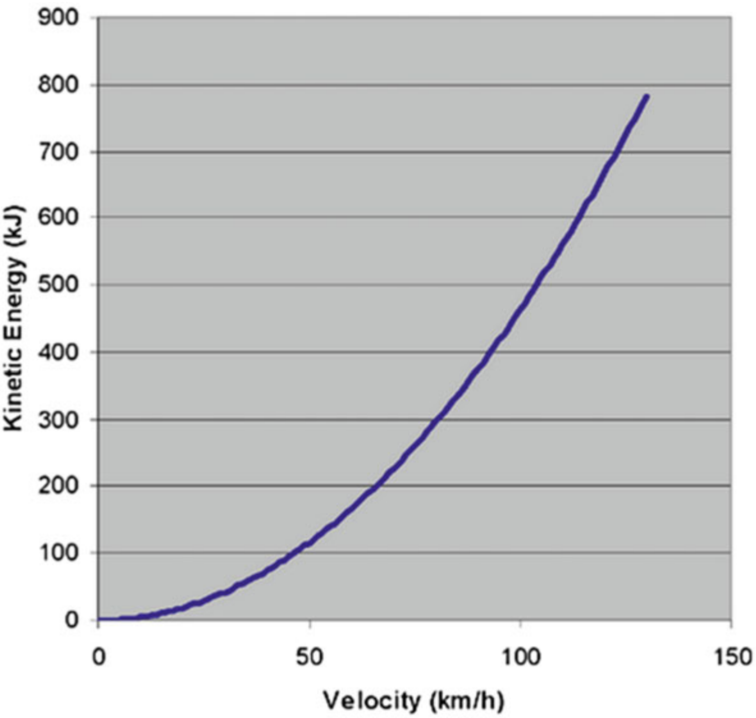

Fig. 2 The relationship between kinetic energy and travel speed

greater threat to the occupants of lower mass vehicles. To avoid this negative safety effect for the occupants of lower mass vehicles, a universal reduction in vehicle mass across the fleet would be needed.

The second option for the safe management of kinetic energy concerns its dissipation during the crash phase. Vehicle design has made a major contribution to the safer dissipation of kinetic energy in a crash, through features such as seat belts and seat belt pre-tensioners, front, side, center and curtain air bags, structural design, especially in the sides and fronts of vehicles, active head restraints, and side- and rear-underrun barriers on trucks (https://www.euroncap.com/en). Overall, these developments have been valuable but are of limited effectiveness when the threshold energy levels common in crashes, even at legal speeds, are exceeded (i.e., the Vision Zero boundary condition speed is violated). Vehicle crashworthiness limitations and aggressivity levels need to be considered, as part of a cohesive system, in determining the Vision Zero boundary conditions for various crash types and road user combinations.

At this point in human existence, road user errors will continue to occur and therefore crashes will also continue. Exposure can be managed to reduce the extent to which system users are exposed to crash potential but because societies need and wish to move about, exposure reduction will offer only a partial solution, even if sizeable shifts from private cars to public transport occur. Managing injury risk through road design is an underdeveloped and underutilized option for eradicating deaths and serious injuries.

Impact Biomechanics and Injury Risk

The biomechanical thresholds for severe injury have been the subject of considerable research over past decades. Despite the continual improvement in research methods, including data collection and crash reconstruction tools, productive debate continues among road safety experts as to the validity of the various risk curves that have been developed for a number of key crash types. Because consensus on scientific method is unlikely to be reached in the near future, practical, maximum tolerable impact speeds that align with the Vision Zero aspiration of eliminating death and severe injury have been defined and adopted for each of a number of systemic crash types. The difficulties inherent in establishing scientifically robust mathematical relationships linking the risks of death or of serious injury with impact speed should not impede efforts to avoid preventable severe injuries and loss of life. Research efforts will likely continue to achieve greater scientific rigor. In the meantime, the general shape of the risk curves can be used to guide the establishment of a boundary condition impact speed for each major crash type, above which the risk of death begins to rise rapidly with increasing impact speed.

These challenges are discussed in the recommendations of the AEG, formed for the Third Global Ministerial Road Safety Conference in Stockholm in February 2020 (Swedish Transport Administration 2019). It is concluded that "... to protect vulnerable road users and achieve sustainability goals addressing livable cities, health and security, we recommend that a maximum road travel speed limit of 30 km/h be mandated in urban areas unless strong evidence exists that higher speeds are safe." This recommendation seeks to present a practical, evidence-based perspective that will deliver benefits broadly across the Sustainable Development Goals (SDGs).

The very nature of seeking to define a single impact speed that represents the biomechanical threshold for each crash type is, in itself, questionable. There are many variables that influence the notion of a threshold impact speed in real-world collisions. These include the age, stature, and health status of pedestrians and other unprotected road users, the mass and frontal design features of the impacting vehicle, and the physical surroundings of the crash site (e.g., into which a pedestrian, cyclist or motorcyclist may land after impact). These variables can lead to many combinations of crash conditions, resulting in a distribution of risks of death (and serious injury) as a function of impact speed. By adopting maximum tolerable impact speeds that align with the best available research, and also with real-world experience, valuable progress can be made. As new, more robust evidence comes to light, the maximum tolerable impact speeds can be adjusted up or down, as appropriate. Experience with emerging vehicle safety technologies, such as Autonomous Emergency braking (AEB) and vehicle connectivity, will provide valuable new opportunities to manage speeds to avoid severe injury across all systemic crash types.

The mathematical definition of risk as a function of impact speed is important for reliably estimating the potential savings in severe trauma. However, accurate mathematical relationships are less important to defining the impact speed that should not be exceeded for each major crash type, if severe injury is to be avoided. A pragmatic approach that reflects real-world experience and outcomes is essential while research continues to inform us.

In the context of the above discussion, the following maximum tolerable impact speeds have been adopted to achieve alignment with Vision Zero principles. Drawing upon the results of past research (Swedish Transport Administration 2019), impact speeds that coincide with the point on the risk curves where the risk of death rises sharply with increasing impact speed have been found to provide valuable practical guidance for road designers and system operators. These speeds each correspond with an approximate 10% likelihood of death in the event of a crash (ITF 2016; SWOV 2006):

- 30 km/h for **impacts with pedestrians, cyclists, and motorcyclists**
- 30 km/h for **side-impacts of passenger cars into narrow rigid objects** such as roadside trees and utility poles
- 50 km/h for **side-impacts** between passenger cars of similar mass
- 50 km/h for **frontal-impacts into narrow rigid objects** such as roadside trees and utility poles
- 70 km/h for **head-on impacts** between passenger cars of similar mass – the corresponding threshold impact speed is even lower for narrow offset head-on crashes

These maximum tolerable impacts speeds will be much lower if a criterion of avoiding serious injuries is strictly applied, or where one or more of the impacting vehicles is large, such as a truck, bus, or tram, or when older road users are involved (e.g., 65 years or older).

The Relationship Between Impact Speed and Travel Speed

The relationship between impact speed and travel speed is not always clear; however, it is known that in a substantial number of road deaths and serious injuries, no braking by the driver of the impacting vehicle took place (e.g., Anderson et al. 1997; Kusano and Gabler 2011). This means that, often, the travel speed becomes the impact speed.

Today's five-star vehicles are equipped with technology capable of detecting a potential crash and, by braking automatically, sooner than is typically possible by a human, either avoiding the impact entirely or shedding speed prior to impact – that is, reducing the speed at impact, and hence the risk of death or severe injury.

It has been established that impacts with pedestrians of 30 km/h can produce serious injuries and, in some circumstances, death. Some researchers (e.g., Ashton 1980; Anderson et al. 1997 and Ministry of Transport and Communications 1997) have concluded that at 30 km/h, approximately one in ten pedestrians will die if struck by a vehicle. Other researchers (e.g., Rosén and Sander 2009; Rosén et al. 2011; Davis 2001) have found that higher impact speeds correspond with an approximate 10% risk of death to the struck pedestrian. As noted earlier, this lack of consensus has led to the adoption of a Safe System boundary condition speed for pedestrians of 30 km/h, in the knowledge that an impact at this speed causes unacceptable outcomes for the individual and for society, irrespective of the accuracy of the alternative risk curves describing the pedestrian-vehicle conflict.

To avoid impacts causing severe injury or death to a pedestrian (or other unprotected road user), it is proposed that vehicle travel speeds be limited to 30 km/h, or less, and for vehicle technologies to reduce travel speeds by around 20 km/h when a collision occurs. Technologies such as AEB are capable of detecting pedestrians on a collision trajectory and automatically braking the vehicle earlier than is possible by a typical driver. The resultant shedding of vehicle speed before impact dramatically alters injury risk.

Autonomous Emergency Braking (AEB)

This section examines the role of AEB (https://www.euroncap.com/en/vehicle-safety/the-rewards-explained/autonomous-emergency-braking/) in preventing severe trauma to pedestrians, by comparing vehicle performance with and without AEB. While the focus is on pedestrians, largely because of their high prevalence in urban areas, the same or significant benefits can be expected for other urban road users.

For a typical vehicle, not fitted with AEB, traveling at 30 km/h and being driven by a person with a 1.3 s perception-reaction time, the vehicle's stopping distance will be around 16 m, should the driver need to brake to avoid a pedestrian, or other road user, on a conflicting path ahead. The stopping distance trajectory is calculated from the following basic equation of kinematics, found in textbooks on classical mechanics:

$$v^2 = u^2 + 2as,$$

where:

v = the final speed of the vehicle
u = the initial speed of the vehicle
a = the acceleration of the vehicle (equal to μg, where μ is the coefficient of friction between the tire and the road surface, and g the gravitational constant (9.8 m/s^2))
s = the distance traveled at any point along its trajectory

Stopping distance profiles for an average passenger vehicle are shown in Fig. 3, for a range of driver perception-reaction times of 0.65, 1.30, 1.50, 1.70, 1.90, and 2.10 s. These estimates assume a coefficient of friction of 0.7, which is reasonably typical for urban roads, though will vary considerably across the globe, especially for countries with poorly maintained or unsealed road surfaces. For roads with lower values of the coefficient of friction, the risks of severe injury to pedestrians and to other unprotected road users will be even greater than described in this comparison.

For the pedestrian who is located just 10 m ahead of the approaching vehicle when the driver perceives the need to brake, the impact speed without AEB will be around

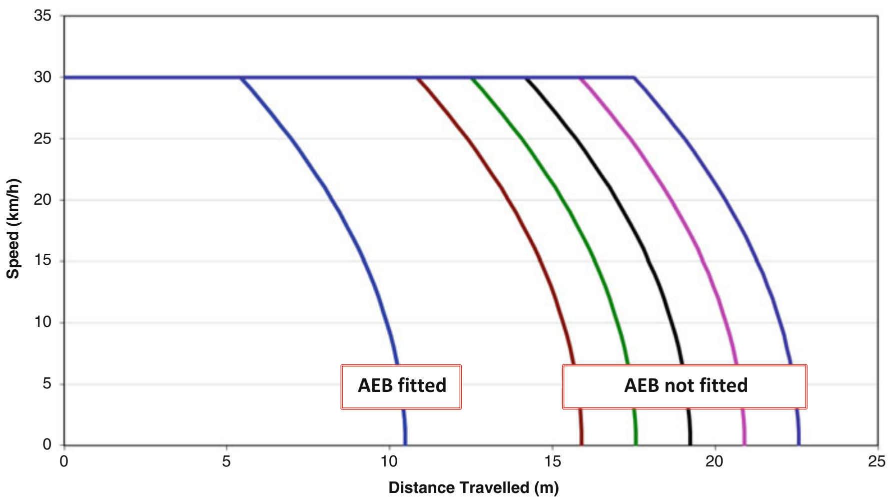

Fig. 3 Stopping distance profiles for an average passenger vehicle, for perception reaction times of 0.65 (AEB fitted), 1.30, 1.50, 1.70, 1.90, and 2.10 s (AEB not fitted). Note: assumed value of coefficient of friction is 0.7

30 km/h. This is because the vehicle travels about 11 m before the driver is able to initiate braking. If we are to design according to Vision Zero principles and, therefore, to virtually eliminate the risk of death to an unprotected road user, in this case a pedestrian, impacts at 30 km/h are unacceptable and much lower speeds at impact are required.

Under the same scenario described above, a vehicle fitted with AEB will be capable of braking earlier than is possible according to an average driver's "perception-reaction time." If the time for an average driver to react can be halved (i.e., 0.65 s for AEB c.f. 1.30 s for the driver), the impact speed would reduce to around 10 km/h. At this vastly reduced impact speed, the kinetic energy of the vehicle at impact would be almost 90% lower than at 30 km/h. The risk of a serious injury to a pedestrian would rapidly approach zero, other than for older/frail pedestrians who need only fall to sustain a potentially life-threatening injury. Present-day AEB systems are activated when the driver has failed to brake sufficiently early to avoid a collision. Should a pedestrian step into the path of an approaching vehicle equipped with AEB, at a distance greater than the vehicle braking distance, it should be possible to avoid an impact provided the pedestrian is detected immediately and that braking commences instantaneously. If, however, the pedestrian steps into the path of an approaching vehicle equipped with AEB, within the vehicle's minimum braking distance, there will be a collision (assuming that the pedestrian is unable to clear the path of the vehicle before it arrives). Under this scenario, the impact speed will depend on the distance of the pedestrian from the vehicle when the pedestrian is detected by the AEB system, which has been designed to initiate maximum braking much more quickly than a human driver. Therefore, for many pedestrian crash scenarios, impact speeds will clearly be within the range required to transform the risk profiles faced by pedestrians and other unprotected road users. Where AEB results in impact speed reductions of 15–20 km/h from 30 km/h, as a result of halving the typical time required to commence braking, risks will align with the Vision Zero aspiration.

While this comparison shows great promise in dramatically reducing impact speeds and hence the levels of kinetic energy experienced by struck pedestrians, its success relies on drivers being compliant with the 30 km/h speed limit. Geo-fencing is a technology that limits vehicle speeds to the speed limit through which the vehicle is passing, or potentially lower if desired. Geo-fencing technology utilizes a vehicle's GPS-based location co-ordinates to determine the applicable speed limit which, to meet Vision Zero principles, should be set to accommodate the significant foreseeable crash types. For densely populated cities and towns, Geo-fencing can be deployed to require drivers to stay at or below the threshold speed deemed appropriate to the systemic risk profile, in this case, 30 km/h to protect pedestrians, cyclists, motorcyclists, and users of personal mobility devices, such as e-scooters, e-skateboards, mobility scooters, and the like.

As a further "line of defense" against severe injury to unprotected road users, the frontal design of vehicles plays an increasingly valuable part. Vehicle frontal design continues to evolve to allow impact energy to be dissipated more effectively by the vehicle structure, so that less of the kinetic energy at impact is shared with the struck pedestrian or other unprotected road user.

The combination of:

- 30 km/h speed limits
- AEB technology with shortened reaction times (around, say, 0.5 s)
- Geo-fencing technology to support driver compliance with 30 km/h speed limits in high risk areas
- Good energy absorbing properties of vehicle fronts
- Has the potential to dramatically reduce risk profiles for the most vulnerable of road users commonly using urban roads and streets

An example of pedestrian passive safety protection devices under development is shown in Fig. 4 (https://www.autoliv.com/products/passive-safety/pedestrian-protection). They comprise:

- Pedestrian Protection Airbag to mitigate head impact to hard structures such as the A-pillars and windscreen frame
- Active Hood Lifters to mitigate head impact with structures beneath the hood, such as the vehicle's engine, suspension tower, and battery

In summary, vehicle technology and structural design, in combination with 30 km/h urban speed limits where pedestrians are prevalent, supported by

Fig. 4 Example of pedestrian passive safety protection devices (https://www.autoliv.com/products/passive-safety/pedestrian-protection)

technology and infrastructure to achieve high levels of compliance with speed limits, indicate that “Vision Zero” is feasible in the future for unprotected road users in urban areas. Automotive technology manufacturers are, today, developing and testing external airbags and bonnets that lift to absorb the kinetic energy in a collision with an unprotected road user.

However, the safety benefits derived from vehicle technology and structural design will be relatively slow to penetrate jurisdiction vehicle fleets, even in the most advanced nations, where fleets typically require 20–30 years to be largely replaced. Therefore, in the intervening years, the achievement of low-risk vehicle speeds, through appropriate speed limit setting practices and supportive infrastructure design, remains critical to protecting citizens who use urban roads and streets. To give credence to the potential of creating low risk cities and towns for unprotected road users, the Norwegian capital of Oslo reported a fatality-free year in 2019 for pedestrians and cyclists (and other active travellers), and just one fatality to a vehicle occupant for the entire year (https://www.smh.com.au/national/nsw/oslo-cut-road-deaths-to-one-in-2019-can-sydney-do-the-same-20200111-p53qmz.html).

Vision Zero Design and Operation for Urban Roads and Streets

Safety and Environment

In urban areas, there are multiple modes of travel, ranging typically from pedestrians, cyclists, scooter-riders, and motorcyclists, through to passenger cars, trams, buses, and trucks. Electric personal mobility devices, sometimes referred to a micro-mobility devices, for example, e-scooters, e-skateboards, and e-bikes, are emerging rapidly in some parts of the world, presenting challenges for regulators, road designers, and system operators to integrate these relatively new devices safely and functionally into existing systems. In the various and changing settings that characterize urban areas, it is important to be able to assign different priorities to the movement of individual modes in order to create efficient, liveable, and sustainable cities and towns. In this context, it is contended that two ethical imperatives should apply:

- All road user groups, whether assigned higher priority or not, must not only *feel* safe but also *be* safe.
- Future changes to the road transport system should not detrimentally affect population health or the environment and, ideally, should reduce traffic-related impacts, such as noise and emissions. Furthermore, existing levels of social inequity, resulting from the way in which the road transport system operates, should not be worsened and, wherever possible, should be improved.

In the case of safety, designing and operating to assure the safety of vehicle occupants will not necessarily address safety for unprotected road users, namely, pedestrians, cyclists, motorcyclists, or the users of the variety of innovative personal mobility devices on urban streets. The riders of e-skateboards, e-scooters, e-bikes, and scooters for the mobility-impaired are all effectively unprotected in traffic and share similar injury risks to pedestrians. However, by designing to ensure the safety of society's most vulnerable road users, namely, children and older pedestrians, vehicle occupants and other unprotected road users are also naturally accommodated. Thus, under Vision Zero, designing for pedestrians and cyclists becomes the ethical and scientific benchmark for urban areas. That is, assuring the safety of unprotected road users should be the default position for cities and towns. This means that travel speeds higher than the biomechanical tolerance level of humans should only be possible where truly effective separation has been provided.

Separation Versus Managing Kinetic Energy

In cities and towns, effective separation can take the forms of overpasses, bridges, tunnels, elevated roads and the like; however, while these types of infrastructure have a place in modern cities, they are typically very costly and sometimes not in keeping with the aims of good place-making. A common example in some parts of the world is shown in Fig. 5.

For pedestrians and cyclists, overpasses and tunnels may also be inconvenient to use, often requiring substantial detours and/or changes in levels, which can be difficult for people with health or mobility concerns. While it is highly desirable to design these structures to include features that prevent pedestrians or cyclists from interacting with high-speed traffic at street level, this can be difficult to achieve in practice. If it is found that pedestrians and/or cyclists continue to mix with vehicles traveling at high speeds, further steps must be taken to assure effective separation or to manage speeds to below the boundary conditions described above.

Fig. 5 Pedestrian overpass of a high-volume, high-speed urban road (Melbourne, Australia)

Other commonly used devices (e.g., traffic signals, and pedestrian and cyclist crossings) are often described as providing separation, albeit time-based separation. Regrettably, experience has shown that separation is only partially effective, despite the existence of comprehensive, detailed regulations specifying how traffic signals and other traffic control devices are to be used. Too many drivers, pedestrians, cyclists, and other road users fail to comply fully with red traffic lights, flashing lights, zebra crossings, and an assortment of other devices designed for full compliance. When such system failures occur, legal travel speeds in many urban areas produce collisions far outside the Vision Zero boundary conditions for unprotected road users, and often for vehicle occupants as well. Traffic control devices, as used in many countries today, fail to accommodate the requirements of effective energy management when the inevitable human error occurs.

The example shown in Fig. 6 illustrates how speed platforms can be used to achieve reduced risk where pedestrians cross busy urban roads.

Effective physical separation is needed, otherwise speeds must be managed to ensure foreseeable impacts do not exceed the boundary condition for the main systemic crash types. Designing expressly for speeds within the relevant Vision Zero boundary condition is needed to prevent serious harm.

Fig. 6 Speed platforms in advance of pedestrian crosswalks along busy urban roads (Dubai, UAE)

The Practical Application of Kinetic Energy Management Principles

Unprotected Road Users

Pedestrian Collisions

Broadly speaking, pedestrian collisions can be categorized as occurring at intersections or between intersections. Because the previous section addresses pedestrian risk at intersections, this section focuses on risk along roads and streets between intersections.

Exposure

In keeping with the Global Goals for Sustainable Development, in particular:

Goal 3: Good health and well-being
Goal 11: Sustainable cities and communities

the opportunities available through exposure modification to reduce deaths and serious injuries to pedestrians are limited by the need to encourage the active modes of travel, especially walking, cycling, and public transport use. More walking, cycling, and public transport use helps to create healthy, sustainable cities and towns. While it is undesirable to limit pedestrian exposure for these reasons, there may be opportunities to restrict pedestrian access to roads and streets where walking is high-risk or otherwise undesirable.

Limiting exposure to crashes by limiting walking is generally undesirable; however, the exposure of pedestrians to crash opportunities can be substantially reduced by limiting vehicle access to busy pedestrian streets and areas. Options could include preventing vehicle access entirely or limiting access to low risk times of day and days of week. Pedestrian malls and car-free streets, sometimes operated with time-based restrictions, are increasingly common examples of exposure reduction measures that help to assure the safety of unprotected road users in cities and towns. Figure 7 illustrates the opportunities that are presented to enhance urban settings where streets can be made car-free.

Restricting vehicle access is often not a viable option and therefore other options must be considered.

Crash Likelihood and Injury Risk

Given the limited opportunities to protect pedestrians through exposure modification, other possibilities will often be necessary to support the safety of pedestrians. The combination of reducing crash likelihood and injury risk offers considerable scope.

A common circumstance in which pedestrians are injured, even killed, is when they are attempting to cross from one side of a road to the other, without the assistance of a traffic control device. In this everyday situation, pedestrians are required to choose a safe gap in traffic, a task that may sound simple when expressed in a traffic regulation but, in practice, can be extremely challenging, especially when

Fig. 7 Opportunities to enhance liveability in car-free streets (Stockholm, Sweden)

traffic speeds are high. The main factors that contribute to crash risk include (Corben et al. 2008; Walk This Way 2012):

- the speed of traffic
- the width and number of traffic lanes to be crossed
- the number of directions of traffic to be negotiated
- the volume of motorized traffic
- the capabilities of the pedestrian to make good decisions and execute their decisions successfully, for example, the experience and maturity, physical agility, and judgment of the pedestrian making the crossing

Sometimes, though not normally, pedestrians may be provided with traffic control assistance, such as a zebra crossing, traffic signals, school crossings, or similar devices. While the majority of drivers and pedestrians comply, full compliance is not assured. Drivers are known to run red lights, deliberately or unintentionally, typically at speeds that will result in severe injury or death to the pedestrian, should a crash occur. Pedestrians, too, will often cross against red signals or at nearby, high-risk locations, rather than wait for the green pedestrian signal (refer to Fig. 8).

There is a long history of the traffic engineering profession attempting to improve compliance, through signage, pavement markings, more conspicuous signals and shorter cycle times. While these efforts are commendable, failure by both drivers and pedestrians to comply fully continues at unacceptable levels, suggesting more effective methods are needed.

Of the above list of main factors contributing to pedestrian crash and injury risk – there are many more – speed plays a vital role. Travel speeds not above 30 km/h are essential to achieving the lowest practical risk levels for several reasons:

Fig. 8 Pedestrian and driver compliance with signals is challenging (Melbourne, Australia)

- In a highly complex traffic setting, as is often encountered in urban areas, drivers and riders are more likely to reach the threshold of their information processing capabilities when traveling at higher speeds. At 30 km/h or lower, decisions can generally be made in a more timely fashion.
- Driver willingness to give way to pedestrians on crossings increases with reductions in travel speed. Thus, the frequency of conflict between motorists, and pedestrians and cyclists, can be reduced further at lower travel speeds compared with legal speeds commonly encountered today (Johansson 2004).
- Vehicle stopping distances are substantially reduced with lower travel speeds (refer to Fig. 3).
- Past research on pedestrian safety (Anderson et al. 1997) shows that in about half of all pedestrian fatalities, no braking occurred and therefore the travel speed is too often the impact speed. This is likely to be true for cyclists as well.
- A review of research on the biomechanical tolerance of humans to various vehicle impact speeds (Logan et al. 2019) shows a rapid rise in the risk of a pedestrian (or cyclist) fatality above an impact speed of around 30 km/h. For serious injury risk, the corresponding threshold impact speed is likely to be much lower. Risk is even more acute when the striking vehicle is a tram/light rail vehicle or other large vehicle and/or when children and older people are involved.
- ITF (2016) also discussed the lack of clarity with research in the field and recommended the adoption of 30 km/h as the target Safe System speed, until

> more robust research comes to light. The ITF report notes that "Whilst there is, and will continue to be, considerable debate on safe impact speeds and the shape of various fatality risk curves, precise definitions are not possible or meaningful in reality. They represent some form of population average over a sizeable number of cases but there is considerable variability in outcomes, and hence risk, among individuals due to uncontrollable factors such as the type and size of the vehicle, the age and health status of the road user, the point of impact, etc. There is a certain randomness about these factors that is often beyond the control of the system designer or operator. Because of this variability in the incidence and circumstances of real world crashes, a conservative position should be adopted concerning risk so as to account for a broad range of population, vehicles and conditions. We must also be cognisant that the use of fatality risk curves, and the tenth percentile value to determine safe impact speeds, is by definition permitting the incidence of some deaths and serious injuries, notwithstanding the commitment to eradicating deaths and serious injuries from road crashes."

In support of the importance of assuring low risk speeds for pedestrians (and other road users), the AEG formed to make recommendations in the context of a Third Ministerial Conference on Road Safety, held in Stockholm in February 2020, recommended as follows (Swedish Transport Administration 2019): "In order to protect vulnerable road users and achieve sustainability goals addressing livable cities, health and security, we recommend that a maximum road travel speed limit of 30 km/h be mandated in urban areas unless strong evidence exists that higher speeds are safe."

Given the need for a pragmatic decision on the boundary condition for pedestrians and cyclists, 30 km/h is regarded as an appropriate, practical threshold, until such time as more reliable estimates emerge. In reality, a lower threshold could legitimately be considered to accommodate the greater vulnerability of older people, young children and people with disabilities, or where the striking vehicles are large and/or have unforgiving frontal designs (e.g., trucks, trams, and utilities fitted with "bull bars").

Powerful opportunities to reduce pedestrian deaths through speed moderation are illustrated in Fig. 9, which shows the long-term trends in pedestrian deaths in the Australian state of Victoria. From an annual average of 146 pedestrian deaths during the 1980s, an unprecedented step-drop in deaths occurred in 1990, following the introduction of a large-scale automated speed enforcement program during 1989. The number of fatalities fell to just 93 in 1990 from 160 in the previous year, and settled below this level over subsequent years. Another large step-drop was experienced in 2002, compared with 2000, when Australia's default urban speed limit was reduced to 50 km/h from 60 km/h and enforcement tolerance levels were reduced in 2002. A number of other measures were also introduced in 2001 and 2002, such as the provision of new speed enforcement technology and random breath-testing (Cameron et al. 2003).

Following each of these step-changes in annual pedestrian fatalities, the long-term trend line has settled at new lower and generally declining levels. This four-

Fig. 9 The long-term trends in pedestrian deaths in Victoria, Australia (1980–2019)

decade history is indicative of the power of lower travel speeds to reduce pedestrian fatality risk. The drop that occurred in 1990 was very likely the result of improved driver and rider compliance with existing speed limits (rather than reductions in speed limits), again underlining the potential power of lower limits to cut unprotected road user deaths when introduced in busy pedestrian settings.

A number of other road safety interventions, not involving speed moderation, were being implemented during the period shown in Fig. 9. However, none is likely to explain the step-drop observed in pedestrian fatalities.

To achieve vehicle speeds not exceeding 30 km/h in densely populated urban areas, greater use of speed-moderating design forms is needed. There is also an ongoing need for design innovation to create a wider range of measures that suit or can be adapted to different urban settings. The evolution of modern and future vehicle technologies is highly likely to interact with safe infrastructure design, which highlights the potential value of road/traffic engineers collaborating with their automotive engineering counterparts to optimize system-based designs for the protection of pedestrians, cyclists, and other unprotected road user groups (Strandroth et al. 2019).

For pedestrians crossing roads and streets between intersections, effective separation, or speed moderation is needed to assure their safe passage. For high-speed and/or high-volume roads, serving an important traffic movement function, separation may be more appropriate than speed moderation. Also, in high-density urban settings, such as shopping centers, public transport interchanges, and major commercial land uses, high investment in separation can be more readily justified. Figure 10 shows how full separation has been achieved in central Stockholm, where rail, shopping, and other commercial activities predominate. The choice will be influenced by the type of urban setting through which a road or street passes. For

Fig. 10 Grade-separation of pedestrians from city center motorized vehicles (Stockholm, Sweden)

roads that serve an important vehicle movement function, a variety of design forms, such as pedestrian bridges or tunnels, elevated roadways or tunnels for vehicles are used to achieve separation (Austroads 2020). Banning pedestrian access to freeways is generally seen as reasonable, but preventing or limiting access across other urban road classes is typically not desirable for cities and towns.

Full separation is often difficult to achieve and can impact unfavorably on the urban surroundings, involves high costs, and offers only a limited number of locations at which pedestrians can cross safely. In particular, pedestrian tunnels create feelings of personal insecurity for pedestrians (and cyclists) who might use them, unless they are designed exceptionally well. Pedestrian bridges linking buildings can prove safe and convenient if located on the pedestrians natural desire line; however, requiring pedestrians to walk long distances and/or undergo significant changes in levels is inconvenient and potentially highly restrictive for people with mobility impairments. Moreover, restricting pedestrian movements to a relatively small number of locations does not support the high-order goals of social equity and of sustainable cities and communities.

Measures that help to achieve travel speeds not exceeding 30 km/h include:

- 30 km/h speed limits (or lower) along busy pedestrian routes or throughout dense urban areas

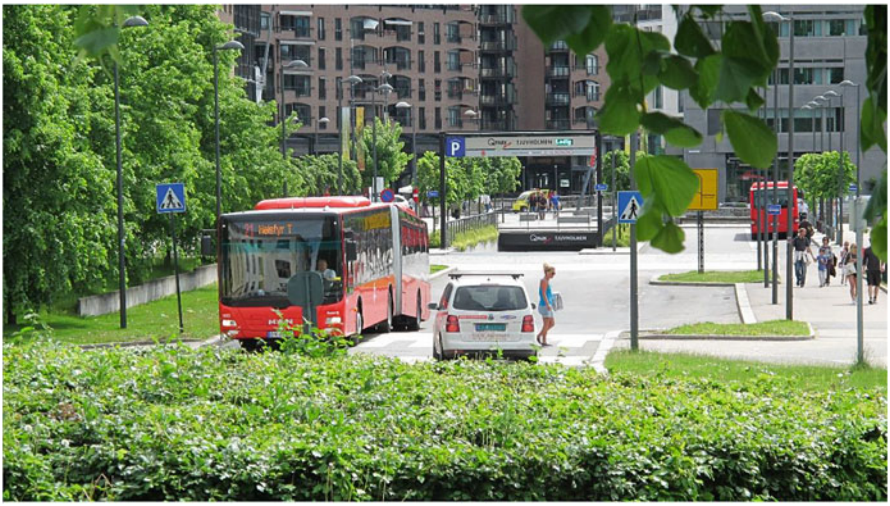

Fig. 11 Pedestrian crossings on speed platforms (Oslo, Norway)

- Pedestrian signals or crossings positioned on speed platforms designed to elicit 30 km/h speeds or lower (refer to Fig. 11)
- Road narrowing that permits only a single lane of traffic at a time
- General traffic-calming along a street to ensure 30 km/h travel speeds
- Plateau intersections separated by distances that achieve travel speeds up to 30 km/h
- Shared spaces requiring speeds not greater than 10 km/h
- Various forms of tactical urbanism, which has been described as introducing low-cost, temporary changes to the built environment, usually in cities, intended to improve local neighborhoods and city gathering places (Pfeifer 2014). Tactical urbanism techniques are being used increasingly in cities and towns, especially in North America, to accelerate the pace of change (refer to Fig. 12).

Cyclist Collisions

Cyclists are among the most vulnerable of road users when involved in a crash. They face similar risks of severe injury as pedestrians when struck by a vehicle but are characterized by differing forms of conflict and levels of exposure to crash potential.

Exposure

There is a wide range of levels of cycling in cities and towns across the world. In car-dominated societies, cycling is at relatively low levels, but in many places these levels are increasing quite rapidly, often in response to concerns about the high costs of car ownership, traffic congestion, climate change, and personal health. As with walking, cycling is a sustainable mode that delivers a wider array of benefits beyond being a convenient and effective mode of transport. Cycling is healthy, does not pollute, and is spatially compact when compared with motorized transport,

Fig. 12 Tactical urbanism (New York, USA)

especially when parking requirements are considered. Cycling can also interface well with public transport, either through the provision of parking at rail and bus stations or by being able to travel on some public transport modes, although these options may often need to be restricted to low patronage times. In essence, cycling has many positive features and the use of bicycles as a meaningful transport mode should be encouraged along suitable urban road classes. Use on freeways and motorways, where the speeds and volumes of motor vehicles are high, will be an obvious exception, unless separated cycling paths can be provided alongside these types of urban corridor. This leaves limited scope to address cyclist safety through exposure reduction, other than along roads that are highly unsuited to this mode.

Crash Likelihood

While the vulnerability to injury in a crash is similar for pedestrians as for cyclists, their interactions with traffic differ considerably. Cyclists share the road with the full range of motor vehicles, from other cyclists and motorcyclists to passenger cars, trams, buses, and trucks. The major conflict types involve drivers failing to give way to cyclists at intersections, commonly leading to side-impact crashes and crashes involving motorists turning across the paths of cyclists riding along the same road or street.

Crash likelihood is affected by factors such as the speeds and speed differentials between vehicles and cyclists on conflicting trajectories, the sightlines between drivers and cyclists, and the natural tendency for drivers not to see riders even though they are in plain view. This effect of "looked but did not see" is recognized as a crash risk factor for motorcyclists and cyclists, alike. It has been hypothesized that this difficulty in perceiving an approaching cyclist (or motorcyclist) is exacerbated by their small physical size relative to other traffic, and the resultant greater difficulty in perceiving and judging their approach speeds. The presence of other vehicles (e.g., queued or moving slowly) can obscure cyclists from the view of surrounding motorists, as can the structure and size of left-turning trucks (right-turning for countries where traffic travels on the right-hand side of the road). A number of countries experience serious crash problems caused by turning truck drivers being unable to see a cyclist approaching from behind and traveling in the same direction as the truck, largely because of the height and physical design of the truck cabin. Very severe injuries, including death, commonly result, even for trucks turning at relatively low speed.

Given the types of factors affecting crash likelihood for cyclists, it is generally preferable to provide physical separation for riders. Separated cycling facilities may lead to a rise in exposure to crash potential, due to increasing numbers of cyclists – a desirable consequence from the perspective of supporting healthy, sustainable transport – with any increase in exposure likely be offset by reduced crash likelihood.

As noted above, a substantial proportion of severe trauma between cyclists and motor vehicles occurs at intersections, often involving turning maneuvers by drivers. While conjecture exists as to whether roundabouts assist cyclists, it is contended that roundabouts offer substantial safety benefits for cyclists because of the natural tendency of roundabouts to reduce vehicle speeds and conflict angles at locations of concentrated conflict, and to also simplify the pattern of conflicts. Further research may be needed to determine the effects of roundabouts on cyclists, in terms of crash likelihood and injury severity risk. In a study undertaken in 2009 (Scully et al. 2009), it was found that motorcyclists experienced the same magnitude of reductions in casualty-producing crashes from roundabout construction, as did vehicle occupants (around 80–85%).

Where physical separation of cyclists from motor vehicles is impractical or undesirable, speed management is required to reduce crash risk and to ensure impact speeds between cyclists and vehicles remain within the Vision Zero boundary condition for severe harm.

Injury Risk

Cyclists share similar risk profiles for severe injury as pedestrians. Though not mandatory in many countries, the wearing of helmets moderates the risk of head injuries sustained by cyclists who fall or are involved in collisions with vehicles (or other road users). Further, riders are generally positioned at greater heights than pedestrians when struck, which may contribute to a larger vertical component in their speeds at impact with the ground. The dynamics of these crashes tend to be complex and difficult to interpret reliably. Suffice to say that cyclists mixing with traffic should not be subjected to vehicle travel speeds greater than 30 km/h. For the same reasons explained for pedestrians, impact speeds of 30 km/h are known to cause severe injury and therefore are unacceptable under a Vision Zero approach to protecting humans in traffic. Vehicle technology, particularly AEB, will prevent crashes or enable impact speeds to be reduced from 30 km/h by around 15–20 km/h, resulting in a substantial reduction in impact speed and therefore the risk of death or severe injury. Geo-fencing and energy-absorbing frontal design of vehicles will make additional valuable contributions to the compliance of drivers with 30 km/h on roads and streets used by cyclists, and to injury severity in the event of a cyclist-involved collision, respectively.

Vehicle Occupants

Intersection Collisions

Intersections concentrate conflict. The more traffic entering, the greater the extent to which vehicle and other road user paths intersect. This leads to more opportunities for crashes. If the speeds of vehicles on conflicting paths are high, then the chances of severe injury, when crashes occur, will also be high.

Exposure

Exposure to potential conflicts is generally growing as populations and road use increase. While crash likelihood can be minimized, it is inevitable that crashes will occur as a result of lapses in human performance or intentional risk-taking. It is therefore necessary to manage the energy transfer between roads users at intersections to avoid exceeding the boundary conditions for the various combinations of road user types that conflict at intersections.

Crash Likelihood

There are large differences in the kinetic energy levels for different forms of intersection design and operation. For example, for an intersection within a 60 km/h speed zone, the kinetic energy levels of entering vehicles will potentially be more than double for conventional traffic signal design or regulatory signing, compared with a well-designed roundabout. This twofold difference has a vast effect on the ability of the designers to keep vehicles separated and, more importantly, to ensure the energy dissipation in any resulting collision will not lead to death of serious injury.

Injury Risk

The boundary condition for side-impacts between passenger vehicles at intersections is 50 km/h, indicating that the risk of death to an occupant of the struck vehicle rises rapidly above this impact speed. For pedestrians and cyclists, the boundary condition is around 30 km/h. As noted earlier, it is not possible or meaningful to set a precise value for the various boundary conditions, as crash circumstances vary by vehicle type and mass, and road user age and health condition, as well as the exact point of impact on the struck vehicle.

A well-designed roundabout constrains vehicle travel speeds to 40 km/h or lower, depending on the local design philosophy of the road authority, and therefore will be successful in reducing both crash likelihood and injury severity, given a crash between conflicting vehicles. However, even for a 40 km/h design speed, pedestrians, cyclists, motorcyclists, and the riders of personal mobility devices will remain exposed to impact speeds beyond their biomechanical tolerances to the impact forces experienced in a crash. This means that, if we are to eliminate deaths and serious injuries, we must design for the most vulnerable of the road users found at urban intersections. These will typically be pedestrians and cyclists, as well as motorcyclists and the riders of various types of personal mobility devices – this group of highly vulnerable road users will now be referred to as unprotected road users.

In many countries today, only a minor proportion of vehicles are capable of detecting unprotected road users on a conflicting path at intersections. However, it is expected the five-star rated vehicle of the future will have this capability as a standard feature. Leading vehicle manufacturers and automotive technology suppliers are optimistic that the next generation of five-star vehicles will be able to avoid many potential collisions with unprotected road users at intersections or shed up to 20 km/h prior to impact, and so turn life-threatening incidents into low severity injury events at worst. However, in the case of older pedestrians, severe injuries occur even at 10 km/h impact speeds. With aging populations, designers and system operators must be mindful of such risks.

We can manage energy more effectively at intersections when we design to keep impact speeds below the boundary condition for unprotected road users. Because travel speeds are quite often the impact speeds in vehicles without automatic braking technology (e.g., Anderson et al. 1997; Kusano and Gabler 2011), speed limits and road design features need to elicit travel speeds not exceeding the respective boundary condition speeds.

Urban roundabouts have proven highly successful in achieving speeds within the boundary conditions for vehicle occupants and for unprotected road users. This is because roundabouts integrate several essential design features that affect crash and injury risk simultaneously:

- **Reduced crash likelihood**, as a result of lower travel speeds and a large reduction in possible conflict points within the intersection – just four main conflict points compared with 32 in a standard four-leg cross road.
- **Reduced injury severity in a crash**, as a result of lower travel speeds and more favorable impact angles – the combination of lower speeds and acute angles markedly diminishes the lateral component of force to the struck vehicle in an impact between vehicles that would otherwise occur at around 90°. The occupants of a struck vehicle are at the greatest risk when the impact angle is 90°, as vehicle structures are able to offer only limited protection in this common scenario. When the impact angle is 30° instead of 90°, the lateral component of both force and impact speed are halved and the effective kinetic energy level reduced to a quarter of the value in a 90° collision. Good geometric design can change fundamentally the physics of crash likelihood and injury risk.

Well-designed roundabouts are an ideal default design form for urban intersections. In their basic form, they can be designed to operate at low risk for vehicle occupants but need explicit attention for unprotected road users. For pedestrians, the integration of pedestrian crossings on speed platforms helps in ensuring the boundary condition speed of 30 km/h is not exceeded. Figure 13 illustrates a number of desirable safety attributes of urban roundabouts.

Fig. 13 Urban local street roundabout with elevated pedestrian crossings (Melbourne, Australia)

Fig. 14 Urban signalized intersection with speed platforms for cyclists and pedestrians (The Netherlands)

For cyclists, it is desirable to provide separation from motorized traffic when more than one circulating lane is required. This can be achieved through the use of off-road cycle paths that enable cyclists to negotiate intersections without the need to share traffic lanes. Instead, cyclists can cross intersecting roads in a similar manner to pedestrians, with the benefit of cyclist crossings on 30 km/h speed platforms. Figure 14 shows a Dutch example of speed platforms at traffic signals to reduce both crash and injury risk to pedestrians and cyclists.

Fig. 15 Semi-urban turbo-roundabout (The Netherlands)

In the Netherlands and some other European countries, turbo-roundabouts have been trialed to address safety issues of this type on multi-lane roundabouts. Both safety and operation have been found to improve, with a 10–15% increase in vehicle throughput at turbo-roundabouts compared with conventionally designed roundabouts. Figure 15 shows a turbo-roundabout in a semi-urban area of The Netherlands.

In summary, for urban intersections to perform according to the Vision Zero aspiration, vertical and/or horizontal deflection would ideally be designed into the intersection layout to achieve travel speeds within the boundary condition for unprotected road users. That is, the basic design elements of horizontal and/or vertical deflection are essential features for safe intersection operation, unless vehicle speeds can otherwise be controlled to low risk levels. Technologies such as Geo-fencing offer this possibility but their widespread use is considered unlikely in the next 10–15 years, and therefore there is an ongoing need for road design and system operation that produce safe travel speeds.

Lane Departure Collisions (Head-On and Single-Vehicle)

It is commonplace for urban roads and streets to be lined with trees, utility poles, lighting poles, and other objects that can present a hazard to a vehicle occupant or rider who leaves the road at speeds outside their respective boundary conditions. The often narrow and rigid nature of trees and poles explains why vehicle occupants suffer severe injury and death in impacts with these objects, even when traveling at legal speeds.

Communities value trees, and other road and street vegetation, because they provide shade and can offer considerable aesthetic and environmental value. Trees make an important contribution to cleaning the atmosphere of air and water-borne pollutants, so common in modern cities, and help to make city streets more walkable.

Utility poles carry electricity to homes, industry, and businesses (and more) and enable modern-day telecommunications services to operate throughout urban areas and beyond. These essential services in modern cities can, in some circumstances, be located underground within road reserves. To date, however, this has proven impractical and/or costly, and seemingly beyond the abilities of utility and telecommunications companies to achieve. While new, safer, and more aesthetic means of delivering these essential urban services to the world's cities and towns should continue to be sought, current conditions are unlikely to change markedly in the short- to medium-term future.

Urban areas are often characterized by the presence of street lighting, mounted on utility poles or columns specifically designed for the purpose. Progress has been made over recent decades with designing frangible/energy absorbing columns to reduce the risk of severe injury to the occupants of vehicles which collide with these frequently encountered hazards. Poles serving a street lighting function are typically found in roadsides and medians, depending on the cross-section of the road, and often within just a few meters of the traffic lanes.

So while trees, utility poles and street lighting represent a substantial source of risk for many road users, they are fundamentally important to today's urban life. This is unlikely to change in the medium-term future.

Exposure

As with other systemic crash types, the loss of life and the incidence of severe injury as a result of collisions with roadside hazards can be reduced by moderating exposure. However, this will make only a limited contribution to eradicating trauma involving lane departure collisions. Finding ways to shift vehicle occupants onto public transport, for example, will reduce exposure to this type of risk. Where practical, encouraging traffic to roads that are inherently less hazardous, in terms of the outcomes of lane departure collisions, will also make a contribution. The degree of success with using exposure reduction methods will be defined by the magnitude of the shift that can be achieved.

Crash Likelihood

There is also a range of measures that have been used with varying degrees of success to reduce the likelihood of crashes involving vehicles leaving their lanes and colliding with roadside hazards or with oncoming traffic. This is a particularly common crash type in rural areas where higher travel speeds, corresponding with disproportionately higher levels of kinetic energy, play a key role in the severity of injury outcomes. Measures that reduce crash likelihood include:

- Reconstruction to create larger radius curves.
- Improvements in the quality of delineation of road and lane alignments, using for example, curve warning and delineation signs, enhanced marking of center, lane

and edge lines (i.e., with audio and/or tactile feedback when a vehicle's tires traverse them).

- The introduction of new, or the widening of existing, clear zones – this measure tends not to reduce the incidence of vehicles leaving their lanes, and may even increase this risk due to the higher travel speeds that can result from wider roadways. Clear zones also reduce the likelihood of an object being present on the trajectory of a vehicle which has entered the roadside.
- The removal of such hazards, especially in the vicinity of sharp curves.
- The use of high-friction surfacing to heighten the chances of vehicles remaining on the road while negotiating curves, especially where there may be unfavorable cross-fall.
- Reduction in speed limits.

The above sample of measures used to reduce crash likelihood are, in themselves, insufficient where travel speeds are above the Vision Zero boundary condition speed for impacts with trees and poles, or for head-on collisions with oncoming vehicles. The boundary condition speed for collisions with trees and poles is around 50 km/h when the impact involves a frontal collision, and around 30 km/h for side-impacts. For head-on collisions, severe injury, even death, may occur at around 70 km/h.

Injury Risk

Crashes involving passenger cars into trees and poles produce severe injury, sometimes death, at impact speeds between 30 and 50 km/h. On this basis, travel speeds above 50 km/h increase the likelihood of severe injuries from crashes above the boundary condition for collisions with narrow, rigid objects. That is, the crashworthiness of modern vehicles does not provide adequate protection to occupants above the boundary condition speeds. As with other systemic crash types, the travel speed is often the impact speed, given that factors such as alcohol, drugs, distraction, and drowsiness are commonly present in lane departure events.

For roads and streets with speed limits above the boundary condition speed for an impact with a tree or rigid pole, it is necessary to provide energy absorbing barriers (or similar systems) to prevent the transfer to vehicle occupants of levels of kinetic energy that exceed human tolerance to severe injury. Modern vehicles have the capability to remain within their lanes, provided the lanes are effectively delineated at all times of day and in all weather conditions. In addition, AEB technology, as described in earlier, will also assist with crash avoidance and injury mitigation in potential collisions with median and roadside hazards.

Unfortunately, only a small proportion of vehicles comprising today's vehicle fleets are fitted with these features. This proportion is likely to vary considerably between high- and low-income countries but will grow significantly over the years ahead, as older vehicles are replaced with new vehicles. This means that for a period of some 20–30 years, a substantial proportion of vehicle occupants will be exposed to unacceptable risks due to roadside hazards when speed limits are set above the boundary condition.

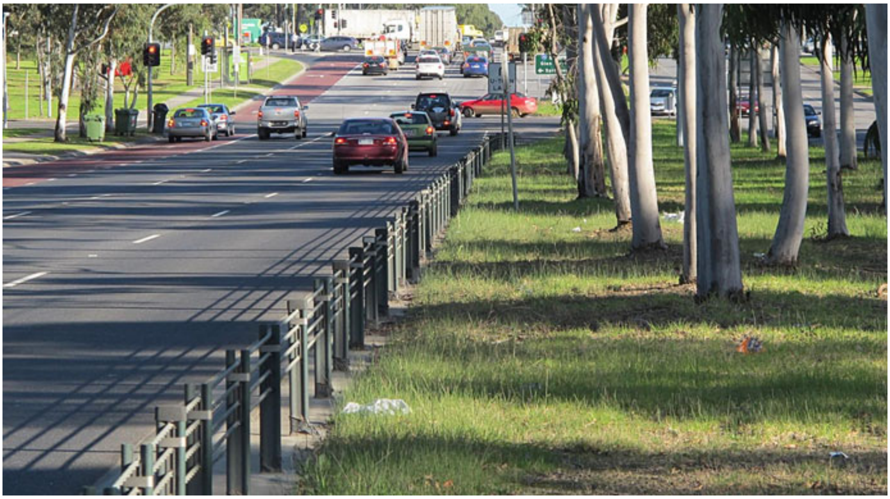

Fig. 16 Continuous flexible barrier systems to manage kinetic energy in lane departure crashes along high-speed, high-movement roads (Melbourne, Australia)

Given that exposure management can exert only a modest (but, nevertheless, worthwhile) effect on the potential for lane departure crashes, and measures that address crash likelihood will offer only limited reductions, a sizeable residual risk remains unaddressed. To tackle this problem in ways that are aligned with Vision Zero principles, either energy absorbing infrastructure is needed on roads with speed limits above 50 km/h, until such time as key vehicle safety technologies have penetrated the vast proportion of vehicle fleets, or speeds must be constrained to 50 km/h or lower. At these speeds, and below, side-impacts with narrow rigid objects, which have a boundary condition speed of around 30 km/h, become less likely. This is largely because, at lower travel speeds, loss of control through loss of surface adhesion or uncontrolled vehicle dynamics is less likely than at higher speeds.

Figure 16 highlights the opportunities along some urban roads, where it is desired to allow high travel speeds, to use flexible barriers to manage the high energy levels of errant vehicles. Without such barriers, much lower speeds are needed to meet the Vision Zero aspiration.

Rear-End Collisions

Rear-end collisions are among the most common crash types, though, on average, they tend to produce less severe injuries than other systemic crash types. Rear-end crashes are more prevalent along busy roads where traffic does not flow freely. Intersections are among the sources of interruption to smooth traffic flows, with traffic signals being a substantial generator of rear-end collisions, both at signal-controlled intersections and also upstream. The onset of a red signal display, typically every 1–2 min, sets up the conditions for rear-end collisions, as drivers traveling at the speed limit are required to respond to the closing yellow/red signals. Some drivers have a natural propensity to try to get through an intersection when presented with a yellow/red signal, while others endeavor to stop if they can do so safely. When a driver with the latter tendency is being followed in the same lane by a driver with the former tendency, the potential for read-end impacts is heightened. Heavy vehicles have also been found to be more highly represented in rear-end collisions at traffic signals than traffic generally, which can lead to more severe outcomes because of incompatible vehicle masses, structures, and/or geometry. Many other factors and incidents can lead to rear-end collisions along roads and streets, especially in urban areas where roadside activity tends to be much higher than in rural settings. In fact, in large cities, where intense interactions occur between the movement of traffic and the human activities underway in the places through which the traffic passes, there is an inherent potential for rear-end collisions.

Exposure

The reduction in exposure is a universally applicable approach, though far from sufficient in itself. Exposure reduction can include network-level shifts from the use of motor vehicles to public transport and/or rail-based freight movement. Other options that encourage use of roads less prone to rear-end collisions can also be employed; however, these approaches are unlikely to make large-scale gains in safety, other than if implemented to a significant degree, with a view to lasting change. Where possible and well-aligned with the SDGs, exposure reduction opportunities should always be considered and assessed as a means of supporting active travel and the more sustainable modes.

Crash Likelihood

To date, the elimination of rear-end crash risk has proven elusive for the road safety, policing, and road design and traffic engineering professions. This is because crashes happen as a result of speed differentials between vehicles in the same traffic stream, and drivers and riders being unable to respond in a consistent and timely way to prevent collisions with slowing or stationary vehicles ahead. Excessive speed differentials, together with inherent limitations on human perception-reaction times, the tendency to follow too closely, to be distracted or inattentive, to speed or to be tired or otherwise impaired while driving, all contribute to the risks of rear-end collisions. It has not proven possible to modify human performance in traffic to eliminate these risk factors and there is little potential to do so without the aid of modern vehicle technology. Features such as active cruise control (ACC), AEB, Intelligent Speed Assist (ISA), and Geo-fencing offer considerable potential but, today, too few vehicles are fitted with these technologies. This will, of course, change gradually over the years ahead as more and more new car sales will include vehicles with these features fitted as standard.

Injury Risk

On the assumption that rear-end crashes will continue to happen on a substantial scale in the coming 20 or more years, new measures will be required to achieve the very low risks expected from successful deployment of Vision Zero thinking, while modern vehicles with AEB and ACC penetrate urban vehicle fleets. Indicative speed differentials of around 40 km/h (Trafikverket 2014) should not be exceeded if the Vision Zero boundary condition for rear-end collisions is to be met. An even lower speed differential will be necessary to remain within the respective risk levels for avoiding fatal or serious injuries when, for example, trucks, buses, or trams are involved in rear-end crashes with smaller, passenger vehicles.

Given that rear-end crashes often involve the struck (front) vehicle being stationary, and no braking by the driver of the striking vehicle, travel speeds of 40 km/h cannot be exceeded to align with Vision Zero principles. To ensure a high level of compliance with 40 km/h speed limits on urban roads, vehicle technologies such as Geo-fencing and ISA will be needed. These technologies may obviate the long-term need for the deployment of traditional police speed enforcement resources and possibly automated speed enforcement methods as well.

The high degree of incompatibility that exists between the masses and structures of passenger vehicles and trucks illustrates the elevated risk of severe outcomes when these two vehicle types collide in a rear-end configuration. Trucks without under-run protection at the rear can cause especially severe injuries to the occupants of passenger vehicles which strike the truck, even at relatively low impact speeds. Similarly, the front of trucks, trams, and buses often have aggressive structures and geometric features that do not interface well with the structures of passenger vehicles, leading to severe injuries to passenger vehicle occupants.

In the interim, until a high degree of saturation has occurred in urban vehicle fleets with technologies such as ACC, AEB, ISA, and Geo-fencing, urban speed limits of not greater than 40 km/h will be needed to avoid fatalities and severe injuries caused by rear-end crashes.

Barriers to Implementing Safe Urban Speeds

This chapter underlines the vital role of effective management of vehicle speeds, especially in urban settings, in protecting the lives and well-being of citizens. There is a history of resistance to lowering speed limits from some interest groups and individuals in society. Often, the concern expressed is about the impacts of lower speed limits on travel times, with potential harm to economies also sometimes cited as the reason for opposition to lower speed limits. While increases in travel times are an understandable concern, particularly for rural, high-speed travel over long distances, where impacts may sum to minutes, lower urban speed limits do not typically lead to appreciably longer trip times (Haworth et al. 2001).

Along urban roads and streets, other factors such as high traffic volumes, congestion, and traffic signals are influential in determining travel times for urban journeys. The need to create gaps in flow along busy routes using, for example, traffic signals to assist motorists on intersecting roads and streets to cross, leave, or

Fig. 17 Streets that allow walking and cycling prosper commercially (Utrecht, The Netherlands)

join major roads is a chief source of delays. The regulations governing the operation of traffic signals require motorists to stop for durations of around 1–2 min, sometimes longer when the intersecting roads carry high traffic volumes. The durations of these delays are far greater than the impacts of lower speed limits on overall journey time. Other factors, such as motorists entering and leaving parking spaces or waiting in traffic queues, simply because the traffic volumes exceed the physical capacity of roads, also have a dominant effect on travel time. If speed limits were raised in these circumstances, motorists would more likely reach the tail of the traffic queue sooner, while experiencing and imposing increased risk of road trauma, increasing harmful emissions and generally diminishing the liveability of urban areas. In some circumstances, lower travel speeds can actually lead to smoother flow and increased vehicle throughput.

Not only have lower travel speeds in urban areas been proven to save lives and prevent severe injuries, they also contribute to the liveability and sustainability of cities and towns. Where people can walk and cycle, local economies are often found to prosper (refer to Fig. 17).

Achieving Synergies with Other High-Order Goals

In the early part of this chapter, reference was made to the importance of achieving the Sustainable Development Goals (SDGs). Much of the focus of this chapter has been on achieving either separation or travel speeds within the boundary conditions for each of a number of systemic crash types, in order to align with the aspirations and principles of Vision Zero. This has led to the specification of various speed limits for each crash type found to be common to urban roads and streets. The scope has been confined to systemic crash types known to lead to death or severe injury.

On some roads and streets, it has been concluded that speed limits should not exceed 30 km/h, while on others not used by unprotected road users (namely, pedestrians, cyclists, and motorcyclists), speed limits not exceeding 40 km/h are needed to prevent severe trauma from rear-end collisions and speed limits not exceeding 50 km/h are needed to provide protection for vehicle occupants in collisions with each other or with roadside trees, poles, and other like-hazards. Where effective separation of road users from these specific hazards can be achieved, higher travel speeds can be permitted from a safety perspective, though they may not always be desirable from other viewpoints. For example, higher travel speeds may increase traffic noise, vehicle emissions and fuel use, detract from local place-making and diminish feelings of security, and overall liveability of cities and towns.

In closing this chapter, it is valuable to consider the opportunities presented by initiatives aimed at achieving alignment with Vision Zero objectives, as well as to contribute to a number of specific SDGs. Potential contributions are now discussed briefly.

Population Health

The main gains in population health are expected to come from lower travel speeds supporting active travel. Achieving urban travel speeds that align with Vision Zero goals will not only reduce the risks of death or severe injury to pedestrians and cyclists, as well as to public transport users, but will encourage more walking and cycling. The health benefits of more pedestrian- and cyclist-friendly communities are well-established and include:

- Improved health as a result of the increased physical activity
- Reduced traffic noise, leading to reduced stress levels and enhanced abilities to learn
- Lower vehicle emissions, resulting in reductions in respiratory illness
- Greater social connection, especially for older and mobility-impaired citizens
- Greater independence for children in being able to walk or cycle, at low risk, for school trips.

Environment

Benefits to the environment of lower travel speeds and more walkable and cyclist-friendly urban areas include a reduction in traffic congestion, leading to a reduction in the harmful emissions that contribute to the greenhouse effect and to global warming. Lower travel speeds are associated with smoother flow of traffic, reduced acceleration and deceleration, and a further reduction in greenhouse gases and wasted fuel use. When travel speeds are aligned with the Vision Zero boundary condition for lane departure crashes, the need to remove trees as part of clearing the roadside is also obviated. As a consequence, roadside trees can be planted or retained without compromising safety and this, in turn, contributes to cleaner air, especially in more densely populated cities, and to general liveability.

Liveability

The liveability of urban areas is strongly influenced by the ease of access to the various activities defining urban life. The aesthetics of roads and streets, especially in local neighborhoods and places where communities gather to socialize, recreate, shop, and study, are also important factors in defining liveability. Matching travel speeds to the Vision Zero boundary conditions applicable to the main systemic urban crash types, including the intrinsic vulnerability of unprotected road users, helps to ensure that place-making, tree-planting, street-scaping, and the creation of highly walkable environments can co-exist with motorized traffic. The choice of safe, convenient, and secure access to public transport, schools, shops, community facilities, and work locations, by foot, bicycle, micro-mobility, or public transport are among the attributes that characterize liveable communities.

Sustainability

Sustainable living and, in particular, sustainable transport are important long-term goals for society. Aligning the operation of the road transport system to Vision Zero helps to meet sustainability criteria. For example, support for active travel, by virtue of full separation or 30 km/h speed limits will lead to greater levels of walking, cycling and public transport use, and, conversely, reduced reliance on private car travel. This is important to the long-term sustainability and environmental goals of the world's most densely populated cities.

Social Equity

Modern societies are increasingly sensitive to the need to assure social equity, especially in densely populated urban areas where safe and convenient mobility is essential to daily life. Yet assuring equity has proven very challenging as populations and urban density grow. Socially well-placed citizens and visitors to cities and towns enjoy a wide range of mode choices, including the use of private car travel. This enables socially advantaged people full access to opportunities for employment, socialization, entertainment, education, health services, and other activities needed to participate purposefully in modern life.

People who are socially less-well placed, due perhaps to low personal or family incomes, or health concerns, tend to be restricted in their mobility choices. For example, low-income individuals and families are generally only able to afford cars that are older and, therefore, inherently less safe. This exposes the occupants to greater crash and injury risks. Those who do not own cars will often be limited to using public transport and (hence) associated active travel. While active travel is, in itself, good for the individual and for society, and therefore to be supported, travel options are restricted to the places and times offered by these services. In the absence of well-designed infrastructure and low-risk travel speeds, active road users face heightened vulnerability, especially when walking or cycling in fast-moving, busy traffic. Among the gender-based concerns are the limitations on mobility for females who feel insecure (and may well be insecure) in some settings, on particular days of the week and/or during higher risk times of the day.

It is not uncommon for there to be under-investment in infrastructure in cities where socially disadvantaged communities live and work. This can occur because of long-standing political priorities and lead to higher exposure to an inherently unsafe road transport system.

Among the most vulnerable road users are children, and older and mobility-restricted people; they are often unable to enjoy full personal independence, easy access to health and other services essential to urban living, and the social interaction with family and friends that can be so important to a person's well-being. In many of today's cities, people are limited in their mobility by threatening traffic speeds, high and constant flows of traffic, narrow or non-existent footpaths and wide roads to cross. Instead of being able to walk or cycle safely to and from school, it is common for children to be driven, which further exacerbates the exposure to risk and the general congestion around schools. This progressive loss of personal freedom impedes the development of young people and limits their opportunities for social interaction and a level of personal independence appropriate to their ages.

Ensuring that vehicle travel speeds align with the Vision Zero boundary conditions for pedestrians and cyclists allows greater urban mobility, thereby helping to compensate for the social-disadvantage common in our larger cities and towns.

Concluding Comment

Translating the Vision Zero aspiration and principles to real-world practice offers opportunities to create safe, healthy, sustainable, and socially equitable road transport systems. A focus on achieving lasting gains will deliver benefits for today, as well as for future generations.

Cross-References

► Automated Vehicles: How Do They Relate to Vision Zero
► Road Safety Analysis
► Sustainable Safety: A Short History of a Safe System Approach in the Netherlands

► The Development of the "Vision Zero" Approach in Victoria, Australia
► Vision Zero and other Road Safety Targets
► Vision Zero in Norway
► Vision Zero in Sweden: Streaming Through Problems, Politics, and Policies
► Zero Visions and Other Safety Principles

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Rural Road Design According to the Safe System Approach

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Helena Stigson, Anders Kullgren, and Lars-Erik Andersson

Contents

Abstract

This chapter covers design of rural roads according to the model for safe traffic used in the Vision Zero approach. Based on expected levels of the safety of vehicles and road users, the roads and the road side furniture should be designed to avoid fatalities and serious injuries. An introduction is presented covering the safe system approach and how speed limits of roads should be set to reflect the safety standard of the road in relation human injury tolerance and the capacity to

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protect the road users. One section will cover countermeasures to protect vulnerable road users, including speed calming road infrastructure, bicycle and pedestrian paths, bus stops. Another section will cover road infrastructure countermeasures addressing vehicle occupants. It is shown how change of velocity, vehicle mean acceleration, and crash duration are correlated and how they influence occupant injury risk. Design of different types of roads on rural roads is described, such as the two-plus-one lane road design with median barrier, and various ways of separating traffic or preventing run-off road crashes including road barrier design and rumble strips. Safe intersection design is an important part on rural roads that is explained. The last part covers design of the roadside area from a safe system approach.

Keywords

Barrier · Car occupant · Change of velocity · Road design · Road safety · Rural roads · Safe System · Vehicle acceleration · Vulnerable road users

Introduction

The basis for creating a safe road transport system is the human tolerance to impact forces. It is necessary to have knowledge of injury risks for all road users in several impact conditions and for various crash severity parameters. For system providers, it is necessary to know the amount of force/acceleration the road user can be exposed to without an unacceptable risk of serious injuries. For a car occupant, the car and its safety systems are acting as a filter which reduces occupant's loading to acceptable levels. For vulnerable road users, there is no protective filter, or at least not to the same extent, and for those it is important to know the maximum impact velocity that they can be exposed to without risk of fatal or serious injury in case of a crash with a motor vehicle. For car occupants in car crashes, the vehicle acceleration is the most important parameter to control. High changes of velocity in a crash can be handled if the vehicle acceleration is kept below levels likely to cause an injury. The occupant acceleration is controlled by the vehicle and its safety systems together with the road infrastructure and the speed limits. In road traffic, two general ways of controlling the crash severity in collisions between two vehicles or between a vehicle and a vulnerable road user can be identified, either keeping the relative velocity between road users within acceptable levels or separating the road users from each other. In single or multiple collisions, forgiving deformable road side objects and safety barriers can keep the vehicle acceleration below levels likely to cause fatal or serious injuries even at roads with high speed limits. Safety barriers can also be used as mid barriers to avoid head on collisions. The coming sections will further explain how vehicle acceleration can be controlled by speed limits and the design of roads and road side objects.

In most countries, speed limits are chosen to achieve a balance between safety and mobility. Since mobility is a high priority in many countries, road authorities often allow higher speeds than those possible to handle to be a safe road transport system. According

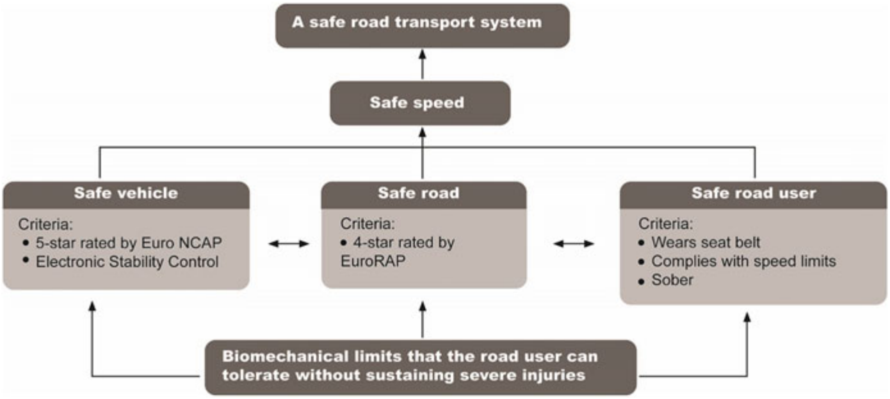

Fig. 1 The model of a safe road transport system with criteria for the vehicle, the road and the road user reflect best practice in the present-day road transport system. (Source: Stigson 2009)

to a safe system approach, the speed limit of the road should be set to reflect the safety standard of the road in relation human injury tolerance and the capacity to protect the road users (Johansson 2008; Stigson 2009; WHO 2008). The speed limit is therefore an explicit design parameter. To address a safe road transport system, the Swedish Transport Administration (STA) has summarized the underlying principles of a Safe System, Fig. 1. The chosen safety performance indicators (SPI) have been shown to have a potential to reduce injury risk and are connected to the road, the vehicle, and the road user and describe how these components together with a safe speed should interact to achieve a safe road transport system (Stigson 2009; Tingvall et al. 2000).

The integrated safety chain described in (Tingvall 2008) illustrates how events from normal driving to a crash can be broken down into phases where every phase can be handled by an action to avoid or mitigate a crash. In a Safe System, the boundary conditions for normal or safe driving in the integrated safety chain are based on the criteria in the Vision Zero model for safe traffic, that is, the conditions that need to be fulfilled to keep the kinetic energy in a crash below levels that could be handled through the chain to avoid serious injuries. Therefore, speed is crucial to either avoid critical irreversible phases in the safety chain or to mitigate an unavoidable situation. Safe driving is defined as compliance with traffic rules: wearing a seat belt, complying with the speed limit, and not driving under influence of alcohol/drugs. Road infrastructure also has conditions that need to be fulfilled in the model. And the infrastructure could support the driver if deviations from safe driving occur and intervene with infrastructural countermeasures (for example speed humps) to return the driver to safe driving. Johansson (2008) uses the Vision Zero model for safe traffic to describe a maximum travel speed related to the infrastructure, given best practice in vehicle design and 100% restraint use:

- Locations with possible conflicts between vulnerable road users and cars, maximum speed limit 30 km/h

- Intersections with possible side impacts between cars, maximum speed limit 50 km/h
- Roads with possible frontal impacts between cars, maximum speed limit 70 km/h or 50 km/h if the oncoming vehicle is of a considerably different weight
- Roads with no possibility of a side impact or frontal impact, speed limit >70 km/h is allowed

To follow the Vision Zero philosophy, these four points have been defined according to best practices, and the Swedish Transport Administration uses these as design guidelines and to set relevant speed limits in relation to road design (Johansson 2008; Stigson 2009). In the Vision Zero model for safe traffic, these speed limits have been described as safe speed.

Infrastructure Countermeasures to Protect Vulnerable Road Users

To avoid injuries to vulnerable road users, knowledge of correlation between motor vehicle impact velocity and injury risks is necessary to be able to identify a maximum speed limit for motor vehicles in areas with a mix of vulnerable road users and vehicles. Studies have been presented for pedestrian injury risk curves (Kovaceva et al. 2019; Rosén and Sander 2009; Rosén et al. 2011; Stigson and Kullgren 2010). An example is shown in Fig. 2, presenting risk for serious injury (MAIS3+) and fatal injury for older pedestrians above 60 years, who represent the more vulnerable pedestrians. Injury risk curves have also been published for

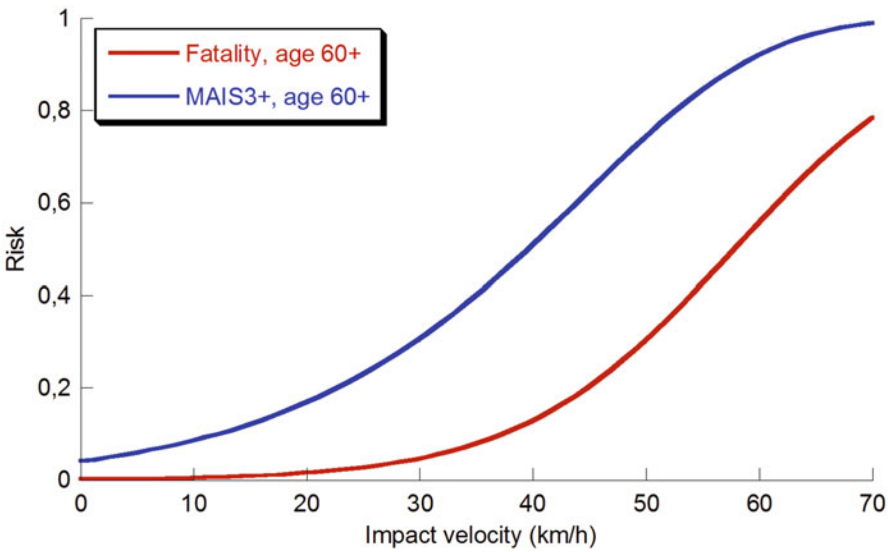

Fig. 2 Risk for fatality and serious injury (MAIS3+) for pedestrians above 60 years age as a function of impact velocity. (Source: Stigson and Kullgren 2010)

motorcycles (Ding et al. 2019). The Vision Zero guidelines recommend a maximum speed limit of 30 km/h when there is a risk for collision with vulnerable road users (Johansson 2008; Kullgren et al. 2017; Kullgren et al. 2019; STA 2019). Keeping the speed below 30 km/h entails the possibility to ensure that the injury risk can be below critical levels, but also the possibility to detect a vulnerable road user and to act to avoid a collision. However, on rural roads with lower proportion of vulnerable road users, stakeholders allow higher speeds even in area with mixed road users. It is possible to include further countermeasures. Studies have shown that a combination of speed calming road infrastructure, bicycle helmets, and more protective car fronts may reduce the risk for permanent medical impairment among bicyclists up to 95% (Ohlin et al. 2014). In addition to passive safety systems, Autonomous Emergency Braking (AEB) with pedestrian and bicyclist detection has been introduced in cars lately and has also been shown to be effective (up to 40% reduction) (Rosen et al. 2010). On rural roads, autonomous emergency braking has a large potential to protect pedestrians and bicyclist (Kullgren et al. 2017; Kullgren et al. 2019).

On rural roads, the relative velocity between the motor vehicle and the vulnerable road users is high. As seen in real-world data, maneuvers in which a driver overtakes a cyclist on a rural road are critical since they occur at high speed, with a short duration and with little time to avoid a crash (Dozza et al. 2016). The most common accident scenario on rural roads is that bicyclists are struck while cycling along the side of the road and are often struck in the rear (Kullgren et al. 2019), while pedestrians are most often the struck while crossing the road (Kullgren et al. 2017). In Sweden, vulnerable road users struck by motor vehicles are most often killed on roads with a speed limit of 70 or 90 km/h. As mentioned above, the Vision Zero guidelines recommend a maximum speed limit of 30 km/h but this is rare in rural areas. However, to avoid collisions and to protect vulnerable road users on rural roads, several concepts could be used. Examples are pedestrian and bicycle paths and crossing points, plane separation (e.g., pedestrian tunnels and footbridges) with the intension to separate the road user categories and/or to achieve safe speeds. For well-frequented passages, pedestrian tunnels and footbridges are the most effective solution. To reduce the risk, center refuges are often implemented in intersections where the number of pedestrians and cyclists is low. However, this should not be regarded as a solution according to the Vision Zero since the travel speed of the motor vehicle is not addressed. Studies have shown that roundabouts reduce the number of injured pedestrians (Gross et al. 2013; Hydén and Varhelyi 2000; Persaud et al. 2001; Retting et al. 2001), but increase the number of car-to-bicycle crashes resulting in more injured cyclists (Daniels et al. 2010; Hydén and Varhelyi 2000). Therefore, it is recommended to use speed calming road infrastructure to lower the travel speed.

Speed Calming Road Infrastructure

To protect vulnerable road users in collisions with motor vehicles, it is important to control the vehicle speed. Accident analysis on rural roads (Kullgren et al. 2017)

Fig. 3 Example of use of a chicane to control vehicle speed. Photo: Helena Stigson

have shown that a speed limit alone is not sufficient to reduce vehicle speed in areas with vulnerable road users. There is a need for supplementary measures that physically prevent from speeding. On rural roads, various solutions have been used aimed to reduce vehicle speeds in areas with common occurrence of vulnerable road users. Speed humps and chicanes can successfully be used to both raise attention and to reduce speeds at intersections or at road sections (Agerholm et al. 2017; Lee et al. 2013; Pucher et al. 2010). An example is shown in Fig. 3. Vertical or lateral shifts in the carriageway and road narrowing to a single lane or to a reduced width have also been used and evaluated showing positive results (Harvey 1992).

Bicycle and Pedestrian Paths

To increase safe cycling and walking on rural roads, there is a need for physical separation in form of separated paths if the speed limit exceeds 60 km/h (CROW 2007). Studies have shown that bicycle paths have a large potential to reduce accidents between vehicles and vulnerable road users (Kullgren et al. 2017; Kullgren et al. 2019). The design of bicycle and pedestrian paths often varies between cities/ built-up areas and rural areas. In rural areas it is desirable to have paths separated from the road, an example is shown in Fig. 4, as the expected potential is higher (Kullgren et al. 2019). The separation could also be achieved by a road barrier between the vehicle lane and the bikes lane. In cities bicycle lanes, most often is located at the side of the road due to space requirements.

In rural areas where there is a mix of vulnerable road users and motor vehicles, another road design has been developed and tested to address the safety for vulnerable road users based on road sharing often named two-minus-one rural road, see for example (Herrstedt 2006; Visser van der Meulen and Berg 2018). The two-minus-

Fig. 4 Example of how vulnerable road users could be separated from motor vehicles on rural roads. (Photo: Anders Kullgren)

Fig. 5 Example of Two-minus-one-road from a Swedish pilot study. (Source: Visser van der Meulen and Berg 2018)

one road only has one central driving lane and wide shoulders on both sides, Fig. 5. Cars should only use the wide shoulders in situations with oncoming traffic, otherwise the intention is that all motor vehicle traffic should use the central lane. The solution is used on rural roads where both speed and traffic flow are low and with the purpose to give more space to pedestrians and cyclists. The concept has been used in the Netherlands, Denmark, and Sweden.

Bus Stop Location in Rural Areas

Safety for public transport users during accessing or ending theirs trips is essential since public transport users begin and end their journeys as pedestrians. When choosing the location for a public bus stop, the possibility for pedestrians to access the bus stop should be taken in consideration. It is important to avoid forcing the pedestrians to walk along a road towards a bus stop, or to cross the road to/from the bus stop or to stand at the roadside waiting to hail a bus. It is important to take in account that pedestrians, in case they need to cross the road to reach a bus stop on the other side of the road, will take a shortcut if possible. A safety fence close to the bus stop could be used to prevent pedestrians to cross the road in a noncontrolled way (Kullgren et al. 2017). Access to crossings, tunnels or footbridges should be close to the bus stop. The use of safety fences can also address and prevent suicide.

Infrastructure Countermeasures Addressing Vehicle Occupants

In car crashes, the crash severity level to which a human is exposed to depends on several factors, such as relative velocity between a vehicle and its collision partner, the mass and structure of the vehicle, and its collision partner and the crash situation, including impact angle, overlap, etc. Various crash severity parameters, such as change of velocity and mean and peak acceleration, are influenced in different ways by all the above-mentioned factors. From a mechanical standpoint, the change of velocity of a studied vehicle is primarily influenced by the relative velocity between two vehicles or vehicle and object and the vehicle masses, and only to a small degree influenced by the structure of the involved vehicles and objects, whereas the vehicle acceleration depends on all the above-mentioned factors. Therefore, the influence on vehicle acceleration and change of velocity varies depending on the mass and structure of the collision partner, for example, stiffness. With the help of data from recorded crash pulses (Event Data Recorders (EDRs) or crash pulse recorders), that entail the possibility of measuring acceleration during the crash phase, this can be verified under real-world conditions. Studies based on real-world collisions have shown that especially change of velocity and vehicle acceleration during the crash phase of a car crash influences the risk of being injured. An example of how change of velocity and vehicle mean acceleration are correlated in crashes is shown in Fig. 6. It has also been shown that if the mean acceleration is below a critical level, the duration of the crash is allowed to increase without an increase in injury risk, Fig. 7. Correlation between injury risk in frontal impacts versus crash severity measured in real-world collisions (change of velocity, mean and peak acceleration, and crash pulse duration) has been presented by, for example, Gabauer and Gabler (2008); Kullgren (1998, 1999); Stigson et al. (2012); Ydenius (2002,

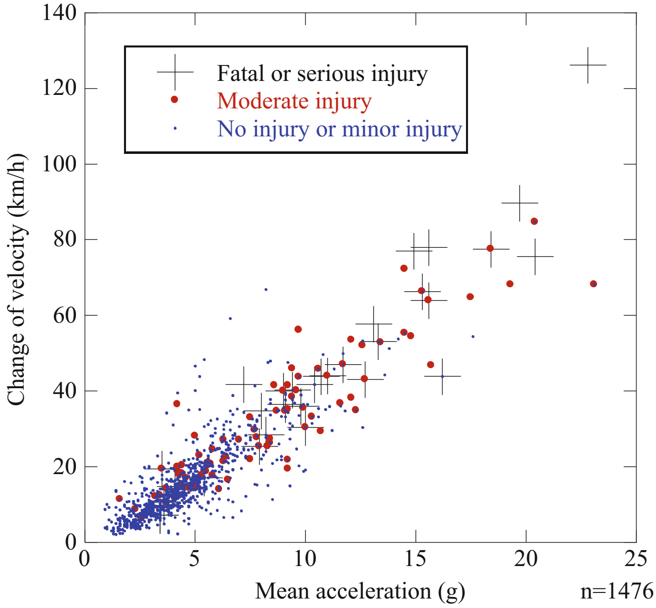

Fig. 6 Correlation between change of velocity and mean acceleration for crashes with occupants of different injury status. (Source: Folksam)

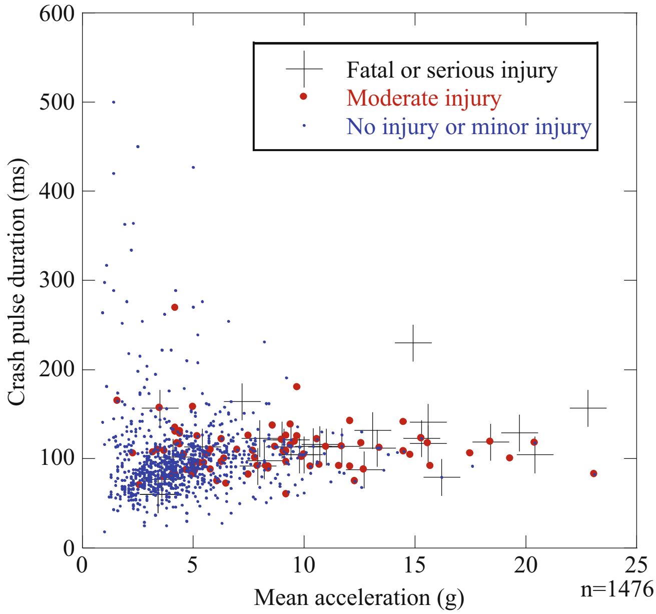

Fig. 7 Correlation between mean acceleration and crash pulse duration for crashes with occupants of different injury status. (Source: Folksam)

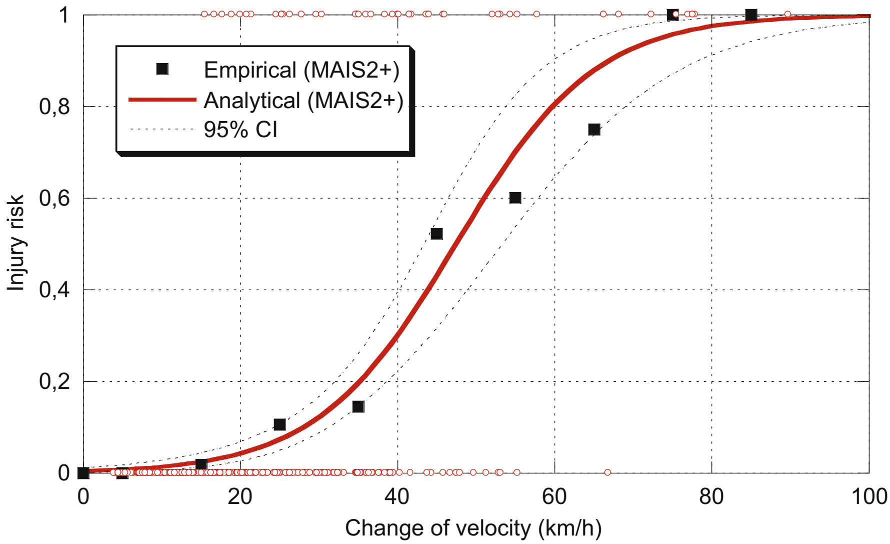

Fig. 8 Risk of a MAIS2+ injury for front seat occupants versus change of velocity in frontal impacts (Stigson et al. 2012)

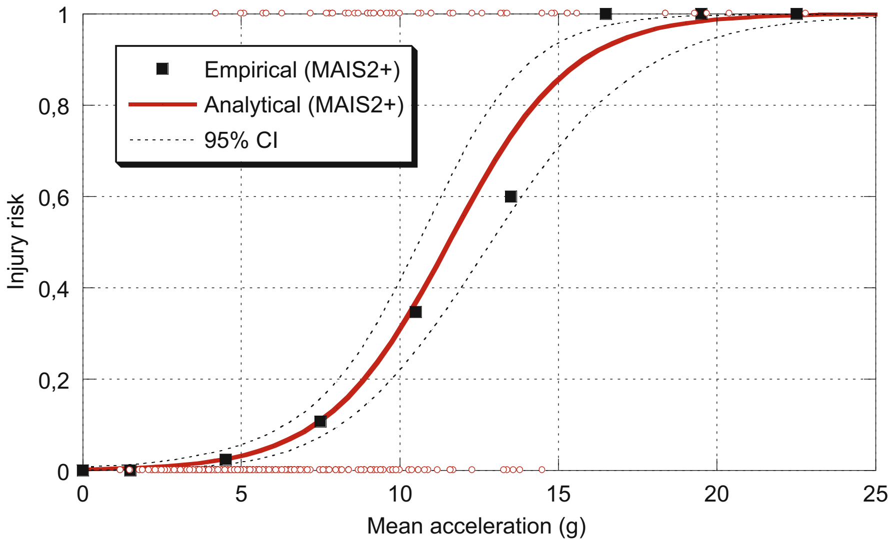

Fig. 9 Risk of a MAIS2+ injury for front seat occupants versus mean acceleration in frontal impacts (Stigson et al. 2012)

2010). Two examples of injury risk functions are shown in Figs. 8 and 9. And for rear-end crashes, injury risk curves have been presented for both mean acceleration and change of velocity (Krafft et al. 2005; Kullgren and Stigson 2011). Furthermore, risk curves based on real life side impact data have been presented (Sunnevång et al. 2009).

The three most common and severe crash types are head-on crashes, run-off-the-road crashes, and crashes at intersections, and therefore, the thresholds of a safe road transport system mentioned above are designed based on the survivable limits of these three crash scenarios.

To fulfill the criteria of a safe road according to a safe system approach (Johansson 2008; Stigson 2009) and to minimize the injury outcome, different infrastructure design could be used. Crash severity could be limited when foreseeable crash scenarios arise, by, for example, removing trees and other objects close to the road or installing a safety barrier between the vehicle and roadside objects such as trees, poles and rocks. Furthermore, two-way single carriageways with traffic in opposite directions could be allowed with a speed limit of up to 70 km/h based on the current vehicle crashworthiness (Johansson 2008; WHO 2008). To prevent interaction of vehicles with other vehicles and objects at higher speeds, the road should have safety barriers to prevent crossing over and guardrails to protect loss of control into objects in the roadside area (trees, poles, rocks, or rollover tripping mechanisms) (Rechnitzer and Grzebieta 1999). To further prevent run-off the-road crashes, the road needs to have a clear safety zone adapted to the speed limit or equipped with a guardrail. The model of a safe road transport system has been used to identify safety gaps and to find nonconformities in crashes (Lie 2012; Stigson and Hill 2009; Stigson et al. 2008; Stigson et al. 2011). The infrastructure and road safety have been identified to have a significant impact on the severity of the outcome (Stigson et al. 2008). Divided roads were the most effective factor avoiding fatal crashes among car occupants. Furthermore, it has been identified (Stigson et al. 2008) that in Sweden collisions with heavy goods vehicles (HGV) account for over half of all crashes that occurred on undivided roads with a speed limit of 70 km/h. This is one of the safety gaps where the biomechanical tolerance of the road users and the design criteria of the road transport system are not compliant and needs to be addressed.

Road Types on Rural Roads

Road type has been found to be the dominating factor for the rate of killed or seriously injured (KSI). By providing a median separation, often in form of safety barriers, the risk of head-on collisions can be dramatically reduced. Divided roads have half the KSI rate compared with single carriageways. Several studies have shown that the risk of injury is lower for divided roads than for single carriageways (Carlsson and Brüde 2005; Elvik and Vaa 2004; Stigson 2009; Tingvall et al. 2010; Wegman 2003). Furthermore, on undivided roads, the average crash severity is higher and the proportion of frontal collisions with oncoming vehicles is higher (Ydenius 2010). A study on real-world crashes has been conducted based on the Vision Zero model for safe road traffic mentioned above (Fig. 1) and also according to the European Road Assessment Programme (Euro RAP), a program that like Euro NCAP for vehicle safety evaluates and provides star ratings for roads, (Stigson

2009). The study shows that the crash severity is significantly lower in crashes occurring on roads with a safety standard fulfilling the Vision Zero criteria compared to crashes occurring on roads with a poor safety rating. Crash severity and injury risk were lower on roads with a good safety rating with a speed limit of 90 km/h to 110 km/h, compared with roads with a poor safety rating, irrespective of speed limit. On the other hand, crash severity was higher on roads with a good safety rating with a speed limit of 70 km/h, than on roads with a poor safety rating with the same speed limit. While it was found that a higher speed limit resulted in higher crash severity on roads with a poor safety rating, the opposite was found on roads with a good safety rating. The main reason for this was that lanes for traffic travelling in opposite directions were more often separated at higher speeds on roads with a good safety rating.

The crash distribution differs depending on road type, although single-vehicle crashes account for the highest proportion regardless of road type (Johansson and Linderholm 2016). On undivided roads, the proportion of fatally injured car occupants is greatest in head-on and single-vehicle crashes. By using divided roads almost all head-on collisions could be eliminated. Furthermore, intersection crashes are rare on these roads while rear-end crashes are more common. The risk of single-vehicle crashes on divided roads is less than half of the risk on undivided roads. This could be explained by higher safety standard of the roadside areas, but the main reason is that the median barrier will prevent all run-of-the-road crashes to the left. Approximately 40% of the single-vehicle crashes on undivided roads are estimated to be run-of-the-road crashes to the left (Johansson and Linderholm 2016).

The Two-plus-One Lane road Design

The 2 + 1-lane road design incorporates two lanes of traffic in one direction and one lane in the opposite direction separated by a median safety barrier, in many cases a wire-rope barrier, Fig. 10. The 2 + 1-lane roads with wire-rope barriers that were introduced by the Swedish Transport Administration in 1998 have been shown to reduce the number of fatally and seriously injured road users on Swedish roads. The 2 + 1-lane roads were a cost-effective way of increasing road traffic safety on Swedish single-carriageway roads with severe injury pattern records. The existing single-carriageway road have been and are still updated to be provided with a median barrier to separate opposing vehicles mostly within the existing road space required for the old single-carriageway. Follow-up studies have shown that the number of fatally injured road users on these segments has been reduced by approximately 79% compared with the situation earlier (Carlsson 2009). Another study (Brüde and Björketun 2006) supports this finding, since 2+1-lane roads with wire-rope barriers were shown to have the lowest KSI rate of all road types. Vadeby (2016) found that the number of fatalities and seriously injured decreased by 50% and that the total number of personal injury crashes decrease by 21%. Based on best practice, some road designs such as 2+1-lane roads have been considered in a more favorable light than others regarding casualty reduction and cost benefits (Johansson 2008). In case

Fig. 10 Example of a design of a 2 + 1 lane road. Photo: The Swedish Transport Administration

of a crash on these roads, the road and the vehicle design can together reduce crash severity and thereby succeed in protecting the road user from sustaining a serious or fatal injury. The 2+1-lane design has been introduced outside Sweden, for example, in Spain, Ireland, and New Zealand. In general, by applying mid- and side barriers on Swedish rural roads, the number of fatalities can be reduced by 85–90% (Johansson 2008).

Barriers Types

Despite improvements in vehicle safety and the vehicle occupants' awareness of benefits associated with safety devices, fatal and serious injuries continue to occur. Crash tests like Euro NCAP are mainly focused on how passive vehicle safety systems protect occupants in vehicle-to-vehicle crashes. For instance, no crash test is included in Euro NCAP to evaluate the capacity of the vehicle to protect the occupant in a frontal single-vehicle crash into a safety barrier. However, road safety features such as barriers are tested to fulfill standards. Ydenius et al. (2001) show that the characteristics of different types of barriers (concrete, semi-rigid W-beam, and flexible wire-rope barriers) vary considerably regarding transferred crash energy and physical behavior. The study shows that wire-rope barriers can reduce the vehicle acceleration below 5 g even at high impact angles (up to 45 degrees). W-beam barriers also generates relatively low vehicle mean acceleration, while concrete barriers will generate high acceleration levels in the vehicle. Based on real-world crashes with recorded vehicle acceleration, rigid barriers in average generated almost 40% higher mean acceleration than other types of guardrails (Stigson et al. 2009). This is also shown in Table 2 in a coming section. However, all barrier types would fulfil main purposes of mid separation or preventing run-off-road crashes.

Barrier Design for Motorcycles

The design of safety barriers has been criticized by, for example, motorcycle organizations, as the commonly used safety barriers mainly have been designed for cars. However, many designs developed to also protect motorcyclist have been presented and are also used in many countries, such as Austria, Belgium, Check republic, France, Germany, Italy Luxemburg, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, and Switzerland. Figure 11 shows an example from Spain where a motorcycle protection system (MPS) has been added at the lower part of a standard w-beam barrier with the intention to avoid contacts between a sliding motorcyclist and the poles of the barrier.

Sliding crashes will be reduced in the future, due to the fitment of ABS on motorcycles. However, further development and fitment of improved protection of safety barriers is necessary. Crash tests indicate that MPS are beneficial also in upright collisions (Berg et al. 2005; Folksam 2015). But more focus should be directed towards road barrier design for upright crashes (Rizzi 2016). The top of the barrier will have a role for reducing health loss among motorcyclists (Grzebieta et al. 2013) and (Folksam 2015). Advanced top protections have been tested by, for example, Berg et al. (2005). The basic idea is that the top of the barrier needs to be smooth, soft, and also possible to retrofit on existing barriers (Folksam 2015; Rizzi 2016) (Fig. 12).

Fig. 11 Example of W-beam barrier with an added MPS. Photo: SMC, Sweden

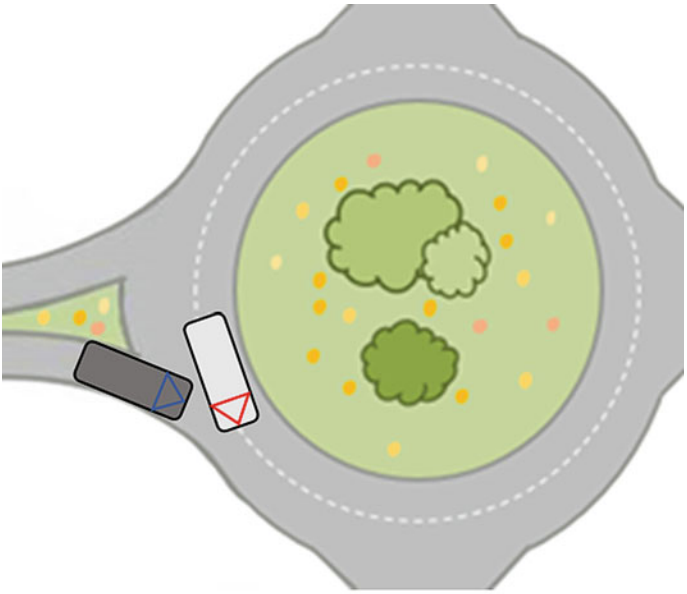

Fig. 12 Impact angle and speed will be changed by replacing a traditional intersection with a roundabout

Rumble Strips

Rumble strips as centerline or road edge lines have been shown to prevent crashes (Persaud et al. 2004; Rajamaki 2010; Sayed et al. 2010; Sternlund 2019). The strips will give a rumbling sound when driving over and thereby alert the driver to act. A large variation in crash reduction associated with drifting has been shown. The studies referred to above show reductions between 10% and 54% depending on the road type, speed limit, type of crash, and injury severity studied. In general, a reduction of 25%–30% of head-on crashes and single-vehicle run-off road to the left was shown. A reduction of 40% (19–56%, 95% CI) has been shown for cars fitted with Electronic Stability Control (Sternlund 2019), which appears to be a bit higher than cars without.

Intersections

To reduce crashes, specifically side impacts, resulting in severe injuries in intersections, a roundabout or a plane separated intersection can be introduced to avoid interference with opposing traffic and with left- and right-turning vehicles. Based on the Vision Zero model or Euro RAP mentioned in the introduction, a high safety rating intersection would be an intersection with a speed limit of maximum 50 km/h (Stigson 2009). According to the Euro RAP rating, roundabouts could allow speeds above 50 km/h since the design reduces the speed to acceptable levels while maintaining the traffic flow. How a safe speed can be achieved in roundabouts is further described below. At high traffic flow and with speed limits, above 50 km/h a grade separation is required. In car-to-car side impacts with modern side airbag-equipped cars, the occupants could be protected from severe or fatal injuries up to an impact speed of 60 km/h (Sunnevång 2016). Therefore, other countermeasures are needed to avoid side impacts at higher impact speeds. In the future, speed could probably be controlled with AEB intersection systems (Sander 2018) or with smart infrastructure communication with the vehicle or with vehicle-to-vehicle communication. The speed in an intersection could also be controlled by chicanes to reduce the speed before entering the intersection.

Intersections with traffic lights should not be regarded as a traffic safety solution in line with Vision Zero, but rather as a solution that supports mobility. Traffic lights will not prevent or correct driver errors at an early stage, and therefore, the crash severity will be higher in case a crash occurs. Road design solutions such as roundabouts have been shown to dramatically reduce the number of crashes resulting in injuries (by up to 80%) at intersections compared with traditional intersection designs (Brüde and Vadeby 2006; Gross et al. 2013; Persaud et al. 2001). Compared to a traditional intersection, a roundabout has less conflict points, which is illustrated in Fig. 13. The advantage of a roundabout is that a roundabout specifically addresses crossing path and left turn scenarios by reducing travel speed and possible impact angle, Figs. 12 and 14. Studies have shown that by replacing intersections with roundabouts, speed, number of conflict points, and number of side impact crashes were reduced and thereby also the number of the injuries to both car occupants and pedestrians (Gross et al. 2013; Hydén and Varhelyi 2000; Persaud et al. 2001; Retting et al. 2001). However, the number of car-to-bicycle crashes has been shown to increase in roundabouts as compared to intersections, resulting in more injuries to cyclists (Daniels et al. 2010; Hydén and Varhelyi 2000). Furthermore, the crash type distribution will be affected when replacing a traditional intersection with a roundabout. Studies have shown that the proportion of rear-end and side-swipe crashes will increase (Mandavilli et al. 2009; Polders et al. 2015). The ultimate solution to minimize potential conflict points at intersections is grade

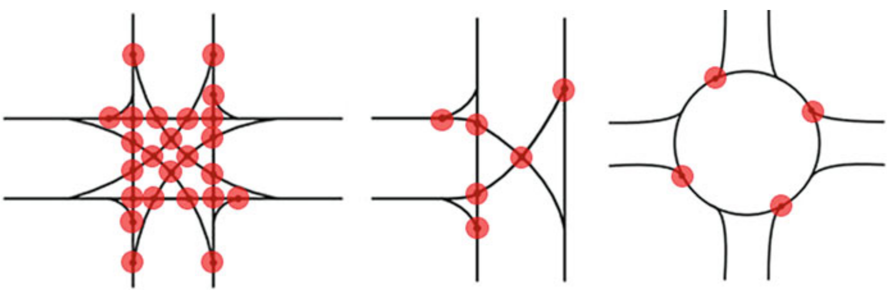

Fig. 13 Potential conflict points of major conflict of intersections, left: four-leg crossing 24 conflict points, middle: T-junction 6 points, right: roundabout 4 points

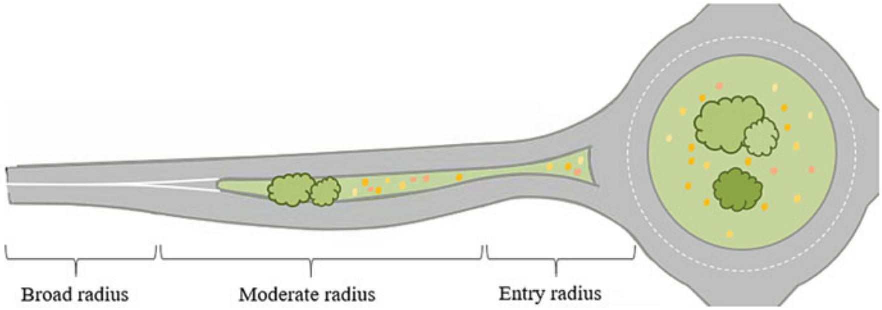

Fig. 14 An example of chicanes at roundabout approach aimed to reduce entrance speed

separation, but this solution is also associated with high costs and is primarily applied on roads with high traffic flow.

Several aspects need to be considered when designing a roundabout. Lateral displacement when entering a roundabout must be designed to achieve the desired speed reduction particularly on rural roads. One example is the use of chicanes on road sections entering roundabouts aimed to reduce the entrance speed, Fig. 14.

Roadside Area

To prevent that a run-off the-road crash results in sever or fatal injuries, the road needs to have a safe clear zone adapted to the speed limit or equipped with a safety barrier. To secure protection for crashes with barriers with all vehicle types, the barrier should be designed and tested for each of them. Based on the Vision Zero model mentioned in the introduction and the criteria set up by Euro RAP, the road should have physical barriers or a safety zone wider than four meters on roads with a speed limit of 70 km/h or higher to protect a car occupant in a loss of control into objects in the roadside area (trees, poles, rocks, or rollover tripping mechanisms). The safety zone that the vehicle needs to stop safely when leaving the roadway or that helps to reduce the crash energy to an acceptable level so that it will not result in a fatal or serious injury differ depending on road type, speed limit, the topography, and factors like curvature as well as traffic flow, Table 1. In addition to this, the size of the safety zone also depends on the bank height, if it is straight or inner/outer curve and radius on any curve (Fig. 15).

A safety zone should not have fixed objects or other hazards. Fixed objects lower than 0.1 m above ground level could be tolerated. Trees exceeding 0.1 m in diameter are considered as fixed objects (Johansson and Linderholm 2016). Examples of hazards are precipices (vertical fall with height ≥ 0.5 m or side slope $> 1{:}3$) and deep water (exceeding 0.5 m at medium water levels). If the requirements regarding safety zone could not be achieved, the road should be equipped with a guardrail. Road side objects needed within the safety zone should be designed and placed in such a way that critical vehicle acceleration levels are not exceeded during a run-off-road crash.

Table 1 Safety zones used in Sweden for various types of roads (STA 2020)

Speed limit (km/h)	Road type	New/redesign	Traffic flow (vehicles per day)	Safety zone (m)
120	F/H			≥ 12
110	F/H			≥ 11
	DR	New	> 8000	≥ 11
	DR		≤ 8000	≥ 10
	DR	Redesigned		≥ 10
100	DR		> 4000	≥ 10
	DR		≤ 4000	≥ 9
	DR	Redesigned		≥ 9
	2-lane	New	≤ 1500	≥ 9
	2-lane	Redesigned		≥ 9
80	2-lane	New	> 8000	≥ 8
	2-lane	New	4000–8000	≥ 7
	2-lane	Redesigned	2000–4000	≥ 7
	2-lane	Redesigned	1000–2000	≥ 6
	2-lane	Redesigned	≤ 1000	≥ 5

Note: F/H: Freeway/Highway (divided), DR: Divided arterial Road with centerline barrier, 2-lane: undivided two-way two-lane arterial road

For example, poles should be deformable or having a base that allow the pole to detach from the base in a controlled way in case of a crash. Figure 16 shows an example of a pole with a deformable element in the base aimed to lower vehicle acceleration in the event of a crash.

Collisions with rigid roadside objects account for a large part of fatal crashes around the globe, in some countries more than 40% (Delaney et al. 2003; DfT, 2005; ETSC 1998; IIHS 2005; RISER 2005). Many studies from different countries have found that trees account for most rigid roadside objects leading to fatalities (Delaney et al. 2003; Evans 1991; IIHS 2005; La Torre 2012). In vehicle collisions with narrow objects, such as poles and trees, the load is often concentrated to only a small part of the car. Therefore, only a minor part of the energy absorption structure is involved (Durisek et al. 2005; Durisek et al. 2004). To lower the vehicle acceleration in a crash, deformable objects should be used, which has been clearly demonstrated in crash tests (Kloeden et al. 1999; Steffan et al. 1998). The resulting vehicle acceleration in a crash should always be kept below critical levels likely to cause an injury. An analysis based on real-world data with crashes into various road side object shows that the least harmful crash type was single-vehicle crashes into deformable guardrails, in which no crash was found with a mean vehicle acceleration higher than 9 g, Fig. 15 and Table 2, (Stigson 2009). A mean vehicle acceleration below 9 g correlates with a less than 25% risk of sustaining moderate or more severe injuries (Stigson et al. 2012). In single-vehicle crashes, the average mean vehicle acceleration was 45% higher in collisions with rigid roadside objects than in collisions with deformable objects. Based on results like this, a design guideline could be identified regarding maximum mean vehicle acceleration to be accepted in frontal impacts. The results presented by Stigson (2009) suggest 9 g as a maximum level.

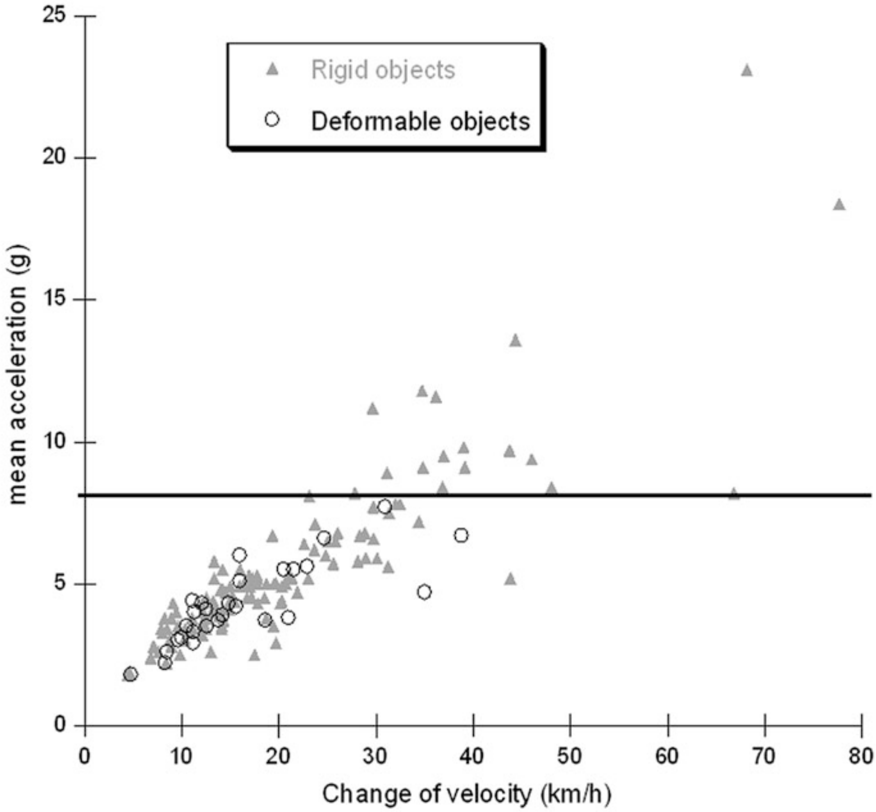

Fig. 15 Distributions of vehicle mean acceleration in crashes with rigid and deformable objects, from (Stigson 2009)

Fig. 16 Lightning column with a deformable element in the base aimed to lower vehicle acceleration in a crash. (Photo: Helena Stigson)

Table 2 Frontal single-vehicle crashes with different collisions partners, from (Stigson 2009)

Type of crash object	Change of velocity Δ V (km/h)	Mean acc. (g)	Duration (ms)	n
Rigid object	21.3	5.8	102.7	74
Trees	22.1	6.1	101.2	23
Rock face cutting	25.1	6.0	117.5	6
Rocks/boulder	20.7	5.2	107.6	12
Culvert	17.9	4.8	106.2	4
Rigid barrier	21.3	5.7	105.9	9
Bridge pier	19.3	6.7	80.0	1
House wall	16.6	5.8	77.9	6
Embankment	22.5	6.0	106.5	13
Deformable object	15.0	4.0	106.1	51
Deformable pole	15.1	4.0	107.4	30
Deformable guardrail	15.0	4.1	104.3	21
Other	12.9	4.0	92.1	33
Total	17.1	4.8	101.5	158

The section above describes the performance of deformable object in crashes mainly with passenger cars. Most deformable object are far too stiff to be able to lower the occupant loadings when struck by, for example, motorcycles and mopeds.

Cross-References

▶ Road Safety Analysis

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Speed and Technology: Different Modus of Operandi

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Abstract

Within Vision Zero as a strategy, it is imbedded the fact that injuries occur when the mechanical energy reaches individuals at rates that entail forces in excess of their thresholds for injury. Therefore, according to Vision Zero, there are three main strategies to eliminate fatalities and severe injuries due to road crashes: protect people from exposure of harmful energy, reduce the risk of events with harmful energy, and protect people from harmful energy in the event of a collision. Controlling speed is therefore of the task of utmost importance in a strategy such as Vision Zero.

A traffic enforcement camera, or "speed camera," system has the possibility to control speed in a road system, and it has the possibility to affect its road users both at a macro and a micro perspective. In a micro perspective, it primarily concerns how effective the cameras are locally at the road sections where the enforcement is focused on, while at a macro perspective it is more focused on how the camera enforcement system and strategies, possibly together with the overall enforcement strategy, affects attitudes and norms related to driving with excessive speed. Experience worldwide has proven the effectiveness of automated speed cameras in reducing speed and, in turn, crashes and injuries.

In this chapter, firstly the rationale behind speed limits, speed management, and speed compliance strategies will be explored and analyzed, in particular from a Vision Zero perspective. Secondly, various different approaches to speed camera systems in Europe, in Sweden, Norway, the Netherlands, and France, will be analyzed and further explored. Finally, based on similarities and differences in approaches in these countries, in the last section some aspects concerning the setting of speed limits, speed management strategies that underpin the choice of camera technology, and modus of operandi, safety effects of and attitudes toward cameras, will be explored and discussed.

Keywords

Vision Zero · Public policy · Speed limits · Speeding · Traffic safety cameras · Speed cameras · Traffic enforcement cameras

Introduction

Speed limits and speed monitoring and enforcement are a rather sensitive topic in most countries. To a significant extent, this is due to what people perceive is the primary goal with the road safety work, namely, the reduction of accidents, or to reduce crashes as many people prefer to express it. In this traditional approach, most of the attention is focused on people's behavior due to the fact that in-depth studies have shown that 90% of all accidents are due to human factors (Evans 2004). In this traditional context, speed becomes one risk factor, among others, used to explain the occurrence of an accident, and many times other factors such as distraction, fatigue, alcohol, and drugs seem to be more obvious and significant.

In October 1997, the Riksdag (the Swedish Parliament) adopted Vision Zero as a new long-term goal and strategy for road safety in Sweden (Swedish Parliament 1997; Belin et al. 2011). Imbedded in Vision Zero as a strategy is the fact, which was revealed by William Haddon already in the 1960s, that injuries occur when the mechanical energy reaches people at rates that involve forces in excess of their injury thresholds (Haddon 1968, 1980). Therefore, according to Vision Zero, there are three main strategies to eliminate fatalities and severe injuries due to road crashes: protect people from exposure of harmful energy, reduce the risk of events with harmful energy, and protect people from harmful energy in the event of a collision. To control the speed is therefore of the utmost important task in a strategy like Vision Zero.

Speed as one important risk factor is a valid logic in the context of a more traditional approach, but if the problem that one tries to solve is not accidents per se but rather the outcome in terms of fatalities and serious injuries, the speed instead becomes the core of the entire road safety work. People do not suffer from injuries due to distraction, fatigue, alcohol, and other factors. To put it bluntly, as long as one’s speed is low, they will survive a crash even if they are driving impaired due to operating under the influence. Speed limits and speed monitoring and enforcement therefore play an important role both traditionally and from a Vision Zero perspective, however, from rather different angles.

Change of speed and its relation to accidents and the severity of injury is one of the most researched topics in the field of road safety. According to Elvik (2009), change of speed and road safety could be described in terms of different power functions, where the power function is greater for higher levels of severity. For example, a reduction of average speed by 10% will reduce fatalities by approximately 40%, serious injuries by 30%, and accidents with minor injuries by 10%.

There are several ways to control the speed in the road transport system – for example, speed limits and a variety of speed-reducing devices. The State of Victoria in Australia is an innovator for road safety practices on a global scale. For example, Victoria was the first jurisdiction in the world to introduce the compulsory use of seat belts, back in 1970, and random breath testing (RBT) in 1976 (Trinca et al. 1988). True to their tradition, in 1989 the State of Victoria started to implement a large-scale automatic speed camera program (Bourne and Cooke 1993). This was the first time in the world that extensive use had been made of this technology (Sagberg 2000). After this, quite a number of jurisdictions around the world have followed.

In this chapter, firstly the rationale behind speed limits, speed management, and speed compliance strategies will be explored and analyzed, particularly from a Vision Zero perspective. Secondly, the different approaches to speed camera systems in Europe, namely, in Sweden, Norway, the Netherlands, and France, will be analyzed and further explored. And then finally, based on similarities and differences in approaches in these various countries, in the last section some aspects concerning the setting of speed limits, speed management strategies that underpin the choice of camera technology, and modus of operandi, safety effects of and attitudes toward cameras, will be explored and discussed.

Setting Speed Limits

The speed limit constitutes the legal objectives for the monitoring and enforcement, similar to the blood alcohol limits establishes legal objectives for how much alcohol a road user is allowed to have in their blood while driving. This is something people mostly accept and take for granted; however motives and criteria that underpin a speed limit system are paramount for its legitimacy and thereby also important for public control and sanctions.

In a Swedish context, it is obvious that motives that underpin a speed limit system have evolved and change over time. In 1907, the Swedish Government launched the first road traffic regulation for automobiles. The regulation stipulated, among other things, that motor vehicles were not allowed to drive faster than 15 km/h in urban areas and 25 km/h in rural areas. During the period 1910–1930, the maximum speed limit was increased to 35 km/h in urban areas and 45 km/h in rural areas (Swedish Parliament 1906). The use of the automobile was heavily regulated primarily because it was seen as an unwelcome element in a transport system which mainly consisted of horse transports. In the 1930s, an opinion was raised against these static speed limits. The advocators argued that the vehicles and the roads had a higher standard and therefore were designed to allow a much higher speed. It was better, according to the advocators, to put the entire responsibility on the individual to adjust their speed according to the situation. Therefore, a new speed regime with free speed, both in urban and rural areas, and with a significant proportion of self-responsibility was introduced in 1936 (Swedish Parliament 1936).

After World War II when the number of cars rapidly increased and along with this, the number of fatalities increased dramatically, the epidemic situation forced the Swedish Government to take a variety of different steps to improve the road safety situation. The experts were not sure that the freedom for the driver to choose their own speed was such a good idea. Besides, it was difficult for the police to enforce inappropriate choice of speed, and the police needed clearer guidelines regarding which speed to allow. The elected officials responded to that request, and the first step was to re-regulate the speed in urban areas. In 1955 a new default speed that stipulated 50 km/h in urban areas (this speed limit is still in place) was introduced (Swedish Government 1955). During the years 1960–1967, temporary speed limits for the rural roads were introduced – especially during holidays. The speed limits were 80, 90, or 100 km/h. In 1968, a trial with general differentiated speed limits was introduced and the idea was to allow higher speed on roads with higher standards. In 1971 a default 70 km/h speed limit for rural roads was introduced. The debate about having speed limits or not vanished from the agenda and was replaced by a discussion of which criteria the speed limits should be based on (e.g., on what roads should the responsible traffic authorities allow 90 km/h or 110 km/h).

One of the most important criteria when the speed limits first were discussed was the drivers' acceptance. The advice was that the speed should be around 85th percentile which means the speed 85% of the vehicles not are exceeding (see Fig. 1, the evolution of speed limit system).

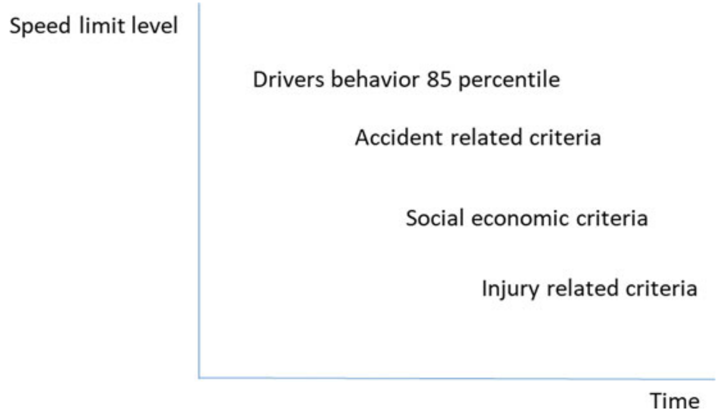

Fig. 1 Evolution of important speed limit criteria in Sweden

Soon it became obvious that alignment routing, passing sight distance, and accident rate needed to be considered before a speed was decided, and these accident-related criteria have dominated since the 1970s (Swedish Government 1978). In the 1980s, the experts advocated that speed limits should be established from a cost-benefit perspective (Carlsson 1976). The idea was that one could calculate an optimal speed limit for different road environments. This method has never been implemented in reality, though.

According to Vision Zero, road users' tolerance against external violence should be the basic design parameter for the speed. Based on this design parameter, it has been suggested that the risk for different crash types should set the maximum speed. For example, in the situation where there are risks for crashes with cars and unprotected road users, the speed limit should not be higher than 30 km/h and for risks for head-on collisions (i.e., cars to cars) at a speed not higher than 70 km/h (https://www.roadsafety.piarc.org/en/road-safety-management-safe-system-approach/safe-system- elements).

A speed management system in order to achieve safe speed in the long run is summarized in Fig. 2. First, one needs some long-term principals which appear in Table 1. However this might be difficult to achieve in the short term; therefore jurisdictions have to allow a higher speed than what is appropriate from a Vision Zero perspective. These should however only be short-term considerations. Irrespective of if the speed limit is established based on long-term safety principals or short-term practical considerations, the governmental authorities need also to ensure that the traffic complies with the speed limits, which is the last step.

Influencing Road Users' Speed Behavior

Kinetic energy is one of these risks in our society that people do not feel and therefore do not have a natural perception of, in comparison with the risks of such things as snakes, spiders, heights, etc. pose. Therefore the speed that people choose is largely dependent

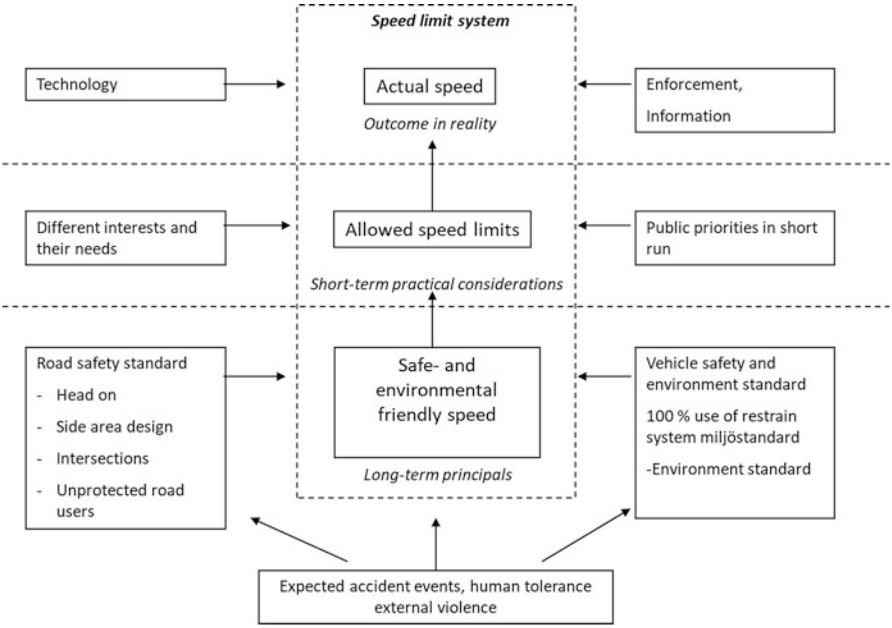

Fig. 2 Speed management system in order to achieve safe speed according to Vision Zero and environment

upon stimuli from the environment such as the road environment, weather, surrounding traffic, and posted speed limits, among other factors. To know intellectually about the risk will also be important. Control interventions such as manual and automated enforcement have significant impact on people's compliance with the speed limits. Risk for sanctions in terms of fees and losing the driving licenses are also important. A couple of important questions are therefore important to discuss; who should be the target group for the enforcement and how are the interventions supposed to work?

Firstly, if the speed limit is set according to the 85%, already a large majority of the traffic will comply with the speed limit. Therefore, enforcement is aimed to influence 15% of the road users. As early as in the 1950s, the expression "people drive as they live" was coined (1953 Års Trafiksäkerhetsutredning 1954). Therefore, these 15% was blameworthy, and the enforcement should focus on this risk group, especially those who are driving too fast. What underpins this high-risk strategy are of course that these groups are, individually, more risky from a road safety perspective. Even though the criteria for setting the speed limits have changed, the most popular enforcement strategy is still to focus on the high-risk groups. However with such approach, one might end up in what researchers refer to as the "public health paradox," (Rose 1981) namely, a more general effect on road safety is obtained if instead of focusing on a small population of speeders, efforts are made to influence the larger normal population who are only speeding little too much. The individual strategy has its advantages (Rose 2001), and it very probably fits well in with how

Table 1 Speed limit system in Sweden, Norway, the Netherlands, and France. Extracted from ETSC (2019)

	Sweden	Norway	Netherlands	France
Proportion (in %) of observed speeds of cars and vans higher than the speed limit on 50 km/h urban roads and mean observed driving speed on these roads in free flow traffic.	46.5 km/h mean speed; 65% below the speed limits	49 km/h mean speed; 54% below speed limits	N/A	49.4 km/h mean speed; 54% below speed limits
Proportion (in %) of observed speeds of cars and vans higher than the speed limit on rural non-motorway roads and mean observed driving speed on these roads in free flow traffic.	Speed limit 70 (2016) 68.3 km/h mean speed; 45% below the speed limits	Speed limit 70 69 km/h mean speed; 57% below the speed limits	N/A	
	Speed limit 80 (2016) 81.9 km/h mean speed; 42% below the speed limits	Speed limit 80 77.4 km/h mean speed; 58% below the speed limits		
	Speed limit 90 (2016) 88.9 km/h mean speed, 52% below the speed limits			Speed limit 90 (2016) 81.6 km/h mean speed; 69% below the speed limits
				Speed limit 110 (2016) 105.2 km/h mean speed; 81% below the speed limits
Proportion (in %) of observed speeds of cars and vans higher than the speed limit on motorways and mean observed driving speed on these roads in free flow traffic		Speed limit 100 (2017) 100.1 km/h mean speed; 47% below the speed limits	Speed limit 100 (2011) 98.6 km/h mean speed; 53% below the speed limits	
	Speed limit 110 (2016) 111.6 km/h mean speed; 40% below the speed limits	Speed limit 110 (2017) 102.3 km/h mean speed; 66% below the speed limits		Speed limit 110 (2016) 103.3 km/h mean speed; 70% below the speed limits

(continued)

Table 1 (continued)

	Sweden	Norway	Netherlands	France
			Speed limit 120 (2011) 113.8 km/h mean speed; 65% below the speed limits	
				Speed limit 130 (2016) 121.8 km/h mean speed; 72% below the speed limits

Unlike Victoria, Australia, the studied countries camera programs are primarily based on fixed cameras, and the number of cameras per million inhabitants varies between 41 (Norway) and 135 (Sweden) cameras. Speeding tickets per 1,000 inhabitants varies between 8 (Sweden) and 391 (the Netherlands)

the police interpret the law and prioritize their operations, namely, to catch offenders. However from a general road safety perspective, they would see more benefit if they influence a large proportion of the normal population.

Secondly, which also to some extent reflect the choice between the high-risk strategy or the population strategy, what is the appropriate mechanism for influence. According to Kahneman (2011), human behavior is based on two different systems, namely, system 1 and system 2. System 1 is fast and automatic, emotional, and unconscious. System 2 is slow, calculating, and conscious. Our enforcement strategies are, mostly implicitly, based on an idea about what system actually influences the road users' behavior. If one believes that the road users are rational and are carrying out conscious calculations about the costs and benefits of speeding, one refers speeding to an action originating from system 2. However if one thinks that speeding is an automatic and unconscious behavior, they believe it stems from system 1. Later in this chapter, speed camera systems in Victoria in Australia and Sweden will be discussed, and it appears that Australia based their system more on system 2 and Sweden on system 1 theory on road user behavior.

Manual Enforcement or Technology

Especially if the goal with the enforcement strategy is to catch those who deliberately violate the law and traffic rules, and therefore put themselves and others in danger, covert manned enforcement seems to be an appropriate strategy. Manual enforcement might also be an option within a more population-focused strategy however in this case based on an overt strategy. However according to some researchers, it is difficult for a police organization to maintain a high-profile manned enforcement over a long period of time (Bjornskau and Elvik 1992). This adaption

Fig. 3 Adaptation process police enforcement

process can be seen in Fig. 3. However technology creates new options. Regardless of strategy, automated enforcement can be put in use 24/7/365 and therefore deal with some of the negative effects and costs of manual enforcement.

Different Modus of Operandi

Many jurisdictions around the world have defined speed and speeding as important factors to control in order to focus on improving the road safety situation or even in the long run achieving a safe system. Many jurisdictions are also using an automated speed camera system to achieve these goals. However there are differences in the design of these systems and the way these systems are set up and operate. In other words, different ideas and strategies underpin these systems. In a study (Belin et al. 2010), speed camera system in Sweden and Victoria, Australia, was explored and compared. First, at least in early 1990, the lack of road safety was seen as caused by unappropriated behavior, and speeding was one of the most important. According to this study, the approach adopted in Victoria was based on the concept that the drivers are rational and they strive for driving as fast as possible and they are doing deliberate calculations of the cost and the benefits and therefore are choosing a speed where these are in balance. Based on an earlier section, it seems that the Australian system is grounded in the theory that speed behavior is emanating from system 2. Second, the Australian seems to have expanded their high-risk group "police model" with the focus on offenders to a large population. Regardless of who and where, speeding is a blameworthy behavior and needs to be detected and punished. Therefore the aim was to catch a large proportion of the drivers that exceed the speed limit, so that they experience the consequences, specific deterrence, and avoid re-offending and in turn tell others that they have been caught and suffered punishment, resulting in a general deterrence. The overall aim appears to be to establish a social norm that speeding is a serious offense along with supporting the introduction of large-scale camera surveillance. This was supported by broad informational campaigns with the aim to upset and outrage the viewers. Victoria was a forerunner in the beginning of 1990 when they took this new technology from demonstration phase to implementation of a large-scale speed camera system. However Sweden, Norway, the Netherlands, and France followed and gradually implemented their own large-scale speed camera system. In this section, these systems will be described and explored. Based on available data, focus will be on the systems operation in 2015.

Method and Data

A literature review was done in the literature databases Scopus and TRID, primarily focusing on studies from 2008 to 2019. Scopus is the world's largest bibliographic database, focusing on scientific articles in all subjects. TRID is an integrated database that combines the records from TRB's Transportation Research Information Services (TRIS) Database and the OECD's Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database. TRID provides access to more than 1.25 million records of transportation research worldwide. In addition to the searches in the databases, a request about gray literature was made from personal contacts.

In addition to the literature review, data from a study about speed enforcement in Europe done by ETSC (European Transport Safety Council) was used, ETSC (2016, 2019). ETSC is an independent nonprofit organization based in Brussels dedicated to reducing the numbers of deaths and injuries in transport in Europe. The report shows that methods on the levels of speed enforcement differ greatly between EU member states.

To compare attitudes in different countries, data from ESRA (E-Survey of Road Users' Attitudes) is used. ESRA is a joint international initiative of research centers and road safety institutes across the world, and in its first stage (ESRA1 2015), the project has surveyed road users in 38 countries on 5 continents, and in ESRA2 (2018–2019), 48 countries participated. ESRA data is collected through online panel surveys, using a representative sample of the national adult populations in each participating country (at least $N = 1,000$ per country). It is a jointly developed questionnaire, which is translated into national language versions. The themes covered include self-declared behavior, attitudes and opinions on unsafe traffic behavior, enforcement experiences, and support for policy measures. The survey addresses different road safety topics (e.g., driving under the influence of alcohol, drugs, and medicines, speeding, distraction) and targets car occupants, motorcycle and moped drivers, cyclists, and pedestrians. The aim of ESRA is to collect comparable data on the road safety situation and culture indicated by the road users' past and habitual behaviors, attitudes, beliefs, perceived norms, and values. The ESRA data is used as a basis for a large set of road safety indicators. These indicators provide scientific evidence for policymaking at national and international levels (see http://www.esranet.eu).

Four countries in Europe (Sweden, Norway, the Netherlands, and France) with different modus operandi and different levels of enforcement were selected and investigated in more detail, regarding modus operandi, level of speed enforcement, attitudes, and traffic safety effects.

Speed Camera System in Sweden, Norway, the Netherlands, and France

In a couple of reports from the European Transport Safety Council (ETSC) (ETSC 2016, 2019), data has been assembled concerning a variety of countries' speed control methods systems and speed camera system and their characteristics. Based on this, some interesting findings are summarized in Tables 1 and 2.

Table 2 Speed camera program and its characteristics in Sweden, Norway, the Netherlands, and France in 2015. Extracted from ETSC (2016)

	Sweden	Norway	Netherlands	France
Inhabitants	9, 7 million	5, 1 million	16, 9 million	66, 4 million
Total number of cameras (in operation)	1315	341	852	3953
Fixed cameras	1300	317	642	2180 886 (empty boxes)
Proportion of fixed cameras	99%	93%	75%	78%
Time over distance cameras	0	24	24	100
Owner responsibility	No	No	Yes	Yes
Speeding tickets from camera	78,423	90,524	6,609,418	12,728,539
Cameras per million inhabitants	135	41	50	60
Tickets per 1000 inhabitants	8	17,5	391	192

The speed limit, the mean speed, and the compliance of speed limits differ between the studied countries. All countries have 50 km/h, but it seems that Sweden has lower mean speed and higher compliance of the urban speeds compared to Norway and France. When it comes to rural roads, however, Sweden seems to have, compared with Norway and France, a lower compliance with the speed limits. The same pattern can be found when it comes to compliance with speed limits on motorways.

Even though all four countries studied based their camera operation on a system of fixed cameras, there are differences in the manner in which the owners of a vehicle are regulated, the number of traffic tickets, and number of cameras, and this might reflect strategic differences in the modus of operandi between these countries.

Firstly, both in Sweden and in Norway, in order for the government to assert liability for a speeding violation, the driver must be identified by a photograph. In the Netherlands and France, at least for the less severe speeding violations, it is sufficient to identify the car via the number plate and send a ticket to the owner of the car. If the owner hasn't driven the car, he or she will need to file a report as to who the actual driver was. Owner or driver liability could be a sensitive legal issue (SOU2005: 86), and, at least from a Swedish point of view, the government has not seen any possibilities to put any type of liability on the registered owner of the car for speeding violations. According to Swedish legal experts, owner liability conflicts with Swedish legal tradition. Driver versus owner responsibility could therefore has a large impact on how a camera system can operate from an administrative point of view and that might, at least partially, explain the number of traffic tickets that are issued. Secondly, there are large differences between Sweden and the rest of the countries in terms of the number of cameras per million inhabitants and how many traffic tickets are issued per 1,000 inhabitants. Sweden has about 2.5 more cameras per inhabitants however at the same time 50% less tickets issued per 1,000 inhabitants than in Norway. The Netherlands has similar number of cameras as Norway and France; however 49 times more tickets per 1,000 inhabitants are

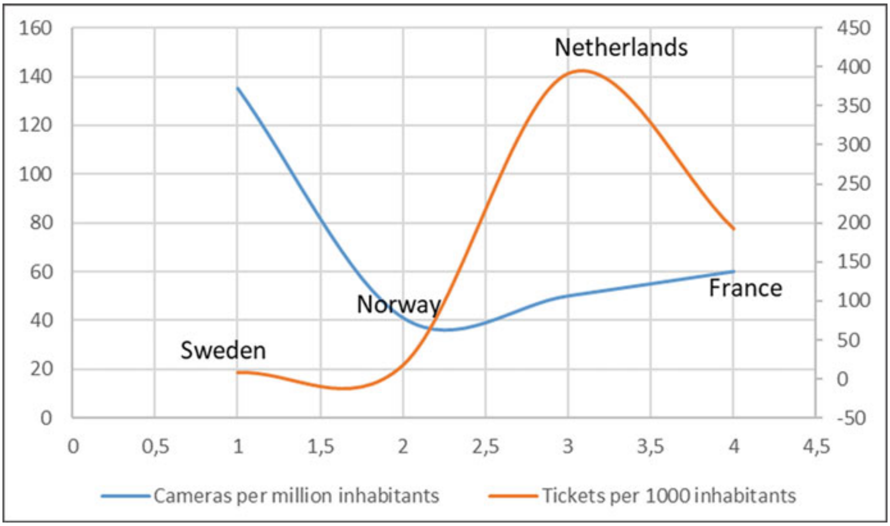

Fig. 4 Cameras and speeding tickets per inhabitants in Sweden, Norway, the Netherlands, and France. (Data from Table 2)

issued in the Netherlands than Sweden. The number of cameras and tickets per inhabitants is summarized in Fig. 4. Apparently, Sweden is at one extreme and the Netherlands is at the other.

Attitudes to Speeding and Enforcement

The different enforcement strategies in the four countries might lead to differences regarding attitudes and self-reported behavior in relation to speeding. Based on data from ESRA (2015), some comparisons of Sweden, Norway, the Netherlands, and France are made. As shown in Fig. 4, the number of speeding tickets per 1,000 inhabitants differs between the countries and especially between Sweden and the Netherlands. In ESRA, questions about perceived risk versus actual risk (self-reported) are investigated. Car drivers were asked to indicate their perceived likelihood of being checked by the police for speeding and how many times they have had to pay a fine for speeding during the last 12 months (Fig. 5). In Sweden it is only 2% that report that they have had to pay a fine at least one and in Norway 4%, while in the Netherlands it is about 15% and 11% in France. The pattern is the same for perceived risk with low values for Sweden and Norway, and higher for the Netherlands and France. In France, about 55% of the car drivers think it is a big chance of getting caught by the police, in the Netherlands 35%, while in Sweden and Norway it is only almost 20%.

Self-declared excessive speed behavior in Sweden, Norway, the Netherlands, and France is shown in Fig. 6. Answers from 1 (never) to 5 (almost) always, the figure reports 4–5 (often). Sweden and Norway show somewhat higher levels of self-

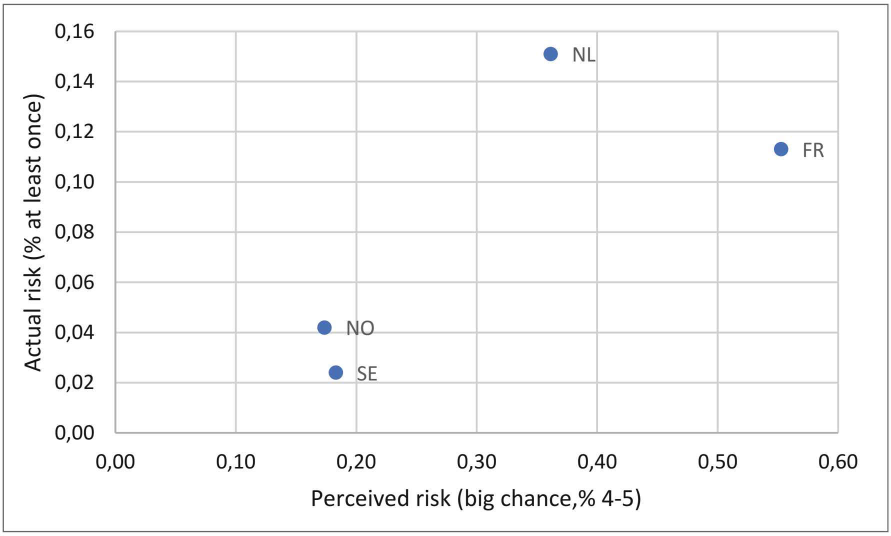

Fig. 5 Perceived versus actual risk. Perceived risk: On a typical journey, how likely is it that you (as a CAR DRIVER) will be checked by the police for respecting the speed limits (including checks by police car with a camera and/or flash cameras)? (1 = very small chance to 5 = very big chance). Actual risk: In the past 12 months, how many times have you had to pay a fine for violating the speed limits? (% of at least once). ESRA (2015)

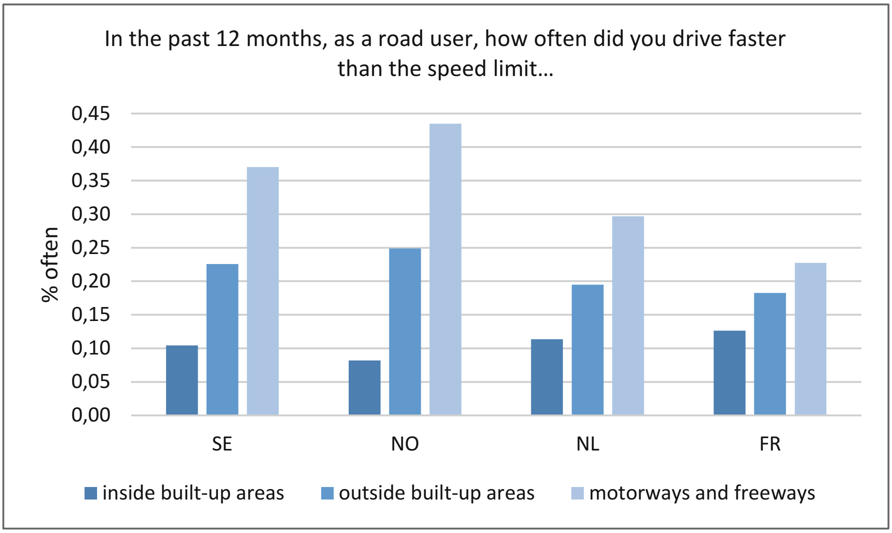

Fig. 6 Self-declared speeding behavior. ESRA (2015)

declared speeding behavior outside built-up areas and on motorways. Inside built-up areas, the trend is opposite with slightly lower reported levels of speeding for Sweden and Norway than for the Netherlands and France.

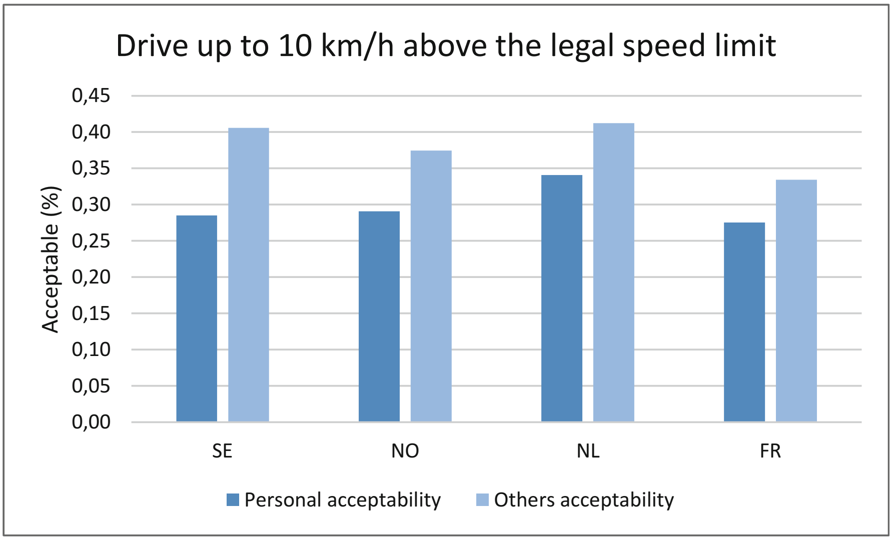

Fig. 7 Personal versus other's acceptability of speeding: "How acceptable … is it for a CAR DRIVER to… ?".% of road users who indicate driving faster than the speed limit as acceptable (% 4–5). ESRA (2015)

In Fig. 7, personal versus other's acceptability of low-level speeding, up to 10 km/h above the legal speed limit, is shown. Answers are on a scale from 1 to 5, where 1 is "unacceptable" and 5 is "acceptable," and the figure shows % answering 4 and 5. It is a rather similar pattern among the countries, with around 30% answering that they personally think it is acceptable to drive up to 10 km/h above the legal limit, while they think that others found it more acceptable (35–40%). The Netherlands has slightly higher values than France, Sweden, and Norway.

In Fig. 8, personal acceptability of unsafe traffic behavior in relation to higher levels of speeding in different situations is shown. Answers are on a scale from 1 to 5, where 1 is "unacceptable" and 5 is "acceptable," and the figure shows% answering 4 and 5. In general, it is more acceptable to exceed the speed limit by as much as 20 km/h on motorways/freeways and not acceptable in urban areas, school zones, and residential streets. On motorways/freeways, Sweden has the highest acceptability for high-level speeding, but on residential streets, France has the highest. In urban areas and school zones, none of the countries found it acceptable.

Traffic Safety Effects of Speed Cameras

Experience worldwide has proven the effectiveness of automatic speed cameras in reducing speed and, in turn, crashes and injuries. Section control, sometimes referred to as "average speed control" or "distance control: trajectory" (using the

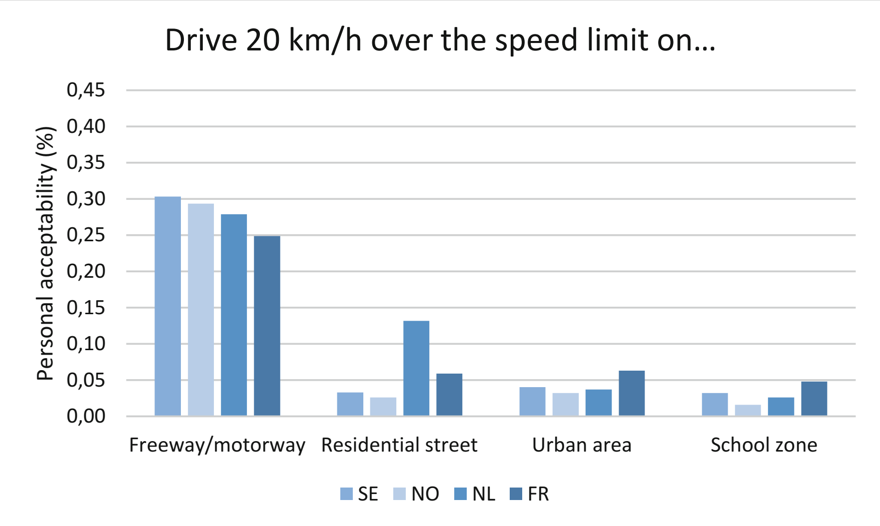

Fig. 8 Personal acceptability of speeding: "How acceptable do you, personally, feel it is for a CAR DRIVER to… ?"% of road users who indicate driving faster than the speed limit as acceptable (% 4–5). ESRA (2015)

measurement of the average speed over a section of road), is a relatively new measure, which seems to be very effective not only in reducing speed but also in contributing to more homogenized traffic flow (ITF 2018).

Comparison Between Section Control and Spot Speed Cameras

In Høye et al. (2019), effects of spot speed cameras and section control are studied. For fixed speed cameras, the mean speeds are reduced by 6%–15% within 500 m from the speed camera. For section control, studies in Norway (Ragnøy 2011) showed that section control reduced the mean speed over the section enforced by 11%, similar as the effects at the fixed camera sites. In a literature review by Soole et al. (2013), it was shown that section control reduced mean speeds between 8% and 28%. One advantage with section control compared to spot speed cameras is that mean speeds decrease over a longer part of the road section.

Looking at traffic safety effects, Høye et al. estimate in a meta-analysis that the number of injury crashes were reduced by 19% (−24, −14) and the number of fatalities by 51% (−72, −12) for spot speed cameras. The closer to the cameras, the larger effects on injury crashes. For section control, the injury crashes were reduced by 27% (−36; −16) and the number of fatalities and seriously injured by 54% (−63; −42).

For spot speed cameras, Høye et al. (2019) estimated that with larger distance from the camera, the effects on mean speed tend to be smaller. Looking at effects on mean speed in the near vicinity of the speed camera (< 250 m), the mean speed decreased by 11%; within 500–750 m after the speed camera, the mean speed decreased by 5%; and between 1,000 and 1,250 m after the camera by about 3%. For longer distances, the effects were smaller, and around 2,000 m after the camera, the mean speed decreased by only 1.4%. The number of personal injury crashes decreased by 18% in the near vicinity of the speed camera (<250 m); by 12%, within 500–750 m after; and by 7% at 1,000 and 1,250 m after the camera.

Change of Speed Distribution

Soole et al. (2013) concluded that section control is effective in reducing mean speed, P85, and speed variations between vehicles, and in many studies referred to in Soole et al. (2013), the decrease in P85 was greater than the decrease in mean speed. Similar changes are seen for spot speed cameras in the immediate vicinity surrounding the cameras (Vadeby and Forsman 2017), which suggests a change in the shape of the speed distribution. Overall, P85 decreases more than the average speed, and the proportion of serious offenses decreases more than total offenses. Figures 9 and 10 show the speed distribution before and after new speed cameras are installed on rural roads with a speed limit of 90 km/h (spot speed cameras at camera sites and between camera sites). Before the cameras were introduced (red line), about 60% of all cars complied with the speed limit at the camera sites and about 50% between camera sites. After the cameras were introduced, 90% of the cars complied with the speed limit at camera sites and 60% between sites. Comparing the change in the speed distributions, this was more pronounced at camera sites (Fig. 9). For high speeds, there was a larger displacement to the left after the cameras were introduced.

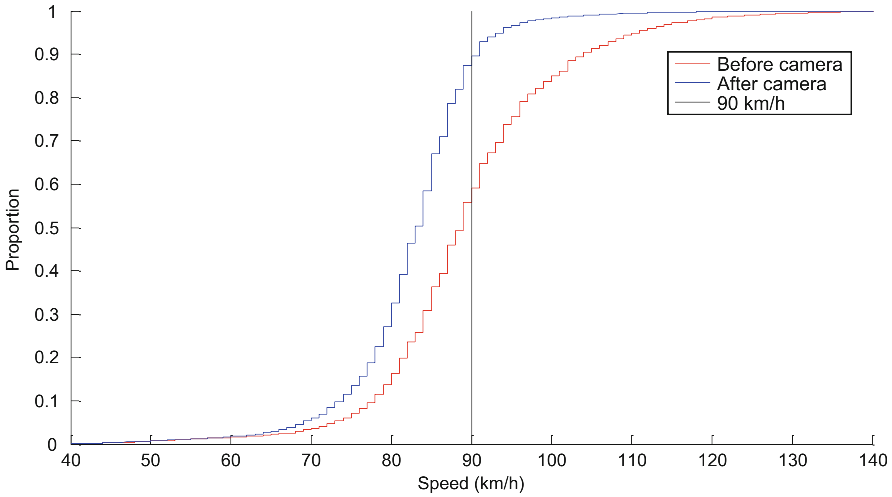

Fig. 9 Effect on driving speed at camera sites of new speed cameras on roads with a speed limit of 90 km/h. Speed distribution for all cars before and after new cameras

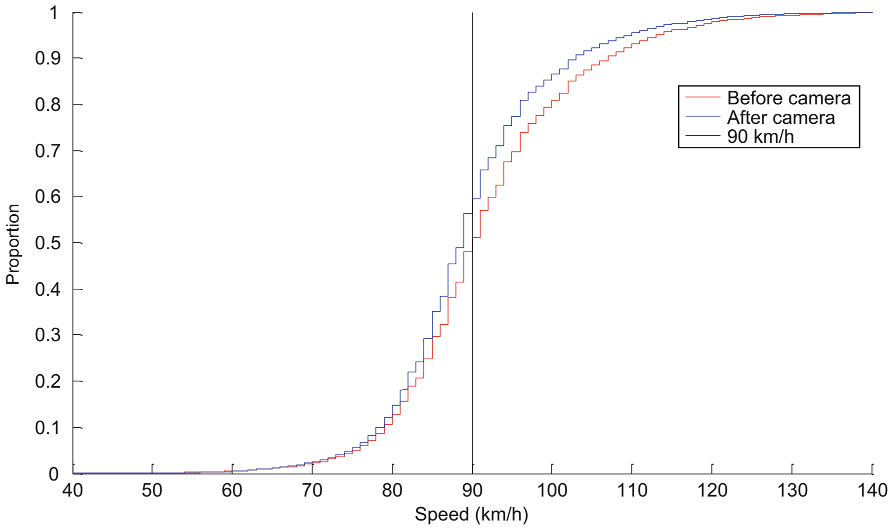

Fig. 10 Effect on driving speed between camera sites of new speed cameras on roads with a speed limit of 90 km/h. Speed distribution for all cars before and after new cameras

Experience from the Netherlands, Sweden, Norway, and France

Sweden

In Sweden, spot speed cameras are used, but the cameras are located along road sections and placed in succession with the aim to lower the speed along the entire road section.

Evaluations of the Swedish speed cameras (STA 2009; Larsson and Brüde 2010) have shown that they decrease mean speed by 4.3% (−3.6 km/h) taken over all camera road sections and speed limits. The reduction at camera sites varies between 7% and 12% depending on speed limit. Between cameras, the reduction was smaller, maximum 5%. It was also shown that the speed cameras reduced the 85th percentile (P85) more than the mean speed, by 5.9% (−5.5 km/h). Similar patterns, with larger decreases for higher speeds, have been found in terms of speed compliance, meaning that those who drive the fastest are most influenced by speed cameras. The proportion of drivers who exceed the speed limit decreased by approximately 34%. As regards traffic safety, Larsson and Brüde (2010) showed that the number of fatalities was reduced by 30% and the number of people killed or seriously injured (KSI) by 25%.

Norway

In Norway, both section control and spot speed cameras are used. Cameras are located on roads with a high injury crash record, and since 2009 there is a criterion on speed (mean speed above the speed limit) and for crash costs (at least 30% above average crash costs on similar roads in Norway). It is possible to install speed cameras at sites that meet one of the criteria.

In Høye (2014b, 2015), the safety effects of spot speed cameras were investigated for speed cameras installed between the years 2000 and 2010. The study showed that on road sections between 100 m upstream and 1,000 m downstream of the cameras, the number of injury crashes decreased by 22%. For longer road sections (3.1 km), the effects were smaller. Ragnøy (2002) evaluated the effects on speeds and concluded that depending on the speed limit and mean speed in the before situation, as well as the distance to the camera, the effect of speed cameras on mean speed varies from −1.4 km/h to −7.1 km/h.

For section control (14 road sections of whom 8 were in tunnels), Høye (2014a) showed that the number of injury crashes decreased between 12% and 22%. An earlier evaluation of Ragnøy (2011) showed that mean speed decreased by 11% at the enforced road section, similar effects as at the near vicinity of the spot speed cameras.

The Netherlands

In the Netherlands, speed cameras are used to register speeding offenses, and the vehicle owners are identified based on vehicle registration number. There are mostly spot speed cameras, both fixed and mobile; however at some motorways, section control has been introduced. The guidelines for where the cameras should be placed states that they should be located at roads with a relatively high number of crashes, where there is a plausible connection between crashes and speed and where there is a relatively high percentage of speeders.

The effects of mobile speed cameras were studied by Goldenbeld and Van Schagen (2005). Their study showed that mean speed decreased with 4 km/h from 82.6 to 78.6 km/h and the percentage of speed offenders decreased from 27.4% to 15.6% on the roads with mobile speed enforcement. The number of personal injury crashes involving motorized traffic decreased by 21%. Effects of regression to the mean were not considered in the analysis, and it is therefore likely that the real effect is somewhat smaller.

France

Automated speed cameras were introduced in France in 2003, following a decision by President Chirac in 2002 to make road safety one of the three major national priorities during his mandate. Fixed and mobile speed cameras were implemented progressively, and between 2003 and 2009, about 1,700 fixed speed cameras were implemented, supplemented by more than 900 mobile cameras. All fixed cameras had a sign identifying its presence approx. 1 km ahead of the camera. In the beginning, it was a central decision to decide exactly where the cameras were to be placed, and they were installed at points in the network with the most traffic. Later on the locations were decided upon at the local level taking the characteristics of the infrastructure and levels of crash risk into account. Between 2002 and 2005, the mean speeds fell by 8.9 km/h on secondary roads and by 7.7 km/h on two- or three-lane highways (two-way roads). Fatalities decreased by 25–35% in rural areas, 38% on urban motorways, and 14% on urban roads (ITF 2018). Viallon and Lamon (2013) showed that the French speed camera program reduced the proportion of fatal crashes attributable to high-level speeding (>20 km/h over the limit) from 25% to 6% over the period 2001–2010 and increased the proportion attributable to low-level speeding from 7% to 13%.

Discussion

In this chapter, speed limits, speed management, and different methods to influence speed behavior has been analyzed and explored. Vision Zero as a policy framework has guided this analysis. The second part of the chapter covers an analysis of Sweden, Norway, the Netherlands, and France speed camera program, or safety camera system which at least Sweden prefer to name it. This analysis also includes a discussion around related traffic safety effects, self-reported behavior, and attitudes.

First, to analyze speed compliance, the speed limits and what criteria that underpins the choice of specific speed limits need to be discussed. In a Swedish historical context, it is obvious that the speed setting rationale has evolved over the years. In practice therefore, there is a mix of speed limits based on different criteria and speed setting regime. It is also obvious that, over the years, every regime drives down the speed limits. The 85-percentile regime implemented in the 1960s has higher speed claims than speed limits set according to Vision Zero. From a safety point of view, this could see as a paradox because at the same time both the infrastructure and the cars have become safer. One explanation could be that safety as a value, within a transport policy framework, has been strengthened over the years and that speed limits are seen as an integrated part of the road transport system rather than only an instrument to limit some road user choice to drive at very high speeds. However from a strict compliance perspective, lower speed limits might increase the proportion of drivers who violate the speed limit (Vadeby and Forsman 2014). Although it is difficult to draw any firm conclusions, it seems that the speed limit sign itself is the most important factor influencing the drivers' choice of speed regardless of the design of the environment and the vehicle. Even if one is on a motorway in a car that can do more than 200 km/h and the speed sign shows 80 km/h, many drivers will comply with the speed sign to a large extent. Without the speed sign, one could expect rather higher speed. Setting the speed limits according to people's actual behavior in order to increase compliance seems therefore rather awkward. Vision Zero is a policy innovation which differs from a traditional approach to road safety in several respects. These differences are also evident when it comes to setting the speed. Traditionally, the speed limit system is seen as an instrument to lower the risk and make the road transport system safer. Based on a

Vision Zero approach, the speed limit system and its different speed limits are seen as a labeling of the safety thresholds. If you as a driver keep within the speed limits, as it is posted and below, then you can expect, if an accident occurs, that you will survive and without any serious injuries. This is radical change in the mind-set when it comes to speed and speed limits, and these ideas are more in line with the society dealing with toxicological substance, for example. These substances are accepted if they are kept below the threshold for serious impact on humans. Although a system like this is complicated and there are lots of trade-offs when it comes to details, this type of system could be easier to communicate to the public. In this context, speed and speed limits are a safety regulation factor. Safe (and environmentally friendly) roads and vehicles enable to facilitate higher speeds regardless of the driver's behavior.

Second, irrespective of what criteria that underpins speed limits, the drivers' speed compliance is an important issue including drivers speed choice and motives. One important dimension is the target group for different interventions, namely, risk groups or population-based strategies. Most countries are most likely carrying out both these strategies; however historically, especially in the more advanced countries, it seems that strategies aiming to increase compliance with speed limits are being advanced with a more population-based strategy. Another important dimension is if drivers' choice of speed is a result of a deliberate calculation of the cost and benefits (the "economic man," an idealized person who acts rationally, with perfect knowledge and who seeks to maximize personal utility) of speeding, or if the choice is more a result of unconscious habits and social norms. In public policy in general and in road safety in particular, the theory about the economic man does have a dominant position. However, due to new research, especially relating to nudging, new perspective has emerged, and the Swedish safety camera system is probably a good example of nudging in practice.

Third, there is a strong ongoing discussion about digitalization automation and new technology in our society. Although these trends could result in completely new products and service, many times it is most cases rather replacements of existing products and services. Speed enforcement is such public service that has gone through a large change from manual enforcement to camera surveillance. Productivity and efficiency are important drivers for this to happen. Finally, speed limit system, speed management, theory about human behavior, use of new technology, and public policies such as Vision Zero are all factors that influence how different jurisdictions manage their speed camera program and its characteristics. In this chapter, we have shown that even though Sweden, Norway, the Netherlands, and France all are countries in Europe, the way that they operate their camera program has both similarities and differences. It seems that all these countries have invested primarily in fixed camera systems. However the systems scale and how they operate are different. It is difficult to evaluate and compare these systems from a safety point view, at least from a macro perspective.

A speed camera system has the possibility to affect the society and its road users both at a macro and at a micro perspective. In a micro perspective, it is primarily about how effective the cameras are locally at the enforced road sections, while at a macro perspective it is more about how the camera enforcement system, possibly together with the overall enforcement strategy, affects attitudes and norms related to speeding. Experience worldwide has proven the effectiveness of automatic speed cameras in reducing speed and, in turn, crashes and injuries. In this chapter where Sweden, Norway, the Netherlands, and France are compared, it is shown that there are large discrepancies in the camera enforcement strategies of the four countries. Looking at the number of cameras, Sweden has 135 cameras per million inhabitants while the other three countries have between 40 and 60 cameras per million inhabitants. If instead the number of speeding tickets is compared, Sweden has only 8 tickets per 1,000 inhabitants, while Norway has 18, France 192, and the Netherlands 391. One interesting question is how these differences affect both the actual outcome of the system in terms of speeds, crashes, and injuries and, however, also the norms and attitudes in the society. In all four countries, evaluations of the camera system are performed; however the evaluation methods are different and the results therefore not exactly comparable. Looking at mean speed, in Sweden the mean speed decreased by about 4% looking at an entire enforced road section, however, with larger effects near the cameras. The Netherlands showed decreases of about 4 km/h as an effect of mobile speed cameras; however the evaluation does not clarify at what distances from the cameras. In France, a general mean speed decrease of about 8 km/h between 2002 and 2005 was seen, attributed primarily to the effects of speed cameras (ITF 2018). In Norway, it was shown that section control decreased average speeds by 11% over the entire enforced road section (Ragnøy 2011), similar effects as in the near vicinity of spot speed cameras. Looking at the reduction of injury crashes, Sweden shows a decrease of severe crashes by 25% and of fatalities by 30%, Norway and the Netherlands a reduction of all injury crashes by about 20%, and France reductions of fatalities by approximately 30% in rural areas. If the differences between injury level in the investigations are considered as estimated by the power model (Elvik 2013; Elvik et al. 2019), it is not possible to show any major differences between these four countries in a micro perspective.

The enforcement strategies and in particular the number of cameras and speeding tickets issued also affect the attitudes and norms of the road users. Results from ESRA show that when car drivers were asked to indicate their perceived likelihood of being checked by the police for speeding, car drivers in Sweden and Norway report much lower perceived risk than the Netherlands and France. In France, about 55% of the car drivers think it is a big chance of getting caught by the police and in the Netherlands about 35%, while in Sweden and Norway it is only about 20%. The pattern is very similar to the number of issued tickets per 1,000 inhabitants. When looking at how many times car drivers that report they have had to pay a fine for speeding during the last 12 months, it is a similar relationship where only 2% in Sweden report they have had to pay a fine at least one and in Norway 4%, while in France 11% and the Netherlands about 15%.

The ESRA survey also investigates self-reported behavior in relation to speeding. In all four countries, it is a similar pattern, where about 30% answering that they personally think it is acceptable to drive up to 10 km/h above the legal limit. The

Netherlands has slightly higher values than France, Sweden, and Norway. Looking at more severe speeding in different situations, it is shown that in general, it is more acceptable to exceed the speed limit by as much as 20 km/h on freeways and motorways and not acceptable in urban areas, school zones, and residential streets. This pattern is the same among the four countries, even though the reported level differs somewhat. On motorways/freeways, Sweden has the highest acceptability for high-level speeding, but on residential streets, France has the highest. In urban areas and school zones, none of the countries found it acceptable to exceed the speed limit by 20 km/h.

In conclusion, the different enforcement strategies regarding the number of cameras and speeding tickets issued has the possibility to affect the society and its road users both at a macro and micro level. Locally, in a micro perspective on the enforced roads, the effects of speed cameras are rather similar among countries, and differences can probably be explained by the type of camera (spot speed or section control), distances between cameras, and local conditions. In a macro perspective, the perceived risk and self-reported risk of getting caught in a speed check is correlated with the number of issued speeding tickets. Though the perceived likelihood of being checked by the police differs between the studied countries, self-reported speeding behavior is rather similar. Therefore, an important aspect that needs to be analyzed and discussed is how to optimize a speed camera system from a road safety point of view. There are two problems that might occur. First, even though a speed camera program delivers lower speed locally, a low amount of fines might hinder the possibility of also affecting a general speed compliance culture. Second, if the system issues many fines, after a while the drivers might regard these fines as simply an extra charge which they are forced to pay – but it will have little or no effect on their speed behavior. A speed cameras system could become primarily a revenue-raising system rather than a road safety instrument. A hypothesis could be that Sweden might not operate their system optimal from a safety point of view and need to increase the number of fines issued. On the other hand, it may be that from a safety point of view in the Netherlands, too many fines are issued. The public perception about raising revenue does matter, considering that it can hinder the implementation of statutes and programs, and it generally has an impact on people's general attitudes.

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Driver Distraction: Mechanisms, Evidence, Prevention, and Mitigation

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Abstract

In this chapter, the reader is introduced to the topic of driver distraction: its definition and mechanisms; its impact on driving performance and safety; approaches to preventing it; evidence-based injury prevention and mitigation countermeasures; and new frames of reference for conceptualizing distraction as traditional driving functions and tasks become increasingly automated. Some strategies that might be considered by societal stakeholders in setting a coordinated agenda for the management of distracted driving going into the future are also presented. Until all vehicles can safely drive themselves, in all conditions, all of the time, it is unlikely that, for driver distraction, Vision Zero will be achieved. In the meantime, however, there is much that can be done to slow its spread and mitigate it effects.

Keywords

Driver distraction · Distracted driving · Road safety · Theory · Impact · Countermeasures · Mitigation · Vision zero

Introduction

Driving is a complex activity that requires, often simultaneously, the performance of one or more driving functions: route finding, route following, velocity control, collision avoidance, rule compliance, and vehicle monitoring (e.g., of fuel status) (Brown 1986). Despite the complexity of this activity, it is common to see drivers engage simultaneously in a range of other, non-driving, activities that have potential to distract them and compromise the performance of these driving functions.

Driver distraction is one of several mechanisms of *driver inattention* (Regan et al. 2011; Engström et al. 2013) and there is converging evidence that it is a road safety problem (e.g., Beanland et al. 2013; Oviedo-Trespalacios et al. 2016; Dingus et al. 2016). This chapter provides the reader with a general understanding of driver distraction and how to manage it as a road safety issue. We commence by defining what is meant by “driver distraction” and distinguishing it from other forms of driver inattention.

Driver Distraction: Definition, Mechanisms, and Impacts on Driving Performance

Defining “Driver Distraction”

Distraction has been defined inconsistently in the literature (Regan et al. 2011). This is problematic as, in the absence of a commonly accepted definition that can be operationalized and used to code crash and incident data, the role of distraction as a contributing factor in crashes and incidents will be ambiguous (Beanland et al. 2013) – and may lead to quite different estimates of its contribution to crashes and incidents (Gordon 2009). Inconsistencies in definition also make the comparison of research findings across studies difficult, or impossible (Lee et al. 2009).

Driver distraction and driver inattention are related constructs. Like driver distraction, there has been inconsistency in the literature around the definition of driver inattention, and some diversity in thinking about the relationship between the two constructs (Regan et al. 2011). To this end, Regan et al. (2011) attempted to elucidate the relationship between driver distraction and inattention, in the form of a taxonomy of driver attention. The taxonomy was derived from a review of previous classifications of attentional failures identified as having contributed to crashes in in-depth crash studies (e.g., Treat 1980; Hoel et al. 2010; Van Elslande and Fouquet 2007; Wallén Warner et al. 2008). Regan et al. (2011) defined driver inattention as "insufficient or no attention to activities critical for safe driving" (p. 1780) and proposed that driver inattention is induced by five attentional mechanisms (identified in Table 1 below), one of which they labelled "Driver Diverted Attention," which is synonymous with driver distraction. (See Regan et al. (2011) for a more detailed

Table 1 Mechanisms of driver inattention (Source: Regan et al. 2011)

Mechanism of inattention	Definition
Driver restricted attention	"Insufficient or no attention to activities critical for safe driving brought about by something that physically prevents (due to biological factors) the driver from detecting (and hence from attending to) information critical for safe driving" (p. 1775); e.g., due to drowsiness or fatigue – driver dozes off momentarily, with eyes closed, and almost hits a pedestrian crossing the street ahead
Driver neglected attention	"Insufficient or no attention to activities critical for safe driving brought about by the driver neglecting to attend to activities critical for safe driving" (p. 1775); e.g., due to faulty expectations; driver neglects to scan to the left for approaching trains at a railway level crossing because s/he does not expect trains to be there (because they are rarely or never seen)
Driver mis-prioritized attention	"Insufficient or no attention to activities critical for safe driving brought about by the driver focussing attention on one aspect of driving to the exclusion of another, which is more critical for safe driving" (p. 1775); e.g., driver looks over their shoulder for too long while merging and fails to see a lead vehicle in front braking rapidly
Driver cursory attention	"Insufficient or no attention to activities critical for safe driving brought about by the driver giving cursory or hurried attention to activities critical for safe driving." (p. 1776); e.g., a driver on the entry ramp to a freeway who is in a hurry does not complete a full head check when merging and ends up colliding with a merging car
Driver diverted attention	"The diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving" (synonymous with driver distraction; p. 1776); e.g., a driver reading a text message on a mobile phone while driving; a driver daydreaming or engaged in internal thought that is driving- or non-driving related

description of their taxonomy and Engström et al. (2013) for a description of a very similar taxonomy of driver inattention derived from a first principles review of human attentional theory.)

Regan et al. (2011) defined driver diverted attention (i.e., driver distraction) as "the diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving" (p. 1776). This definition was modelled on an earlier definition formulated by Lee et al. (2009, p. 34) that was subsequently endorsed by an international group of experts convened by the International Organization for Standardization (ISO): "Driver distraction is the diversion of attention away from activities critical for safe driving toward a competing activity."

Both of these definitions are widely cited in the international literature and are considered suitable by the authors for framing and interpreting the material reported in this chapter. Both definitions carry with them some assumptions (Regan and Hallett 2011):

- Competing activities can be driving-related (e.g., a flashing low fuel warning light) or non-driving related.
- Driver engagement in competing activities can occur involuntarily or be driver-initiated.
- Competing activities can derive from inside the vehicle or outside of the vehicle.
- Competing activities may derive from unknown sources of distraction internal to the mind, such as when daydreaming.
- Driver engagement in competing activities may interfere with the performance of activities critical for safe driving that can be seen (e.g., a lane excursion) or unseen (e.g., a freeway exit missed).

Engström et al. (2013) characterize "activities critical for safe driving" as ". . .those activities required for the control of safety margins" (p. 17). These include (p. 17) "activities at all levels that are required to maintain acceptable safety margins, such as maintaining headway, keeping in the lane, visually scanning an intersection for oncoming vehicles, deciding whether to yield and interpreting safety-related traffic signs, but excludes those driving-related activities that are not directly related to safety margin control, such as navigation, route finding and eco-driving."

While performance of a competing activity may divert attention away from any of the driving functions identified by Brown (1986), it is the impact of this diversion on activities critical for safe driving that has been of most interest to the road safety community – and is the reason why the two distraction definitions described above have been framed in the way they have.

Factors That Trigger Driver Distraction

An episode of driver distraction may be triggered through various mechanisms that have been found to relate to a driver's state, driver needs, properties of the source of the distraction, internal (to the mind) stimuli that trigger distraction, and a driver's personality characteristics. These mechanisms can, in turn, be classified broadly as either top-down (voluntary; endogenous) or bottom-up (involuntary; exogenous) mechanisms (e.g., Trick and Enns 2009; Lee et al. 2020).

Various driver *states* may trigger a diversion of attention, including boredom, sleepiness, or fatigue (e.g., Atchley and Chan 2011), social angst (e.g., fear of missing out; Atchley and Warden 2012), and emotionality (e.g., affective state; Chan and Singhal 2013). Driver *needs* may also trigger a diversion of attention and include the need to communicate with others (Oviedo-Trespalacios et al. 2020a), to be informed (Engelberg et al. 2015), to be entertained (George et al. 2018; Steinberger et al. 2016), and to satisfy basic biological drives like hunger (Irwin et al. 2015). For example, a biological feeling of hunger may trigger a whole chain of internal thoughts about what a driver would like to eat, where they might find what they want to eat, etc., all of which will distract them. These triggering factors that stem from driver states and needs can be characterized as top-down factors (Trick and Enns 2009).

The physical properties of a source of distraction may themselves become distraction triggering factors from a bottom-up perspective. For example, things that are moving, unusual, attractive, unexpected, threatening, salient, or conspicuous are most likely to entice a diversion of attention away from activities critical for safe driving (Regan et al. 2011). Similarly, internal thoughts or internal stimuli from deep within the mind can trigger distraction in a bottom-up manner (as when daydreaming, mind-wandering, or engaged in task-unrelated thoughts; e.g., Smallwood and Schooler 2006). Finally, personality factors, such as a driver's willingness to engage in distracting activities (Lerner and Boyd 2005) and whether they are particularly vulnerable to attentional capture (distraction prone; Peña-Suarez et al. 2016), may also act as distraction triggers.

There are, in short, many factors that can trigger driver distraction: that is, trigger a diversion of attention away from activities critical for safe driving toward a competing activity.

Competing Activities and Sources of Distraction

A competing activity can be conceptualized as an action performed by a driver on a source of distraction that competes for attention required for the performance of activities critical for safe driving (Regan et al. 2009); for example, as in dialling (the action) a phone number using a mobile phone (the source of distraction). The source of distraction and the actions performed on it by the driver, together, define a competing activity (Regan et al. 2009).

Regan et al. (2009) reviewed seven research studies (five crash studies and two observational studies) in which driver distraction was cited as a contributing factor. They identified around 60 different sources of distraction that gave rise to competing activities in these studies and distilled them into the following broad categories (Regan and Hallett 2011):

- Objects (e.g., mobile phone, advertising billboard, apple).
- Events (e.g., crash scene, lightning).
- Passengers (e.g., child, adult).
- Other road users (e.g., cyclists, pedestrians, other vehicles).
- Animals (e.g., dog).
- Internal stimuli (e.g., that trigger thoughts or the urge to cough or sneeze).

These sources of distraction will be distracting only if drivers interact with them. Regan et al. (2009) identified 53 separate, although not necessarily mutually exclusive (e.g., answering, drinking, listening) actions, that were performed on the various sources of distraction revealed by their analysis.

A consistent finding in the literature is that around 30% of distraction-related crashes derive from driver engagement with distraction sources *outside* the vehicle. These include animals, architecture, advertising signage, construction zones/equipment, crash scenes, incidents (e.g., road rage), insects, landmarks, road signs, road users, scenery, other vehicles, and weather (e.g., lightning) (Gordon 2009).

A failure to differentiate between a source of distraction and the actions performed on it by a driver can lead to imprecision in the classification of distraction sources. Regan et al. (2009), for example, noted a tendency in some of the studies they reviewed to confound the reporting of events, objects, and actions as sources of distraction. The following, for example, were reported as sources of driver distraction in some of the studies they reviewed (e.g., Gordon 2005): "automobile mechanical problem," "trying to find destination/location," "driver dazzled by sunstrike," "checking for traffic," and "police/emergency vehicles".

There is also some confusion in the literature about whether driver states (e.g., fatigue) are themselves sources of distraction. The following, for example, were reported as distraction sources in one of the studies reviewed by Regan et al. (2009; Glaze and Ellis 2003): "driver fatigue/asleep" and "alcohol and fatigue/sleep." Driver states, such as being fatigued or intoxicated by alcohol, are not in themselves sources of distraction. Rather, they are biological states that can give rise to inattention in the absence of a competing activity (Regan et al. 2011). In the taxonomy of inattention proposed by Regan et al. (2011) (see Table 1), this mechanism of inattention is referred to as driver restricted attention.

Types of Distraction and Triggered Responses

Types of Distraction

A source of distraction has certain "modal properties" (Hallett et al. 2011) which, along with its other physical properties, the state of the driver, drivers' needs and their personality characteristics, may also trigger a diversion of attention away from activities critical for safe driving.

It is the modal properties of a source of distraction that have been invoked in the literature to define "types" of distraction. An advertising sign, for example, may induce "visual distraction" if a driver looks at it and "internal distraction" (see below) if s/he thinks about the message(s) it conveys (Regan and Hallett 2011). Types of distraction have been characterized in the literature in two ways. Regan (2010) and Regan and Hallett et al. (2011) differentiate as follows between six types of distraction based on the sensory modality through which the diversion of attention toward a competing activity is initiated:

- Diversion of attention towards things that we see ("visual distraction").
- Diversion of attention towards things that we hear ("auditory distraction").
- Diversion of attention towards things that we smell ("olfactory distraction").
- Diversion of attention towards things that we taste ("gustatory distraction"; e.g., the taste of a rotten piece of apple).
- Diversion of attention towards things that we feel (tactile distraction; e.g., the feel of a hairy spider crawling on one's leg).
- Diversion of attention towards things that we think about (internal or "cognitive" distraction).

It is more common in the literature, however, for "types" of distraction to be differentiated according to the *impact* that a competing activity has on activities critical for safe driving (e.g., WHO 2011):

- "Visual distraction" – taking one's eyes off the road
- "Cognitive distraction" – taking one's mind off the road
- "Auditory distraction" – taking one's ears off the road
- "Biomechanical distraction" – taking one's hand(s) off the steering wheel.

There are, however, problems with this latter way of conceptualizing "types of distraction": (1) it results in an artificially restricted range of distraction types which have potential to interfere with activities critical for safe driving (i.e., it excludes consideration of tactile, olfactory and gustatory distraction); (2) taking one's ears off the road is really a by-product of taking one's mind off the road (e.g., as when failing to hear the sound of an approaching motorcycle when engrossed in a mobile phone conversation), rather than a type of distraction per se; and (3) "biomechanical distraction" is actually a form of bimanual, or structural, interference (Kahneman 1973; McLeod 1977) induced by distraction, not a type of distraction per se.

Triggered Responses

The repertoire of driver actions (e.g., answering, listening, writing) that may be performed on all the sources of distraction known to exist is potentially huge. However, the behavioral effects triggered by these driver actions, that may lead to interference (see below) with activities critical for safe driving, appear finite in number. Hallett et al. (2011) have referred to these behavioral effects as "triggered responses" and have characterized them (for distracted drivers) as follows:

- *Eyes off the road* – driver takes eyes off activities critical for safe driving.
- *Mind off the road* – driver takes mind off activities critical for safe driving.

- *Ears off the road* – driver takes ears off activities critical for safe driving (as a result of having one's mind off the road).
- *Hands or feet off controls* – driver takes hands and/or feet off activities critical for safe driving.

Conceptualized this way, a given type of distraction (e.g., visual distraction; as defined by Regan and Hallett 2011) may give rise to one or more of these triggered responses, often simultaneously. For example, visual distraction, such as that deriving from the diversion of attention toward an advertising billboard, may take both a driver's eyes off the road (as when looking at the billboard) and their mind off the road (when thinking about its contents), and while thinking about its contents, their ears off the road (if they become oblivious to auditory information around them critical for safe driving).

Interference

Triggered responses created by a driver performing an action, or actions, on a source of distraction will likely interrupt or interfere in some way with the performance of activities critical for safe driving.

Driving is a complex, multitask activity (Regan and Strayer 2014; Lee et al. 2009) and different types of attention are required for the performance of activities critical for safe driving, depending on the moment-to-moment requirements of driving. These may include focussed attention, selective attention, divided attention, sustained attention, and switched attention (Wickens and McCarley 2008). Driving, and specifically activities critical for safe driving, also require for their performance the execution of a range of psychological processes that span all stages of the human information processing chain (Michon 1985): detection, perception, short- and long-term memory, decision-making, and responding. Driving typically involves, at any one time, the concurrent execution of multiple tasks, each involving one or more of these types of attention and human information processes. When attention is diverted toward a competing activity, the triggered responses that it generates may interfere with the performance of any or all of these processes during the time that attention is diverted, and may even continue to interfere with activities critical for safe driving for some time after attention returns back to driving (e.g., Strayer and Fisher 2016).

Generally, the degree of interference generated by a competing activity will be a function of three factors (Wickens 2002, 2005):

- The joint demand of the activities critical for safe driving and the competing activity being performed.
- The degree to which both activities compete for access to common human information processing resources (stages of processing [perceptual-cognitive versus action or early versus late processing], processing codes [verbal versus spatial], perceptual modality [auditory versus vocal], and visual channel [focal versus ambient]).

- The manner in which the driver's attention is distributed between both activities in order to meet their joint demands, whether it is divided between both activities or is focussed primarily on the competing activity.

The research community is still at an early stage, however, in operationalizing the specific mechanisms of interference brought about by distraction, which are discussed further in this chapter in the section "Evidence Implicating Distraction as a Traffic Safety Problem." While few of these mechanisms have been operationalized, the impacts that they have on driving performance are better researched and understood. They are discussed in the section "Moderating Factors and Self-Regulation."

Moderating Factors and Self-Regulation

The impact that the performance of a competing activity has on activities critical for safe driving is not constant. The same competing activity (e.g., talking on a mobile phone) may have different effects on activities critical for safe driving depending on factors such as the characteristics of the driver, the demands of driving, the demands of the competing activity, and the ability of the driver to self-regulate their behavior in the face of, or in anticipation of, distraction (Young et al. 2009). Young et al. have labelled these factors "moderating factors" and distinguish between four such factors.

- *Driver characteristics*: There are characteristics of the driver which may influence the impact of distraction on activities critical for safe driving – by moderating a driver's willingness to engage in distracting activities, their ability to divide attention between multiple tasks, and their ability to self-regulate their driving in order to maintain suitable safety margins when distracted (Young et al. 2009, p. 340). These characteristics include driver age, gender, driving experience, driver state (e.g., drowsy, drunk, angry), familiarity with and amount of practice with the competing task, and personality (e.g., the propensity to take risks and succumb to peer pressure) (Huth and Brusque 2014; Oviedo-Trespalacios et al. 2020b).
- *Driving task demand*: The characteristics of the primary driving task itself may influence, in at least two ways, the impact that a competing activity has on activities critical for safe driving: (a) by increasing or decreasing the driver's mental workload and, hence, reducing or increasing the amount of cognitive resources available for performance of competing activities and (b) by modifying the probability that the driver will have to react rapidly to an unexpected critical event that can give rise to a collision (Young et al. 2009). These characteristics include traffic conditions, weather conditions, road conditions/design, the number and type of vehicle occupants, the ergonomic quality of vehicle cockpit design, and vehicle speed (Li et al. 2020a; Onate-Vega et al. 2020; Oviedo-Trespalacios et al. 2017a, 2020b).

- *Secondary task demand*: The demands of the competing activity will also influence the degree to which it interferes with activities critical for safe driving, and hence distracts the driver. Secondary (competing) task characteristics that influence secondary task demand include (a) how similar the task is to driving sub-tasks (e.g., whether it requires visual and/or manual control actions similar to those required for performing activities critical for safe driving), (b) its complexity, (c) whether or not it can be ignored, (d) how predictable it is, (e) how easily it can be adjusted, (f) how easy it is for the task to be interrupted and resumed, and (g) how long it takes to perform the task (Young et al. 2009; Regan et al. 2011; Oviedo-Trespalacios et al. 2020b).
- *Self-regulation:* Self-regulation, in the distraction context, refers to the ability of a driver to self-regulate their behavior in the face of, or in anticipation of, a competing activity in order to compensate for its potentially adverse effects (Young et al. 2009). Young et al. (2009) suggest that self-regulation can occur at the strategic, tactical, and operational levels of driving control (Michon 1985) – in order to regulate their exposure to competing activities (strategic control), to regulate the timing of their engagement in the competing activity (tactical control), and to control mental resource investment in it (operational control). Examples of self-regulation at each of these levels include turning off a mobile phone before a trip (exposure; strategic control), interrupting speech with a passenger when driving through an intersection (timing of engagement; tactical control), and increasing inter-vehicle headway when engaged in a mobile phone conversation (resource investment; operational control) (Saifuzzaman et al. 2015; Oviedo-Trespalacios et al. 2019a; Li et al. 2019; Chen et al. 2020; Bastos et al. 2020).

Impact on Driving Performance

When a driver diverts attention away from activities critical for safe driving toward a competing activity, this may interfere, through the mechanisms discussed, with the performance of driving activities.

Various driving performance deficits are known to arise when drivers are distracted, for a wide range of competing activities – ones that involve interaction with technologies (e.g., mobile phones, iPods, DVD players, navigation systems, e-mail systems, radios, and CD players) and ones involving performance of everyday activities (e.g., eating, drinking, smoking, reading, writing, reaching for objects, grooming, and conversing with passengers). These performance deficits have been discovered in laboratory studies, driving simulators, and in instrumented vehicles driven along test tracks.

The various driving performance deficits reported vary primarily according to the triggered responses induced by the different types of distraction (i.e., eyes off road, ears off road, mind off road, or hands and/or feet off vehicle controls).

Competing activities that primarily take drivers' *eyes* off the road have been found to effect specific aspects of driving performance: the selection of information (e.g., failing to detect relevant information from the roadway; spatially concentrated gaze on the forward road center when eyes are returned to the forward roadway); information processing (e.g., longer reaction times to roadway warnings and braking lead vehicles; change blindness that disrupts the detection of changes in the road scene); and vehicle control (e.g., degraded lane keeping performance; reduced speed; increased following distance). For reviews, see Bayley et al. (2009), Horberry and Edquist (2009), and Bruyas (2013). Generally, delays in event detection are greater for competing activities that are visually distracting than for those that are cognitively distracting (that take one's mind off the road) (Victor et al. 2009).

Competing activities that primarily take a driver's *mind* off the road have also been found to affect specific aspects of driving performance: the selection of information (e.g., spatially concentrated gaze on the forward road center; less attention to peripheral hazards; less checking of rear-view mirrors, speedometer); information processing (e.g., inattention blindness, resulting in the "looked but failed to see" phenomenon; memory loss, resulting in an inability to remember some things that have been seen during a drive); and vehicle control (more hard braking; looking less at traffic lights and missing red lights; more navigation errors; reduced variability in lane keeping performance resulting from gaze concentration; no appreciable impact on following distances; acceptance of shorter gaps when turning across oncoming traffic; small decreases in speed; fewer lane changes; more conflicts with vulnerable road users; more traffic rule violations [speeding; red light running; crossing solid lines]; reduced ability to cope with wind gusts; errors [e.g., stopping at green lights and taking off before lights are green]; reduced scanning of intersection areas to the right; and reduced situation awareness [being less able to identify, locate, and respond to hazardous vehicles and to avoid accidents]). For reviews, see Bayley et al. (2009), Horberry and Edquist (2009), and Bruyas (2013).

The authors are unaware of any experimental research that has isolated the impact on activities critical for safe driving of taking one's hands and/or feet off vehicle controls when distracted (e.g., when steering with one hand while talking on a handheld phone; when steering the vehicle with both knees, as is sometimes seen in video footage from so-called naturalistic driving studies).

Regan et al. (2011; see also Ranney 2008 and Regan 2010) have noted some difficulties in making sense of specific data deriving from studies of the impact of distraction on driving performance. First, it is difficult to rank competing activities in terms of how more or less distracting they are because of differences across studies in methods, measures, and competing tasks employed. Secondly, it is difficult to judge whether a deficit in driving performance within a study brought about by distraction is acceptable, because there is currently no agreement within the international research community on what is an acceptable level of performance degradation for any given competing activity. Finally, the magnitude, and indeed presence, of any performance decrement will be a function of the various moderating factors discussed previously, especially the amount of freedom drivers have to interact in their own way and time with the competing task. Constraining participants to interact with competing tasks in experimental settings in a manner that they would not in the real world may produce performance deficits that simply do not materialize in the real world.

Perhaps one of the greatest difficulties in interpreting driving performance deficits, as pointed out by Regan et al. (2011; see also Wijayaratna et al. 2019), is in knowing to what extent a given reduction in driving performance (e.g., a 20% increase in lateral lane excursions) translates into increased crash risk. Algorithms that link the two remain to be developed and validated.

This section has focussed on the impact of distraction on driver and driving performance. In the following section, we review what is known about the contribution of driver distraction to crashes and crash risk.

Evidence Implicating Distraction as a Traffic Safety Problem

In this section, we examine the impact of distracted driving on traffic safety. We focus here on two types of studies:

- Crash studies that gather information on the frequency and role of distraction involvement in crashes.
- Crash risk studies that aim to provide information about the increased driving risk posed by driver involvement in a distraction-related activity over and above that of the normal risk posed by driving.

Crash Studies

Crash studies use police crash data, medical crash data (from hospital archives), and safety survey data as their main sources of data (Kweon 2011).

In a review of studies using police records from the United States and New Zealand, driver distraction contributed to 10–12% of crashes, and approximately 20% of these crashes involved driver interaction with technology such as mobile phones (Gordon 2009). The Australian National Crash In-depth Study (ANCIS) revealed that 15.9% of crashes were distraction related (Beanland et al. 2013), most commonly involving in-vehicle distraction (13.9%) such as talking with passengers or using the mobile phone. In the USA, a more recent study using the Fatal Accident Reporting System (FARS) database found that 7.7% (13,707 out of 178,677) of all fatal crashes involved distraction (Qin et al. 2019). In a study from Norway, including data from the Norwegian Public Roads Administration (NPRA), it was reported that mobile phones are involved in 2–4% of all fatal crashes, while other in-vehicle distractions excluding mobile phones (i.e., GPS, laptop or tablet computer, video camera, backing camera, passengers, etc.) contributed to 8% of all fatal crashes (Sundfør et al. 2019).

Eby and Kostyniuk (2003) found that rear-end crashes and single-vehicle-run-off-the-road crashes are the two most common types of crash associated with driver distraction. Concerning rear-end crashes, it was estimated that distraction accounts for

21% of all rear-end crashes when the lead vehicle was moving and 24% of all rear-end crashes when the lead vehicle was stopped. Regarding single-vehicle-run-off-the-road crashes, it is estimated that distraction might be the cause of 12–14% of these events.

These studies confirm that distraction is a contributing factor to road crashes. The findings derived from them, however, have some limitations and, as such, must be interpreted with some caution.

Generally, police and hospital crash reports are prone to underreporting of non-fatal cases and a lack of behavioral detail preceding the crash. The lack of behavioral detail around driver distraction could result in an overestimation or underestimation of the problem. In addition, it also limits our capacity to understand the impact of specific behaviors or interactions on crash counts. For example, a common reporting issue in the USA is that a large proportion of crashes reported to involve distraction do not have a specific competing activity listed; rather they specify "distraction/inattention details unknown" (NHTSA 2016). This means that we are often unable to understand the role that technology plays in crash causation in comparison to non-technology distraction or external distractions. Therefore, it is reasonable to argue that crash data should not be the only source of information used for informing evidence-led initiatives for managing distracted driving. More research and innovative data collection and analysis tools are needed to understand the full impact of distracted driving in road crashes.

An emerging alternative to overcome these limitations is the use of naturalistic driving studies, where vehicles are instrumented with video and other sensors to measure driver behavior and performance over extended periods of time. An example of this is the US Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS; Dingus et al. 2016), which is the largest naturalistic study ever conducted. The SHRP 2 NDS, also mentioned later on in this chapter, recorded a total of 905 injury and property damage crashes. Dingus et al. (2016) found that observable distractions were associated with 68.3% of all crashes. Given that naturalistic driving studies show the causal link between distraction and crash outcomes (i.e., injury and property damage), at least for observable distraction, it is not surprising that distraction was found to be a greater contributing factor to road crashes in the SHRP 2 NDS than in official records (i.e., police and medical crash data).

Crash Risk Studies

Analyzing crash risk requires additional, supplementary, data on distraction exposure (Kweon 2011); that is, the amount of time spent performing different distraction-related activities while driving. This type of information is typically not collected by police or recorded in hospital archives. Usually, it is collected through safety surveys and in on-road observational studies. It is beyond the scope of this chapter to review in detail all of the literature pertaining to the impact of driver distraction on driver safety. Other resources exist for this purpose (e.g., Cunningham et al. 2017a; Dingus et al. 2016). Rather, we present here an overview of key developments in the understanding of the impact of distracted driving on crash risk.

On-road studies, on which we focus here, comprise naturalistic and quasi-naturalistic approaches that allow for the observation of driver behavior in uncontrolled, or controlled, environments, respectively. In these studies, drivers are observed in their natural driving environment, for weeks or even years, using instrumented vehicles, usually owned by drivers themselves, equipped with video, accelerometers, and other sensors and recording devices (Regan et al. 2013). With new technological developments in in-vehicle driver monitoring, the outcomes of so-called "naturalistic driving studies" (Klauer et al. 2011), which are conducted in uncontrolled environments, are being increasingly reported in the road safety literature. These studies utilize epidemiological methods to sample and analyze the data recorded and provide insightful indications of changes in exposure and risk associated with driver engagement in distracting activities.

Impact of Distraction on Crash Risk

The largest and most comprehensive naturalistic driving study ever undertaken, the US Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS; Dingus et al. 2016), involved a comprehensive analysis of the impact of driver distraction on crash risk. Data were collected for 3 years from 3,500 volunteer vehicle drivers, aged between 16 and 98 years. With regards to general distraction (i.e., diverting attention to a secondary task), results from the SHRP 2 NDS demonstrate that, overall, observable distractions increased the odds of having an injury or property damage crash by a factor of 2.0 (odds ratio). An odds ratio (OR) value of 1.0 is considered equivalent to driving while not distracted. Hence, an OR of 2.0 represents a two times increase in crash risk relative to "normal" driving, suggesting that engaging in distracting activities, generally, is a risky activity.

The SHRP 2 study also revealed that, in comparison to other risky behaviors, distraction is one of the most prevalent. Specifically, as can be seen in Table 2, distraction was present during 51.93% of driving time, while other risky behaviors were less prevalent: drug/alcohol impaired driving (0.08%), drowsiness/fatigue (1.57%), speeding (over limit and too fast for conditions; 2.77%), and following a vehicle ahead too closely (0.70%). However, distracted driving risks are relatively lower than some risks generated by other behaviors. Additionally, some distracting activities have been found to be riskier than others. The following section focusses on the risks of some key distracting behaviors reported in the scientific literature, including mobile phone use while driving, and the use of in-vehicle information systems.

Table 2 Crash risk and prevalence of distraction relative to other risky driving behaviors

Behavior	Odds ratio (95% CI)	Baseline prevalence
Observable distraction	2.0 (1.8–2.4)	51.93%
Drug/alcohol impairment	35.9 (17.0–75.8)	0.08%
Drowsiness/fatigue	3.4 (2.3–5.1)	1.57%
Speeding (over limit and too fast for conditions)	12.8 (10.1–16.2)	2.77%
Following too closely	13.5 (4.4–41.4)	0.07%

Adapted from Dingus et al. (2016)

Impact of Mobile Phones Use While Driving on Crash Risk

Naturalistic studies have provided crash risk estimates for driver engagement in a wide range of secondary activities. In addition to the SHRP 2 NDS, another comprehensive naturalistic study was conducted by Fitch et al. (2013), which aimed to understand handheld and hands-free phone use while driving and its impact on crash risk among 204 drivers during a period of 4 weeks in the USA. In the case of mobile phone use while driving, Fitch et al. (2013) found handheld mobile phone use, overall, to increase the odds of having a crash by a factor of 1.4, while Dingus et al. (2016) reported SHRP 2 NDS data confirming that interaction with a handheld mobile phone, overall, increased the odds of having an injury or property damage crash by a factor of 3.6. These findings, however, can be further considered in terms of the different ways in which drivers use their mobile phones.

The following table illustrates the odds of crash risk associated with driver engagement in specific visual-manual mobile phone tasks while driving. As shown in Table 3, the odds of having a crash increases by 73% for drivers engaged in mobile phone tasks that involve visual-manual interactions (i.e., odds ratio of 1.7). Overall, when considering all of the visual-manual interactions with a handheld mobile phone that have been analyzed while driving as shown in Table 3, "dialling a number on a handheld mobile phone" carries the highest risk (i.e., odds ratio of 12.2).

Crash risk data for handheld mobile phone conversations and hands-free mobile phone conversations are presented in Table 4. Dingus et al. (2016) reported that handheld mobile phone conversations increase crash risk by more than two times (OR: 2.2; CI:1.6–3.1). In a more recent study, Dingus et al. (2019) found that talking/listening on a hands-free mobile phone did not increase crash risk (did not have an increased OR).

Recently, Young (2017) recalculated the odds ratio of handheld mobile phone conversations using the SHRP 2 NDS data after controlling for selection and confounding bias and reported that this resulted in an odds ratio of 0.9. This value is not significantly different from 1, implying that there is no change in risk. It is important to note that this result is similar to findings reported in previous naturalistic studies (Fitch et al. 2013). Table 4 also illustrates the odds of crash risk associated with driver engagement in hands-free mobile phone conversations while driving. As can be seen in Table 3, there is no significant change in crash risk for hands-free conversations, with odds ratios of 0.7 for mobile phone portable

Table 3 Crash risk associated with visual-manual tasks

Study	Observed distraction	Odds ratio (95% CI)
Fitch et al. (2013)	Mobile phone visual-manual task (i.e., text messaging/browsing, locate/answer, dial, push to begin/end use, and end handheld phone use)	1.7 (1.1–2.7)[a]
Dingus et al. (2016)	Mobile phone handheld browse	2.7 (1.5–5.1)[a]
	Mobile phone handheld dial (a number)	12.2 (5.6–26.4)[a]
	Mobile phone handheld text	6.1 (4.5–8.2)[a]

[a]Indicates a difference at the 0.05 level of significance

Table 4 Crash risk associated with manual-cognitive tasks (handheld or hands-free device)

Study	Observed distraction	Odds ratio (95% CI)
Fitch et al. (2013)	Mobile phone handheld talk	0.8 (0.4–1.4)
Dingus et al. (2016)	Mobile phone handheld talk	2.2 (1.6–3.1)[a]
Young (2017)	Mobile phone handheld talk	0.9 (CI 0.3–2.3) or 0.9 (CI 0.5–1.7)
Fitch et al. (2013)	Mobile phone portable hands-free talk	0.7 (0.36–1.5)
	Mobile phone integrated hands-free talk	0.7 (0.3–1.7)

[a]Indicates a difference at the 0.05 level of significance

hands-free talk and 0.7 for mobile phone integrated hands-free talk (Fitch et al. 2013). Again, neither value is significantly different from 1, further implying that there is no change in risk. Thus, it would seem that handheld mobile phone conversations and hands-free mobile phone conversations are not generally associated with any significant increase in crash risk.

An important warning, however, is necessary here: conversing (speaking or listening) using a handheld or hands-free mobile phone does not occur in isolation in real driving, as implied in the odds ratios reported above. To perform these actions, drivers are often required to first locate the device, reach for the device, dial, or answer the handheld device. These task sub-components of handheld mobile phone conversations could entail highly intensive visual, cognitive, and manual interactions (e.g., dialling or battery/duration monitoring) which could increase crash risk (Oviedo-Trespalacios et al. 2016). For example, in the Dingus et al. (2016) study, reaching for a handheld mobile phone was an extremely risky interaction, specifically increasing the odds of crashing by 4.8 times. This result is concerning given that limited public education has been provided with regards to the increased risk associated with this kind of mobile phone interaction (Oviedo-Trespalacios et al. 2017b).

Impact of In-Vehicle Information Systems (IVIS) on Crash Risk

As the capabilities of in-vehicle information systems (IVIS) have continued to expand over the years, questions have arisen as to whether or not the use of such systems for entertainment (i.e., infotainment) creates risks on the road.

With regards to crash risk, Dingus et al. (2016) found that driver interaction with IVIS increased the odds of having a crash by 4.6 times among drivers in the USA. The same study found this behavior to pose a higher crash risk in comparison to other risky driving behaviors such as fatigued driving (odds ratio = 3.4) and overall handheld mobile phone use (odds ratio = 3.6). A recent meta-analysis conducted by Ziakopoulos et al. (2019), however, found operation of an IVIS to cause only a small percentage of safety-critical incidents, specifically only 1.66% of total crashes. It is important to note, however, that the results from this study were based on a small number of older articles published from 1996 to 2012, when the range of IVIS technologies and functions was more limited. As the capabilities of IVIS continue to increase, more current, up-to-date, research is required to determine the risks associated with use of these systems.

Impact of Interactions with Passengers on Crash Risk

Dingus et al. (2016) also analyzed crash risk associated with active driver interactions with passengers. Crash risk was calculated using data collected from video segments where drivers interacted with adult/teen passengers 6 s prior to a crash. Information related to talking on a handheld mobile phone while driving, discussed above, was gathered in a similar fashion. The results were as follows:

- Drivers interacted with passengers more frequently (14.5% of the total driving time) in comparison to talking on a handheld mobile phone (3.2% of the total driving time).
- However, talking on a handheld mobile phone while driving increased crash risk by 2.2, while interaction with passengers was associated with only a 1.4 increase in crash risk.

Another meta-analysis conducted by Theofilatos et al. (2018) also calculated crash risks associated with passenger interactions. The analysis included a total of seven studies, and the results were as follows:

- 3.55% of crashes were caused by passenger interactions regardless of age.
- 3.85% of crashes were caused by passenger interactions when teen and child passengers were excluded from the analysis.

Recently, Maasalo et al. (2019) examined fatal crash data to determine the crash characteristics and crash risks of drivers with child passengers. The authors found that:

- Female drivers are involved in twice as many fatal crashes with child passengers in comparison to male drivers.
- Drivers with child passengers have a higher tendency to engage in distractions while driving and pose risks particularly around intersections.
- Drivers with child passengers have fewer risk-taking behavior-related fatal crashes (e.g., through speeding) in comparison to drivers with no child passengers.
- Adult passengers lower drivers' fatal crash risk by helping drivers with child-related tasks.

Collectively, the evidence suggests that primarily cognitive secondary tasks – that take a driver's mind off the road – are not associated with increased crash risk (increased odds ratios) relative to *all* driving but are associated with a small but significantly increased odds ratio relative to model driving (i.e., when drivers are alert, attentive, and sober; OR = 1.25, 95% CI [1.01, 1.54]). (Dingus et al. 2019). The effect on crash risk of driver engagement in primarily cognitive secondary tasks is reliably less severe than engagement in tasks that take the driver's eyes and/or hands away from the driving task (Dingus et al. 2019).

Impact of External Distractions on Crash Risk

As noted earlier, in the section "Competing Activities and Sources of Distraction," there are many sources of distraction external to the vehicle that have potential to distract drivers. Apart from advertising signs, very little is known about the impact of these on crash risk. Generally, it is known from the work of Dingus et al. (2016) that an extended eye glance duration to an external object increases the odds of having an injury or property damage crash by a factor of 7.1 (OR). Driver interaction with both in-vehicle and external sources of distraction may, therefore, increase crash risk.

Roadside advertising signs are designed deliberately to attract and maintain driver attention to information that is irrelevant to driving. In their meta-analysis of existing studies investigating digital roadside advertising signs (i.e., moving images and/or film clips), Sisiopiku et al. (2015) found an increased crash risk associated with driver interaction with digital roadside advertising signs. However, the effect was only observed on sections of road with intersections. Experimental research, on the other hand, suggests that crash risk increases by approximately 25–29% in the presence of digital roadside advertising signs (Oviedo-Trespalacios et al. 2019b). Fixed object, side swipe, and rear-end crashes have been found to be the most common types of crashes in the presence of roadside advertising signs (Islam 2015; Sisiopiku et al. 2015).

Impact of Other Distractions on Crash Risk

Some other distractions have also been shown to increase the odds of crashing (Dingus et al. 2016):

- Reading and writing (including with tablets) – by 9.9 times.
- Reaching for objects inside the vehicle (excluding mobile phones) – by 9.1 times.
- Drinking (non-alcohol) and eating – by 1.8 times.
- Personal hygiene activities – by 1.4 times.

Generally, as noted above, distracting activities that carry the greatest crash risk are those that involve both visual-manual interactions and occupy a greater proportion of a driver's time. Particularly troublesome, in this respect, is the use of handheld mobile phones which, in the Dingus et al. (2016) study, increased crash risk overall by 3.6 times and engaged them for 6.4% of their driving time.

Prevention of Distracted Driving

The road system is complex and, from a distraction perspective, many stakeholders are ultimately responsible for preventing and managing distraction (Department of Transport and Main Roads 2020b): drivers, regulatory and enforcement agencies, infrastructure planners, the insurance industry, the mobile connectivity industry, road users and their associations, the automotive industry, technology providers, the telecommunications industry, employers, and the research community.

Traditionally, the onus of responsibility for safe driving has been on the driver. This approach implies that drivers are solely responsible for road safety and thus are to blame for a crash by not following a particular road rule (Newnam and Goode 2015). Generally, this "victim blaming" approach has, to date, been the status quo of distraction prevention. However, safety professionals and academics concur that this approach is unsuitable to deal with distracted driving (or any other risky behavior; Tingvall and Haworth 1999; Tingvall et al. 2009; Young and Salmon 2015).

Drivers tend to be, and will continue to be, distracted due to a number of factors that are often difficult to control. A good example of this is the use of mobile phones, which are a key part of today's professional and social contexts. Some experts have conceded that ending or reducing phone use is becoming unrealistic (Panova and Carbonell 2018). In addition, there are reports showing that more individuals are establishing maladaptive relationships with their mobile phone, such as "fear of missing out" (FOMO), that could be linked with mobile phone distraction (Elhai et al. 2018; Nguyen-Phuoc et al. 2020). FOMO is a psychological construct that is defined as the persistent desire to stay connected with others' rewarding experiences and has been linked to both negative affectivity (e.g., stress, depression, anxiety) and increased severity of problematic smartphone use (Wolniewicz et al. 2018). Recent research has shown that problematic mobile phone use, which resembles addiction, is linked with mobile phone use while driving (Oviedo-Trespalacios et al. 2019c). Therefore, if drivers are not able to self-regulate their mobile phone use, it is very unlikely that legal requirements alone will prevent mobile phone use while driving. Several researchers concur that the high prevalence of distracted driving is linked to a heavy focus of legislation on the role of the driver, while ignoring the responsibility of the wider road transport system (Young and Salmon 2015; Parnell et al. 2017; Oviedo-Trespalacios et al. 2019c).

To address these limitations, different philosophies have evolved that recognize that distracted driving is a serious problem with unacceptable consequences (i.e., injuries, economic loss, disruption of the transport system, etc.) that drivers cannot always prevent themselves. Some good examples of alternate philosophies include the Swedish Vision Zero and the chains of responsibility, which are linked to the limitations and capabilities of road users (Tingvall et al. 2009). The common aim of the abovementioned philosophies is to reduce or eliminate the consequences of a road crash. This means that a road transport system assumes variability in human performance and creates safety margins to protect road users from the inevitability of such variability; for example, in the case of vehicles drifting out of their lane, the use of lane departure warnings or roadway tactile edge lining that can alert the driver to potential danger.

The integrated safety chain of responsibility (ISCR) is an approach that has been proposed by Tingvall et al. (2009) in the case of distracted driving (see Fig. 1). The ISCR approach uses the sequence from "normal" driving to a potential crash, broken down in stages of progression towards a crash. These stages are used to identify possible interventions along the chain, such as technology in both the vehicle and infrastructure as well as broader interventions involving police enforcement or community education.

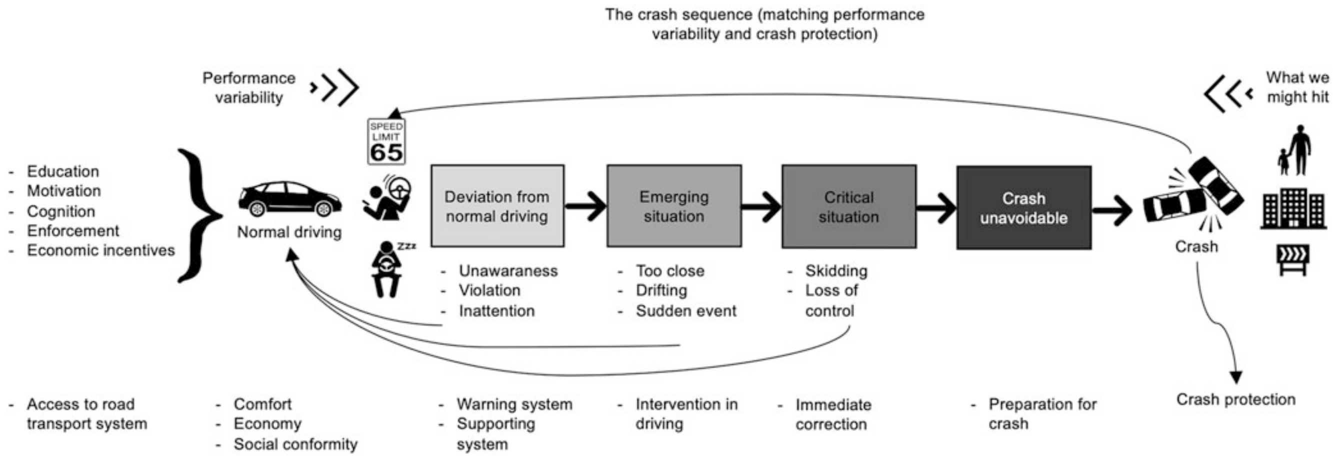

Fig. 1 The integrated safety chain. (Adapted from Tingvall et al. (2009))

The ISCR starts with an understanding of "normal" driving, which includes all the requirements of the driver to achieve this state. Moreover, conceptualizing the notion of normal driving also involves acknowledging that there is a plethora of factors which affect driver performance, such as cognition, motivation, education, police enforcement, and economic incentives. For example, drivers cannot follow a speed limit that they are unaware of or is not appropriately signed. If normal driving is too difficult to achieve, then the number of people capable of driving would be restricted, or we return to blaming the driver for not fulfilling the requirements of normal driving. In the case of distracted driving, evidence around the world shows that a requirement to never be distracted while driving is unrealistic.

The ISCR accepts that deviation from normal driving is going to occur and explains that countermeasures should be applied to correct the deviation back towards normal driving. An example of this, in the case of speeding, is a vehicular speed warning system, referred to as Intelligent Speed Adaptation (ISA; e.g., Regan et al. 2006), which would alert a driver when exceeding the speed limit. If the deviation is not corrected, and the driver finds themselves in an emerging situation, such as being too close to another vehicle or drifting out of the road lane, the ISCR recommends using the vehicle and infrastructure to help the driver regain control. For vehicles drifting out of their lane, the vehicle could automatically take control of the vehicle through electronic stability control (ESC) and lane departure assist systems to return the driver to normal driving or prepare the driver for the potential next phase. If the driver does not regain control, the next phase involves the vehicle preparing for a crash. This could take the form of the vehicle applying automatic braking and traction control. In the final stage, if a crash occurs, both vehicle and infrastructure could help reduce the severity of the consequences with systems such as vehicle airbags and road crash barriers (which serve to attenuate the force of vehicle impacts).

All the different stages from normal driving to a potential crash have the potential to prevent and mitigate the effects of distraction. The ISCR also points to the need to give equal consideration to countermeasures in vehicles as well as road infrastructure. This premise is the basis for the safe system approach which seeks to create a forgiving road environment that allows for driver variability, such as distracted driving. However, an important consideration is that all of these countermeasures need to be rigorously evaluated to prevent unintended consequences or misuse of technology. For example, it has been reported that some drivers potentially stop using their seat belt and start relying on airbags to protect them when their vehicles are fitted with them (Oviedo-Trespalacios and Scott-Parker 2018).

Most recently, prevention approaches for distracted driving have advocated for broadening the scope of intervention beyond a driver-centered approach. The long-established philosophy of the "systems approach," established by Heinrich (1931), has been proposed to achieve this. The systems approach explains that road accidents and safety (broadly speaking) are emergent properties arising from nonlinear interactions between multiple components across complex sociotechnical systems beyond the immediate road environment. In the case of distracted driving, a systems approach can help in identifying and determining the impact of the wider road system factors that moderate the relationship between distraction and error (Young and Salmon 2015). This approach broadens the scope of the ISCR which focusses on how the immediate road environment can support safe driving behavior and tolerate unsafe behavior (Young and Salmon 2015), without considering the roles that other stakeholders in the distraction ecosystem (mentioned above) have in supporting safe driving. A systems approach responds to the call for a more holistic approach to managing driver distraction, which has traditionally been dominated by a focus on driver behavior change through education and legislation (Tingvall et al. 2009).

A tool for managing road safety following a systems approach is Rasmussen's (1997) Risk Management Framework (RMF). Rasmussen's RMF is a generic framework that can be used to develop a complete picture of the factors affecting safety in any domain of interest by describing six levels of the system. In the distracted driving domain, the levels have been conceptualized as follows (Young and Salmon 2015):

- *Level 1*: *Government policy and budgeting:* At the government level, safety is controlled through the legal system and legislation including the development of behavior-regulating laws and legislation, such as bans; provision of funding for public education; and policy development.
- *Level 2*: *Regulatory bodies and associations:* At this level, legislation is interpreted and implemented into rules and regulations (e.g., vehicle design standards). This includes conversion and informing of distracted driving legislation by regulatory bodies, research organizations, and others with a financial interest in distracted driving (such as police and motor vehicle insurers).
- *Level 3*: *Local area government, planning, budgeting*: Here, government policy is developed by local councils, including general road rules related to distracted driving. These rules are later implemented in the next two levels.
- *Level 4*: *Technical and operational management:* Stakeholders at this level include other influential and authoritative bodies and organizations with a direct influence on distracted driver behavior and decision-making; for example, vehicle and mobile phone manufacturers, the outdoor advertising industry, driver training organizations, road designers, etc.
- *Level 5*: *Physical processes and actor activities:* At this level, the focus is on the drivers themselves – the psychosocial influences upon their distracted driving behavior and their actual distracted driving behavior. This level also considers other road users such as passengers, cyclists, pedestrians, etc.
- *Level 6: Equipment and surroundings:* Here, the focus is on the physical environment and surroundings in which the person drives, including the motor vehicle.

Rasmussen's RMF posits that safety is maintained through a process called vertical integration, whereby decisions made at the higher levels (i.e., government and regulatory bodies) should influence actions at the lower levels. Likewise, information about the safety performance of the transport system (i.e., driver behavior and crashes) should flow up the hierarchy and influence decision-making at the higher levels (Rasmussen 1997). Consequently, a systems approach to road safety highlights that responsibility for road safety is shared among a broad group of stakeholders, whose decisions and actions interact and affect each other.

The implementation of the systems approach for distracted driving prevention is still in its infancy. Research has highlighted that some groups of stakeholders, directly linked with distracted driving, have not assumed their responsibilities. A good example is the often-complacent roles of mobile phone manufacturers and application developers in the prevention of mobile phone use while driving (Galitz 2017).

An open question on the systems approach is whether or not the current conception of the system has sufficient breadth. As noted previously, interventions to prevent mobile phone distraction while driving have been heavily focussed on the role of the driver, while ignoring the responsibility of the wider road transport or communication authorities (Parnell et al. 2016; Parnell et al. 2017; Young and Salmon 2015). A systemic approach is more likely to succeed in preventing and mitigating the impact of mobile phone use while driving, and this is exemplified in the recent release of Australia's National Roadmap on Driver Distraction (Department of Transport and Main Roads 2020b) developed by the Queensland Department of Transport and Main Roads in consultation with the Federal Department of Infrastructure, Transport, Cities and Regional Development, along with a wide range of stakeholders (noted above) from industry, academia, and all Australian jurisdictions. The Roadmap was developed through an extensive collaborative design process, with a focus on reducing driver distraction due to mobile devices. The Roadmap contains five overarching strategies to address the challenge of driver distraction: designing for safer interaction; mapping out the adoption of in-vehicle distraction mitigation technology; recognizing the vehicle as a workplace; encouraging greater compliance through enforcement; and changing driver behavior. The Roadmap contains a proposed forward program of work, with a range of projects aligned in support of the five main strategies. The Roadmap is likely one of very few that currently exist that have been developed in a truly collaborative manner involving all key relevant stakeholders in society responsible, directly or indirectly, for the prevention and mitigation of driver distraction.

More recently, it has been suggested that we must also consider the role of other systems, such as the healthcare system, in managing distraction. The link between problematic mobile phone use and mobile phone use while driving might require the use of clinical therapeutical interventions (Oviedo-Trespalacios et al. 2019c).

Consistent with this theme is the Human Factors Integration (HFI) process (e.g., Standards Australia 2016), which requires the specification of human factors requirements that have to be met during all stages of the lifecycle of an engineering product, system, or piece of infrastructure – from concept design through to design, build/implementation, testing, operation (including maintenance), and decommissioning. The purpose of the HFI process is to ensure products and systems are designed from a user-centered perspective to maximize safety, efficiency, user satisfaction, etc. Adherence to an HFI process, in the context of distraction, would ensure that the potential for distraction is considered and mitigated at all stages of the system lifecycle. For example, an engineering consultant, tendering for the design and construction of a new section of roadway, would be required as part of the HFI process to include in the tender a Human Factors Integration Plan that specifies in what ways the piece of road infrastructure will be designed to prevent and mitigate driver distraction during its lifecycle.

Countermeasures for Distracted Driving

Type of Countermeasures

A number of countermeasures have been developed in an attempt to prevent and mitigate distracted driving. However, there is a dearth of evaluations with regards to distracted driving countermeasures. The aim of this chapter is to systematically review countermeasures supported by empirical research, with a focus on those which have successfully reduced the occurrence or impact of distracted driving. Although there are many frameworks that can be utilized to systematically classify the interventions, this chapter will utilize the "Hierarchy of Controls" system, a widely used framework for preventing risks in socio-technical systems.

The hierarchy of controls presents different levels of solutions for the management of identified hazards and risk. In this chapter, we will use the Occupational Health and Safety Assessment Series (OHSAS 18001), which includes five main categories: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE), as can be seen in Fig. 2. The motivation underlying the hierarchy of controls is that more reliable control measures should be utilized rather than measures that are more likely to fail. At the top of the hierarchy is "elimination" which is traditionally considered the most effective countermeasure. Alternatively, countermeasures that rely on individuals behaving in a certain way are

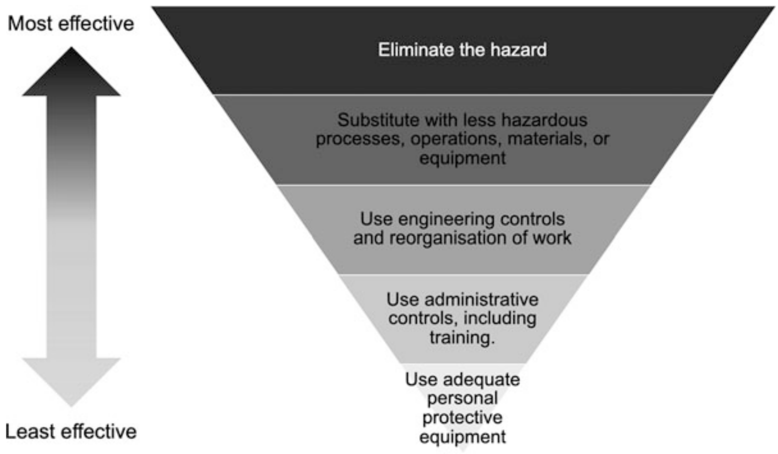

Fig. 2 Hierarchy of controls (Adapted from the National Institute of Occupational Safety and Health NIOSH)

considered less reliable. The adaptation of these five categories to consider countermeasures against distracted driving hazards is explained as follows:

- *Elimination:* Elimination is the first, most effective, control method in the pyramid. With this method, professionals suggest physically removing the hazard completely. While this is the ultimate goal, this method is potentially difficult to implement and not always possible in certain circumstances. This is particularly relevant for distracted driving from mobile phone use, where it has been demonstrated that drivers have difficulties separating from their phones (George et al. 2018). Nonetheless, this method should always be considered first and implemented before the other methods.
- *Substitution*: If elimination is impossible, the hierarchy of controls recommends moving on to the second category, known as substitution. With this method, hazardous practices/materials are replaced with an alternative, less hazardous, practice or material. This method must also be implemented in the very early phases of development, and it is crucial that the new practice or material either removes or mitigates the hazard in order to be effective. A good example of this is the integration of safer ways of interaction with the mobile phone, using technology such as "workload managers" for distracted driving (NHTSA 2016). Workload managers are driver support systems designed to limit or postpone information that is allowed to come through the phone when the driver's workload is high, or limit access to complex interactions that it supports. Specifically, when a driver's workload is high, workload managers can limit or delay information received through their mobile phone, or restrict access to complex interactions facilitated by the devices.
- *Engineering controls*: If substitution is also not possible, engineering controls are used. These include the modification or addition of physical safety features to the machinery or equipment in order to control identified hazards. For example, a workplace can provide ergonomic chairs to reduce risk of injury to the back and neck or add safeguards to prevent access to dangerous parts of a machine. In the case of distracted driving, engineering controls could involve the use of active safety technologies, such as automatic braking systems to reduce the risk of crashing, or the use of wire-rope barriers to prevent distracted drivers from veering off the roadway or into the path of other vehicles. Blocking mobile phone interactions with applications such as "do not disturb while driving" is another example of an engineering control (see Oviedo-Trespalacios et al. 2019d, for a review of applications to prevent mobile phone distracted driving).
- *Administrative controls*: The fourth control method in the hierarchy, administrative controls, involves changing the way individuals work through limiting exposure to a hazard. This can be done through installing signs, rotating jobs, etc. The parallel to driving here is driver behavioral interventions including education, legislation and enforcement, and risk awareness campaigns. Some forms of self-regulation, such as only engaging in distractions when the vehicle is stopped and not moving, could also limit exposure to the hazard (Oviedo-Trespalacios et al. 2019a). It should be noted, however, that this method is not always reliable or effective as it is prone to variability of human performance.

- *Personal protective equipment*: The fifth and final control method is the implementation of personal protective equipment (PPE), such as gloves, safety glasses, earplugs, etc. The rationale behind this method is to protect the body from injury, but it does not eliminate the hazard. Hence, PPE is deemed the least effective. In the case of distracted driving, the corollary to this would be the provision of seatbelts, airbags, and other passive safety elements to minimize the impact of a crash.

Review of Countermeasures

A review of injury countermeasures for distracted driving was undertaken by the authors using the Hierarchy of Controls for distracted driving as an organizing framework. The following table includes the control method used to minimize or eliminate distraction, a description of the method, outcome(s) from its use, and evidence of its effectiveness in achieving the outcome(s). Given that the focus of this chapter is the prevention of distracted driving, personal protective equipment controls were not included because they are post-crash treatments. Prior research studies conducted on post-crash protective measures have concluded that seatbelts, vehicle design, and emergency care can reduce the severity of crashes (Bhattacharyya and Layton 1979).

Elimination

The effectiveness of today's solutions for preventing distraction-related hazards while driving have been limited. Only fully automated vehicles operating in all conditions all of the time with SAE Level 5 automated driving features follows the elimination principle. When the automation is active, drivers do not have to control the vehicle and therefore vehicle occupants may engage in different activities unrelated to the control of the vehicle. Currently, the availability of fully automated vehicles is limited and restricted to highly controlled environments such as mining sites. It is anticipated that the safety benefits of fully automated vehicles are potentially enormous and would largely eliminate distraction-related hazards (Litman 2020).

Substitution

Regarding substitution, a countermeasure that continues to be suggested is the use of workload managers for driver distraction. Workload managers, as mentioned previously, are designed to minimize distraction by controlling, transforming, or limiting the information flow so drivers can safely manage their driving demands. The NHTSA (2016) considers that minimizing the workload associated with performing secondary tasks with a workload manager will permit drivers to maximize the attention they focus on the primary task of driving. Some of the approaches to achieve this include: (*1*) simplifying current distractions for more manageable tasks (Oviedo-Trespalacios et al. 2019d) and (*2*) only allowing drivers to be distracted at points where they can safely resume the driving task (Bowden et al. 2019). Although experimental work has demonstrated that delaying delivery of irrelevant driving-related information to drivers could reduce the impact of distraction (Teh et al. 2018), the technology needs further testing and evaluation.

Engineering Controls: In-Vehicle and Mobile Technology

Engineering controls for vehicles have been developed in increasing numbers in the form of advanced driver support systems (ADAS). ADAS are systems designed to support the driver in their driving task. The logic is that these systems are going to support the driving task by reducing the driver's demands and includes systems such as semi-automated navigation, blind spot monitors, etc. For partially automated vehicles, there is no evidence that these are going to reduce distraction-related hazards. On the contrary, it is expected that partial automation will result in more distraction due to decreased engagement with the driving task (Cunningham and Regan 2018b; Regan et al. 2020). A study in China with Tesla drivers found that drivers often engage in distracting activities while using the autopilot system (Lin et al. 2018). Similar findings have been reported in the USA, where drivers of vehicles with ADAS, such as adaptive cruise control, report engaging more in mobile phone use and texting (Dunn et al. 2019). Additionally, Matthews et al. (2019) showed that autopilot systems elicit subjective symptoms of fatigue and loss of alertness that last even after the autopilot system has been deactivated. These findings suggest that some ADAS are likely to be facilitating distracted driving.

Another issue raised is that ADAS could increase the likelihood of information overload resulting in distracted driving (Lee et al. 2020). ADAS often use auditory, visual, or a combination of auditory and visual alerts to communicate key information to drivers about the state of the vehicle and to instruct actions. However, there is growing evidence that poorly designed alert systems could increase distraction. An early experiment conducted by Biondi et al. (2014) showed that continuous exposure to auditory stimuli from ADAS negatively affects driving performance. These findings were further confirmed by a naturalistic driving study conducted in Australia, where 34 vehicles were retrofitted with collision avoidance technology which gave audio and visual warnings to drivers. The results showed that, although the system was capable of improving driving behavior, drivers did not want to continue using the system because it was too distracting (Thompson et al. 2018). A study conducted in Spain found that drivers consider GPS navigation, automatic parking systems, and lane departure warnings the most distracting ADAS (Lijarcio et al. 2019). These results highlight the need to further investigate strategies to optimize the role of ADAS as a control to reduce distraction-related hazards.

Applications to reduce mobile phone distracted driving are also engineering controls to prevent distractions. Generally, these applications restrict visual-manual and auditory interactions with the mobile phone while the vehicle is moving. A large number of applications is currently available, with different capabilities and at different stages of maturity (see Oviedo-Trespalacios et al. (2019d) for a comprehensive review of applications). Early findings from studies in Australia and Israel show that using applications aiming to block visual-manual interactions significantly reduces phone pickups and activities such as texting and browsing while driving (Albert and Lotan 2019; Oviedo-Trespalacios et al. 2020a). Nonetheless, reports from users of these applications (e.g., “Do not disturb while driving” for Apple iOS) reveal that the applications do not always stop notifications from instant message applications such as Facebook Messenger and WhatsApp (Oviedo-Trespalacios et al. 2020a). This could have negative implications for road safety given that previous research has found that unexpected incoming notifications are associated with reduced situation awareness while driving (Van Dam et al. 2020). Nonetheless, partially reducing exposure to mobile phone interactions could be a very effective countermeasure option in practice. Unfortunately, surveys in Australia and the USA have concluded that acceptance and adoption of these applications has been low, ranging from 3.8% to 20.5% (Oviedo-Trespalacios et al. 2019e, 2020c, d; Reagan and Cicchino 2018). Further work is needed to increase the effectiveness of this technology in preventing phone use while driving and the uptake of this technology.

Recent developments in in-vehicle technology also include technologies being built into the vehicle with the purpose of reducing distracted driving. A key technology that has been scientifically evaluated is feedback systems. The aim of these systems is to deliver information to drivers about their performance, on the expectation that this information will positively influence their behavior. In an experimental study conducted by Merrikhpour and Donmez (2017), it was found that feedback systems that consider parental norms (i.e., information about a parent’s performance) and real-time feedback (i.e., alarms triggered by long off-road glances) are associated with a smaller duration of off-road glances. Results from these experiments are very promising. Other in-vehicle technology such as in-vehicle interfaces that provide connectivity between smartphones, vehicle displays, and controllers (e.g., Apple CarPlay and Android Auto) has been suggested as a potential countermeasure for distraction. However, currently the potential safety benefits are unknown. Indeed, there is emerging research suggesting that there is risk of distraction from using such technology (Oviedo-Trespalacios et al. 2019f; Strayer et al. 2019; Ramnath et al. 2020).

Engineering Controls: Roads

Road and traffic engineers have considerable scope to manage distraction from some of the sources of distraction deriving from outside the vehicle that were mentioned earlier in this chapter (see section “Impact of External Distractions on Crash Risk”).

PIARC (2016) makes three primary recommendations for preventing serious crashes arising from driver distraction:

- *Lower energies through conflict points to within human tolerances* – in the event that a distraction-related crash is inevitable, infrastructure measures will generally ensure that vehicle speeds are within human tolerances for serious injury through relevant conflict points.
- *Design to provide opportunities for road users to recover from mistakes and noncompliance* – e.g., locating crash barriers further from the through traffic lanes provides an opportunity for errant vehicles to recover before hitting the barrier.
- *Design to lower the risk of a crash occurring to an “acceptable” level* – designing the road to minimize the risk of driver distraction occurring in the first place; e.g., by preventing the road from surprising the road user.

PIARC (2016) recommends the following specific road engineering treatments that can be used to mitigate the effects of driver distraction:

- *Hierarchy Level 1 treatments*. These include concrete or steel side barriers, wire rope side and median barriers, lateral shift of the road, roundabouts, grade separation at intersections and speed humps.
- *Hierarchy Level 2 treatments*. These include rumble strips, tactile line markings, speed humps, rough shoulders, and variable speed signs.

The PIARC (2016) document provides high level guidance for road design to prevent and mitigate the effects of distraction. Cunningham et al. (2017b) provide more specific guidance on managing some of the specific external sources of distraction listed earlier in this chapter (see section "Competing Activities and Sources of Distraction") that traffic engineers have some control over. For example:

- *Animals* – on road sections where roadway incursions by animals are common and distract drivers, warning signs, and perhaps barriers, can be used to minimize interaction between drivers and animals.
- *Scenery* – scenic routes and tourist roads are, by definition, distracting and are often located along winding rural roads. Traffic engineers can alert drivers to the potential for distraction along such roads and employ additional engineering control measures to prevent crashes, give drivers more time to recover from the effects of distraction, and reduce impact speeds in the event of a distraction-related crash.
- *Architecture* – there exist many buildings and monuments that have the potential to distract drivers. It may be possible for engineers to visually mask (e.g., with trees, fencing) prominent architectural structures and features that are known to distract drivers in high-risk locations.
- *Crash scenes* – so-called "rubber necking" is a common driver behavior around crash scenes. It distracts drivers and cause crashes, and often creates traffic congestion downstream. Possible countermeasures here might include routing traffic away from crash scenes, where possible, and visually masking the scene in some way from approaching traffic.
- *Traffic signs* – poorly designed traffic signs can, themselves, distract drivers. For example, if they are absent in locations where they should be (e.g., no street name on the road you are turning onto), this may encourage drivers to adopt compensatory search strategies that distract them. Similarly, if signs are poorly designed (e.g., contain too much information or are incomprehensible), this may encourage long eye glances away from the forward roadway. Poorly designed and absent road signs should be avoided.

Ultimately, the road and traffic engineer should strive for a distraction-tolerant road system such that, in the event of a distraction-related crash, no driver or other road user is killed or seriously injured (Tingvall et al. 2009; see also section of this chapter titled "Prevention of Distracted Driving").

Administrative Controls

Administrative controls cover legislation, authority enforcement of legislation, as well as education programs.

Legislation banning or restricting distraction has been a key control in the prevention of distracted driving (WHO 2011). Some of the legislative approaches target general driver performance, such as “without due care and attention,” which covers a wide range of distracting behaviors. Graduated driver licensing (GDL) is a policy used to keep newly licensed young novice drivers out of harm’s way by restricting driving to times and situations demonstrated to be of lower risk. In some jurisdictions, such as Queensland, Australia, the GDL bans young drivers’ use of hands-free phones or loudspeaker functions while driving (Department of Transport and Main Roads 2020a), both of which are otherwise allowed among fully licensed drivers. Additionally, there is also more specific legislation targeting activities such as talking, text-messaging, or playing video games on handheld mobile phones while driving. Unfortunately, few studies have assessed the impact of legislation on distracted driving, and most of the research has been centered on mobile phone use.

Evaluations of legislation targeting mobile phone use show partial success in preventing this risky driving behavior. A common finding highlighting the positive impact of legislation is the reduction of handheld conversations among drivers after handheld mobile phone bans were implemented in the USA (Rudisill and Zhu 2017; Rudisill et al. 2019b). More recently, an analysis of the 2011–2014 Traffic Safety Culture Index surveys showed that handheld calling bans were associated with fewer calling behaviors overall and in all demographic subgroups. Evaluations of distracted driving legislation in New Zealand (Wilson et al. 2013) and the UK (Johal et al. 2005) have also reported reduced mobile phone use post legislation.

However, in other cases, legislation seems to have had a minimal effect on behaviors, such as texting on a mobile phone. In the USA, for example, Rudisill et al. (2019b) found that universal texting bans were not associated with less distraction. In Europe, Jamson (2013) documented that drivers in the most highly regulated country with respect to mobile phone legislation (Italy) report texting as frequently as those in countries with no legislation. Furthermore, the effect of legislation seems to be heterogenous among different groups of the population. An analysis of research in the USA concluded that phone legislative restrictions have no long-term effect on the prevalence of mobile phone use among novice drivers (Ehsani et al. 2016). Rudisill and Zhu (2017) found that, although there are net reductions in handheld interactions, mobile phone use was higher overall among females, younger age groups, and African Americans.

These mixed results on the effectiveness of the legislation can be partially explained by challenges associated with the enforcement of the legislation. Law compliance frameworks, such as deterrence theory, have shown that drivers are motivated to avoid harmful behavior by fear of negative consequences. Thus, breaking the law is more likely to occur if the swiftness, certainty, and severity of punishment are low (Homel 1988). Thus, sustained police enforcement programs are a key element to guarantee a reduction of distracted driving through legislation.

Studies in the USA have demonstrated that handheld mobile phone bans require robust enforcement to have the desired effect on driver behavior in the long term (McCartt and Hellinga 2007; McCartt et al. 2010). Specifically, high-visibility enforcement programs (i.e., visibility elements and a publicity strategy to educate the public and promote compliance with the law) targeting drivers who use handheld mobile phones have been trialled successfully. In California and Delaware, handheld mobile phone use dropped nearly 33% as a result of high-visibility enforcement (NHTSA 2016). Importantly, there is growing evidence that capacity to enforce mobile phone bans is restricted unless technological and legislative innovations take place. Different evaluations of distracted driving law enforcement have found several important barriers to enforcement of distracted driving legislation (Nevin et al. 2017; Rudisill et al. 2019a):

- *Societal factors*: Mobile phones often have a utilitarian function in supporting driving, such as through provision of GPS or maps, which makes it difficult to identify distracted driving. Also, mobile phones experience rapid technological change that is often faster than policy cycles.
- *Contextual factors*: The ability of police to conduct traffic stops safely is often limited and dangerous (i.e., weaving through cars or high-speed traffic).
- *Organizational factors*: Police functions are diverse, and resources limited, resulting in low prioritization of distracted driving legislation. Additionally, the lack of clear and enforceable polices is also one of the main difficulties: that is, officers cannot always be sure if a driver was texting or using the GPS while enforcing texting bans.
- *Interpersonal factors*: Many drivers who challenge police officers during traffic stops increase the difficulty of enforcement operations, and there is not sufficient dialogue among police forces regarding distracted driving.
- *Individual factors*: Police officers largely report engaging in distracted driving themselves and believe that drivers can safely multitask. Thus, the enforcement of distracted driving legislation might be unprioritized and perceived as not legitimate. Also, it was reported that, in many circumstances, detecting distracted driving is difficult without technology.

Another key factor undermining the effectiveness of enforcement operations targeting distracted driving-hazards is behavioral adaptation by drivers aiming to conceal or avoid police enforcement. Drivers have reported scanning the environment, searching for police, covering the phone all the time with their hand, and using the phone on their laps (Oviedo-Trespalacios et al. 2017b). Moreover, Oviedo-Trespalacios (2018) found that drivers who often engage in these behavioral adaptations also report higher engagement in distractions such as texting and browsing on a mobile phone. Alternatively, research has increasingly reported that drivers are using in-vehicle information systems (IVIS) to engage in texting with their mobile phones, making enforcement of mobile phone use legislation more difficult (Oviedo-Trespalacios et al. 2019f). Concerningly, IVIS are distracting even when interfaces such as Apple CarPlay and Android Auto are used (Oviedo-Trespalacios et al. 2019f;

Strayer et al. 2019; Ramnath et al. 2020). The fact that drivers are using these behavioral adaptations to avoid police enforcement undermines the effectiveness of this administrative control and must be addressed in the planning of future legislation and enforcement schemes.

The next group of administrative controls reported in the literature are related to Workplace Health and Safety (WHS) controls to prevent mobile phone use while driving. This is a very important group of controls because employment demands have been consistently linked with distracted driving, during both work-related and non work-related driving (Engelberg et al. 2015). Unfortunately, WHS efforts to prevent distracted driving are relatively new and only a few isolated cases have been evaluated. The main work identified confirmed that truck and bus drivers working for organizations that enforced texting bans have lower texting and driving prevalence in comparison to companies without bans (Hickman et al. 2010). Furthermore, additional research on work-related driving has concluded that implementing WHS policies to prevent distracted driving might not be sufficient to prevent this behavior, needing strict enforcement and sanctions to create a safety culture (Swedler et al. 2015a). Truck drivers in Swedler et al. (2015b) study listed the following examples that could be effective in reducing distracted driving:

- Better procedures for communicating with drivers – delivering a noninvasive signal over dispatch devices to indicate that the driver received a message.
- Enforcing bans on distracted driving activities.
- Video-monitoring to observe drivers engaging in distracted driving.
- Monitoring cell-phone usage if driver is using a company-provided phone.
- Locking out devices while vehicle is in motion.
- Automatically updating package delivery drivers' routes, so drivers do not have to make scheduling/routing decisions while driving.

There is great potential in the WHS space to reduce distracted driving, particularly among people who drive for work. The development of organizational guidelines could provide a great opportunity to increase road safety. Key guidelines to support this process have been developed in Australia by The National Road Safety Partnership Program (NRSPP 2016): "A guide to developing an effective policy for mobile phone use in vehicles." The process considers elements that can influence distracted driving in organizational settings, such as the current engagement in distracted driving, leadership, education, training, collection, monitoring and analysis of critical incident data, enforcement, mobile phone design, and vehicle purchase and design. There is a need to consolidate and increase the uptake of good road safety practices about distracted driving in the corporate sector.

Education programs have been developed in an effort to reduce and/or prevent drivers from using their mobile phones while driving. A number of interventions have been identified with significant gains in preventing distracted driving. In the USA, the telecommunications company AT&T launched the "It Can Wait" campaign. As part of the program, drivers are encouraged to sign a pledge on their website, encouraging them to make a commitment to never drive distracted (e.g., "I pledge to always drive distraction free."). In addition, drivers installed an application capable of detecting when a vehicle is moving more than 25 mph and prevent mobile phone notifications. Furthermore, the campaign also launched a virtual reality experience on their website that helps users experience the dangers of distracted driving. As young adults were the primary target audience for this campaign, AT&T started social media campaigns (i.e., "#ItCanWait" hashtag on Twitter) and released a documentary (i.e., "From One Second to the Next") to raise awareness about dangerous phone use while driving. The campaign evaluation showed a reduction in road crashes and larger awareness of distracted driving risk (Carter 2014). Unfortunately, studies aiming to replicate these results using similar strategies to those in the campaign have not shown the same success. Fournier et al. (2016) reported that neither the distribution of flyers and thumb bands with fear-based slogans (e.g., "It Can Wait") nor the encouragement of drivers to sign a pledge seemed to reduce overall mobile phone distracted driving. Interestingly, however, the type of mobile phone use behavior did change, as drivers were found to decrease calling behavior but increase texting behavior while behind the wheel (Fournier et al. 2016). This apparent replacement of a risky driving behavior with an even riskier driving behavior highlights the need for more research to investigate the actual effectiveness of this campaign (Fournier et al. 2016).

Some educational campaigns have been aimed at specific groups of the transport system, such as employees (i.e., "It Can Wait" educational program) and parents of young drivers (i.e., "Steering teens safe" educational program). Tailored educational programs involve the use of workshops, lectures, and demonstrations about distracted driving. The "It Can Wait" educational program showed that these activities could be extremely useful in increasing awareness about distracted driving risk and road rules (Hill et al. 2020). In the case of the "Steering teens safe" educational program, parents were trained to use motivational interview frameworks to use with their teens besides being given relevant road safety knowledge so they could improve their communication with their teens (Peek-Asa et al. 2014). Although a reduction of distracted driving behaviors was reported, the success of these educational interventions has been limited. Given the importance of considering the role of additional actors, such as employers, parents, and friends, among others, in the prevention of distracted driving, future developments are needed in this space.

Emergent approaches to education of drivers do not seek to prevent distraction but to upskill drivers to engage safely in distracting behaviors. An innovative example of this is the "FOrward Concentration and Attention Learning (FOCAL)" educational program developed by Unverricht et al. (2019). FOCAL educational training develops the driver's capacity to self-regulate off-road glances. Experiments conducted after the training confirmed its effectiveness in reducing the severity of distraction. Specifically, drivers who received the FOCAL training engaged in fewer in-vehicle glances longer than 2 s than drivers who received traditional education on distraction-related risks and road rules (Unverricht et al. 2019). Although evidence is limited, and no inferences about crash risks can be reliably made, this is a very innovative approach with the potential of changing the way we train drivers in the future.

Distraction and Vehicle Automation

New technologies are emerging that are capable of supporting and automating many of the functional driving activities performed traditionally by human drivers. These new technologies have been classified by the Society of Automotive Engineers International (SAE International 2018) as falling into two general categories that span six levels of automation:

- *Driver support features* (also known as advanced driver assistance systems) that provide momentary assistance and warnings (Level 0), steering or brake/acceleration support (Level 1), or both steering and brake/acceleration support combined (Level 2).
- *Automated driving features (ADF)* that (a) can drive the vehicle under limited conditions but require the driver to either take control when required (Level 3), (b) can drive the vehicle under limited conditions but do not require the driver to take back control (Level 4), and (c) can drive the vehicle under all conditions all of the time without human intervention (Level 5; SAE International 2018).

With increasing technological support and automation, the driving functions and tasks performed by drivers will change, and this will change the repertoire of knowledge, skills, and behaviors required by drivers to maintain safe driving performance (Casner and Hutchins 2019; Fisher et al. 2020; Regan et al. 2020; Spulber 2016). Even now, a modern driver has a unique skill set compared to drivers two or three decades ago; many drivers today have never driven a manual transmission vehicle or have been required to pump their brakes on slippery roads (Spulber 2016). As vehicles become increasingly supportive and automated, so too will the impact that distraction has on activities critical for safe driving. This is because the activities critical for safe driving will themselves change and, ultimately, in vehicles equipped with Level 5 ADFs, there will be no requirement for the driver to perform them at all. But will distraction, as a road safety issue, disappear when there is no requirement for humans to perform any activities critical for safe driving? We briefly explore this and related issues in the sections that follow, drawing on some recent thinking and empirical findings reviewed in Cunningham and Regan (2018a) and Lee et al. (2020) (and see also Kanaan et al. 2020).

Automation Creating Distraction

As vehicles become more automated, the technologies that drive them may, themselves, become a source of distraction for drivers. Evidence already exists showing that automation actions and alerts that are unexpected, because of a lack of training, lack of situational awareness, or some other mechanism, may create "automation surprises" (Hollnagel and Woods 2005), and, in doing so, distract drivers. Even routine alerts and indicators in vehicles equipped with existing driver support features may draw attention away from the road at inopportune moments in time (Lee et al. 2020).

As noted, vehicles equipped with Level 3 automated driving features are classified by the SAE (SAE International 2018) as being capable of driving the vehicle, but only in limited conditions. At this level of automation, the driver is expected to resume control if requested by the vehicle (e.g., if the automation fails or drifts out of its operational design domain). Here, the frame of reference for distraction may become different in the mind of the driver; the requirement to supervise the vehicle automation could itself become a source of driver distraction (Hancock 2009; Lee et al. 2020).

It is well documented that drivers tend to engage in secondary activities when supported by vehicle automation (Lee et al. 2020). Evidence for this has been found both in driving simulators (e.g., Carsten et al. 2012; Jamson et al. 2013) and in instrumented vehicles driven on test tracks (e.g., Llaneras et al. 2013; Dingus et al. 2016). The propensity to do so tends to be greater for technologies that provide higher levels of automation.

More generally, as vehicles become increasingly automated, the role of the driver is expected to shift from being that of an active controller of the vehicle to that of a more passive supervisor of the automated driving system (Desmond and Hancock 2001). There is evidence that this reduction in task engagement can induce “passive fatigue” (reduced attentional capacity arising from driving task demands which are too low (Desmond and Hancock 2001; Saxby et al. 2013) and, in turn, driver inattention (Saxby et al. 2013; Körber et al. 2015). Here, inattention is brought about not by distraction, per se, but by other mechanisms.

Thus, drivers may be distracted either because automation demands their attention at inopportune moments in time or it induces drivers to engage more often and more deeply in non-driving activities (Lee et al. 2020).

Distraction and Takeover Ability

In vehicles equipped with SAE Level 0–2 driver support features, the driver is considered to be driving the vehicle and is supported in performing activities critical for safe driving by a variety of technologies (e.g., Autonomous Emergency Braking; Adaptive Cruise Control). While distraction, when it occurs, may impair the performance of activities critical for safe driving, the technologies themselves may help to mitigate any detrimental impacts this distraction may have (Tingvall et al. 2009), as noted previously.

In vehicles equipped with SAE Level 3 ADFs, in which automation is capable of driving the vehicle in limited conditions, the automation is considered to be driving the vehicle (SAE International 2018). The driver is, however, expected to resume control of the vehicle if requested by the vehicle; e.g., if the automation fails or the vehicle is driven outside of its operation design domain. There is evidence that takeover quality in vehicles equipped with automated driving features is impaired when drivers are distracted (e.g., Merat et al. 2014). Interestingly, however, the speed of the motor actions required to commence the takeover (e.g., to reach for the steering wheel or apply the brakes) appears to be little affected (Zeeb et al. 2015, 2016). Some evidence also exists showing that manual driving performance may be compromised for a considerable period of time after the handover of control to the driver has been completed (e.g., Merat et al. 2014; for reviews, see Cunningham and Regan 2018a and Fisher et al. 2020).

Self-Regulation and Individual Differences

Drivers of manually controlled vehicles often, as noted earlier, self-regulate their behavior in an attempt to manage distraction (e.g., Bastos et al. 2020; Oviedo-Trespalacios et al. 2019a, 2020b; Ortiz-Peregrina et al. 2020; Tivesten and Dozza 2014). There is also some evidence that they self-regulate their behavior in automated vehicles. Jamson et al. (2013), for example, found that drivers supported by automation self-regulated their behavior in conditions of high traffic density in order to reduce the likelihood of them diverting their attention away from the forward roadway.

Large individual differences have been found in the nature and frequency of engagement in secondary activities when driving automated vehicles (e.g., Llaneras et al. 2013; Clark and Feng 2017; see also Fisher et al. 2020). Clark and Feng (2017), for example, investigated the impact of driver age on secondary task engagement during automated driving periods. They found that both younger and older drivers engaged in secondary activities when supported by automation. However, younger drivers mostly used an electronic device, while older drivers mostly conversed. Körber and Bengler (2014) reviewed a number of individual differences that may moderate the involvement and impact of driver distraction in automated vehicles. These include complacency and trust in automation, driver experience, and the propensity to become bored and daydream.

“Vehicle Distraction and Inattention”

Will driver distraction remain an issue in vehicles equipped with SAE Level 4 and 5 automated driving systems that obviate the need at all for a human driver to intervene? After all, in these vehicles, so equipped, there would be no controls, no driver, and the vehicle occupant could simply sit back and let the vehicle do all the driving.

This question highlights again the frame of reference through which distraction is conceptualized. Cunningham and Regan (2018a) speculate that, if there are only a few SAE Level 3, 4, and 5 vehicles in the community fleet, which mix with SAE Level 1 to 2 vehicles, then there may emerge a new frame of reference for distraction. Here, it is possible that drivers of vehicles being operated manually might be distracted by the behavior of vehicles operating autonomously if the latter have been programmed to drive in ways that violate drivers’ expectations; in much the same way that drivers are distracted by the behaviors of others who drive or ride erratically in traffic flows.

If it is the responsibility of vehicles equipped with SAE Level 4 and 5 technologies to perform automatically all activities critical for safe driving, is it possible for such self-driving vehicles themselves to be distracted? Regan (in Lee et al. 2020) has labelled this "vehicle distraction." Here, again, the frame of reference for conceptualizing distraction will change. But what competing activities, if any, could divert a vehicle's "attention" (or computational resources), more generally, away from activities critical for safe driving? In fact, what might it mean for a vehicle driving autonomously to be inattentive and, if it was, what might be the mechanisms of inattention? (Cunningham and Regan 2018a, b).

These are interesting questions. For a vehicle to be attentive to activities critical for safe driving, its algorithms will need to be programmed such that the vehicle knows, from moment to moment, to which activities critical for safe driving it should be attending. If so, it will become necessary to specify – a priori – what these activities critical for driving will be, and they will presumably be a subset of the higher-level functional driving activities specified by Brown (1986), referred to earlier. They will change from moment to moment, along any given stretch of road.

But how do software programmers know what activities, critical for safe driving a vehicle operating autonomously, they should pay attention to from moment-to-moment along a stretch of roadway when the research community has not yet itself agreed on what we, as human drivers, should be paying attention to from moment-to-moment (Kircher and Ahlstrom 2016)? For those who have thought deeply about what activities are critical for safe driving (Engstrom et al. 2013; Hallett 2013), we know that this is not a trivial task.

Nevertheless, it is interesting to speculate on by what mechanisms, if any, a vehicle equipped with SAE Level 4/5 automation technology operating autonomously might become inattentive to activities critical for safe driving? The taxonomy of inattention proposed by Regan et al. (2011), noted earlier (see Table 1), is also useful in stimulating thought about the mechanisms by which an SAE Level 5 equipped vehicle might itself become inattentive to activities critical for safe driving. Regan (in Lee et al. 2020; see also Cunningham and Regan 2018a) has speculated on what "vehicle inattention" might mean for each of the five mechanisms of inattention proposed by Regan et al. (2011):

- *Driver restricted attention*: For a Level 4 or 5 equipped vehicle, this category of inattention might describe a vehicle that "goes to sleep," so to speak, if, for example, there is a system failure, or some or all vehicle sensors suddenly become incapable of seeing. Here, the vehicle may become inattentive to some or all activities critical for safe driving.
- *Driver neglected attention:* This category of inattention would seem to be less relevant to the design of vehicles when driven by automation given that, unlike, humans, they will not be prone to the kinds of attentional biases, expectations, and limitations that humans are.
- *Driver mis-prioritized attention*: For a vehicle driving itself, this category of vehicle inattention might come about if the computer algorithms that drive it fail, through inadequate design, to give attentional priority to the most critical

competing activities critical for safe driving at a given moment in time. Even though vehicles when driving themselves will not have the limited attentional capacity of humans, software engineers will nevertheless need to program the vehicle to prioritize who and what the vehicle should pay attention to at any given moment in time during a trip.

- *Driver cursory attention*: For a vehicle driving itself, this is about not providing enough attention to activities critical for safe driving. Again, this category of inattention may be less relevant to the design of highly automated vehicles given that, unlike humans, they will not have the same limited attentional capacity. Nevertheless, it is incumbent on software engineers to ensure that vehicles driven by automation allocate enough attention (computational resources) to activities critical for safe driving to ensure that they are successfully and safely completed.
- *Driver diverted attention*: For a self-driving vehicle, this is about distraction. But is it possible for a vehicle operating autonomously to be distracted? It is probable that, if demanded by consumers, vehicle manufacturers may give drivers the option of operating self-driving vehicles manually. Current evidence suggests that there will be some demand from consumers (Cunningham et al. 2019). In this case, it is possible that drivers themselves could become sources of "vehicle distraction." This might occur, for example, if they attempt to take back control of a fully automated vehicle when they should not, in which case, vehicle "attention" may be diverted by the driver, at least temporarily, away from what the vehicle considers at that point in time to be the activities critical for safe driving to which it must attend. Vehicle distraction might also occur if people elect to drive self-driving vehicles manually (if allowed) in a way that violates the pre-programmed expectations of vehicle algorithms in other vehicles that are being controlled by automation. Here, self-driving vehicles might be seen as being distracted by the behaviors of other self-driving vehicles being operated manually.

The whole issue of what distraction and inattention, more broadly, might mean for self-driving vehicles in future is a fascinating one. The different frames of reference through which distraction may be conceptualized makes it highly unlikely that it will ever disappear as a road safety issue. For vehicles with higher levels of automation, then, countermeasure development will need to focus in future on a somewhat different set of distraction-related issues:

- The prevention of automation surprises (for Level 3 ADFs).
- Support for quality takeover and rapid gaining of control by drivers when requested by vehicle automation (for Level 3 ADFs).
- Prevention and mitigation of secondary-task engagement at inappropriate moments in time when automation is engaged (for Level 3 ADFs).
- Prevention and mitigation of passive fatigue induced by low workload during prolonged periods of automation (for Level 3 ADFs).

- The programming of automated driving features in a way that ensures that the vehicles they control do not violate the expectations of other road users (for Levels 3–5 ADFs).
- The prevention of "vehicle distraction and inattention" (for Levels 3–5 ADFs).

Countermeasure development for driver distraction at higher levels of automation is, however, in its infancy. Those countermeasures known to have been proposed have focussed on a limited number of areas: education and training for maintenance of vigilance of the driving environment and for understanding ADAS/ADF modes and vehicle performance (e.g., Casner and Hutchins 2019; Noble et al. 2020; Regan et al. 2020); human-machine interface design to minimize automation surprises and support safe resumption of manual control (e.g., Carsten and Martens 2019; Campbell et al. 2020); human factors considerations around policy and regulation for vehicle automation (Burke 2020); and use of driver state monitoring technologies and driver feedback to detect distraction and reorient driver attention (e.g., Lee et al. 2009; Lenné et al. 2020).

Conclusion and Strategies Moving Forward

In this chapter, we have introduced the reader to the field of driver distraction: its definition and mechanisms, its impact on driving performance and safety, prevention approaches, countermeasures, and new frames of reference for conceptualizing distraction as traditional driving functions become increasingly automated.

The focus of the chapter has been on driver distraction, although we acknowledge that there are other road users vulnerable to the effects of distraction, including bicycle riders and pedestrians. To our knowledge, there has been no systematic attempt to define distraction from their frames of reference and to define and classify the sources and mechanisms of distraction that lead to interference with activities critical for safe riding or walking. Furthermore, relatively little research has been done to understand the impact of distraction on their performance and safety (Oviedo-Trespalacios et al. 2019b). Prevention and mitigation strategies for these road user groups are, hence, at a relatively early stage of maturity.

Just as activities critical for safe driving will continue to change as vehicles become more automated, so too will the sources of distraction drivers interact with that may impair their performance. These include new infotainment and other technologies being built into the vehicle by manufacturers, special interfaces that provide connectivity between smartphones and vehicle displays and controllers (e.g., Apple CarPlay; Android Auto), and portable devices brought into the vehicle, including smartwatches and other wearables. While there is some limited research on the effects on driver behavior and performance of interaction with these devices while driving (Oviedo-Trespalacios et al. 2019f; Strayer et al. 2019; Ramnath et al. 2020), little or nothing is known about their impact as contributing factors to crashes and increased crash risk. Similarly, we know almost nothing about the impact on crashes and crash risk of distraction created by automated driving features.

While the focus of this chapter has been on the negative impacts that distraction may have on driving performance and safety, there is evidence that distraction may in some circumstances enhance driving performance and improve safety – by, for example, counteracting the effects of fatigue (Williamson 2009; see also Olson et al. 2009). However, the specific mechanisms by which this occurs (e.g., through increased arousal; increased vigilance, etc.) have not, to our knowledge, been researched and operationalized. Further research is needed to understand under what conditions, and how, distraction can be used in a positive way to optimize driving performance.

Laws that regulate the use of particular technology devices (e.g., mobile phones, visual display units) are becoming quickly outdated as new technologies and modes of interaction with them emerge. Australia's National Transport Commission (NTC) has recently advocated a shift away from technology-based road rules towards technology-neutral approaches for regulating driver distraction (National Transport Commission 2019). This approach would provide (p. 8) (a) "a clear list of high-risk behaviours and interactions that drivers must avoid regardless of the technology involved or the source of distraction" and (b) "reduced uncertainty about 'proper control' to address both the observable causes and consequences of behaviours and interactions that can impair a driver's control of a vehicle." This would seem to be a positive way forward that focuses more on those behavioral interactions known to increase crash risk (e.g., long eye glances away from the forward roadway) rather than on the technologies that induce them, and provides clearer, evidenced-based guidance to enforcement authorities on what constitutes improper control of vehicles being driven by distracted drivers.

In addition to the guidance already provided in this chapter, we provide in Table 5 some general strategies that might be considered by society in setting a coordinated agenda for the management of distracted driving going into the future. They have been categorized under headings that will be more familiar to road transport agencies: data collection and evaluation, education and training, employers, legislation and enforcement, licensing, public education, research, road and traffic engineering and design, roadside advertising, stakeholder consultation, technology design, and vehicle design. These strategies derive from material presented in this chapter, our own thinking and some other sources (Regan et al. 2009; European Commission 2015; NRSPP 2016; PIARC 2016; Imberger et al. 2020; Regan et al. 2020; Department of Transport and Main Roads 2020b). It is our hope that the material presented in this chapter, along with the general strategies outlined in Table 5, will go some way towards informing the future management of distracted driving.

Until all vehicles can drive themselves, in all conditions, all of the time, it is unlikely that we will achieve Vision Zero for distracted driving, and even then, self-driving vehicles may themselves be vulnerable to its effects. In the meantime, however, there is much that can be done to prevent and mitigate the effects of driver distraction as we strive, collectively, to achieve Vision Zero.

Table 5 Strategies moving forward to manage driver distraction

	Strategies
Data collection and evaluation	Adopt a common definition of distraction that can be operationalized and used to code crash and incident data. Standardize the way in which distraction data are collected and coded in crash and incident databases. Provide training for police and crash investigators to detect distraction as a contributing factor in crashes and distinguish it from other mechanisms of inattention. Undertake regular studies of driver exposure to distracting activities. Continue to undertake naturalistic driving studies that enable estimates of crash risk to be established for driver interaction with emerging sources of distraction. Evaluate the effectiveness of all distraction prevention and mitigation strategies that are implemented; design them from scratch in a way that allows them to be properly evaluated.
Education and training	Develop a shared national and international narrative for driver distraction. Align stakeholder educational campaigns to drive cultural change and awareness of distracted driving. Provide distraction management education and training for drivers of all ages. Provide drivers with education and training in the use of vehicles equipped with ADAS and automated driving features focussed on distraction. Make driving instructors aware of driver distraction management competencies that should be covered in their driver training programs. Leverage personalized insurance pricing for safe drivers, with an emphasis on distraction mitigation. Educate consumers to make wiser choices regarding their purchases in terms of technology that minimize distraction while driving. Develop new educational models and leverage the potential of new technologies such as virtual reality to create more effective education.
Employers	Develop an understanding of the relationship between job demands and distracted driving. Encourage employers to develop and implement best practice policies for managing distraction – for both professional and nonprofessional drivers. The NRSPP (2016) “Guide to Developing an Effective Policy for Mobile Phone Use in Vehicles” is a good example. Consider insurance as a lever for corporate vehicle fleets – as a mechanism for incentivizing the implementation of best-practice policies for managing distraction and safer driving technologies.
Legislation and enforcement	Evaluate relevance and effectiveness of existing distraction regulations and penalties for driver distraction – monitor Australia’s move towards technology-neutral regulations. Optimize deterrence models to consider legal sanctions, social sanctions, and new road policing activities.

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Table 5 (continued)

	Strategies
	Develop and implement technologies that support police enforcement of regulations for driver distraction. Develop a data platform that enables investigation, tracking, and sharing of crash and infringement data resulting from driver distraction.
Licensing	Incorporate information about distraction in licensing programs. Incorporate into computerized testing driver knowledge of distraction and ability to manage it. Incorporate into on-road testing, criteria for assessing driver ability to manage distraction.
Research	Following an extensive, evidence-based review of the nature and size of the distraction problem in the EU, the European Commission (European Commission 2015) identified the following priorities for distraction research (p. 5): • "Voice recognition: How should such systems be designed? • "Night vision: Can such systems present extra information to drivers in such a way as to alert the driver to potential risks, but without being too distracting?" • "Biometry: Can systems spot inattention quickly enough to permit useful intervention or alerts? Can they be reliable enough to avoid drivers wanting to turn the systems off (e.g., false alarms)?" • "Legislation of usage conditions: How should legislation be designed and worded with the pace of technology development (e.g., new input and output modes) being so quick?" • "Public information campaigns: What is needed in such campaigns beyond the provision of information? How can behavioural change techniques help?" • "Auditory/vocal (cognitive) distraction and how it relates to driver performance and crash risk." • "Sociological aspects of distraction: What makes drivers willing to take part in distraction activities? How do social norms play a role? Does the need for 'connectedness' outweigh risks in the perception of drivers?" • "Views of young drivers on driving and distraction: What makes young drivers particularly susceptible to distraction by devices? Which sub-groups of young drivers are particularly at risk?" • "Effects of countermeasures: Which countermeasures can be shown to really work? What are the relative benefits of enforcement approaches? Can behaviour change" approaches to work to reduce exposure to distraction?" • "Pedestrian distraction studies: What is the exposure of pedestrians to distraction? What behaviours other than crossing the road are affected? How does the increased risk for pedestrians (per unit of travel) compare with that of other road users?" • "Distraction/alertness in the transition to automated driving: How long do people need to move from a distracting task to taking

(continued)

Table 5 (continued)

	Strategies
	over control of an automated vehicle? What are the best ways of alerting drivers in this situation?” • “Self-regulation of road users and good driving behaviour: Does behavioural adaptation (e.g., reduced speed) actually reduce risk for some distracting tasks? What are the distraction tasks that cannot benefit from behavioural adaptation?” • “Future trends and challenges in distraction: Does the ageing population represent an increased distraction risk? Will ‘wearable technology’ improve the situation or make things worse?” • “New vehicles and distraction: Will new vehicles with different behavioural profiles (e.g., electric bicycles with higher speeds) reduce distraction-related safety margins?” • “Business models and eco systems of new distraction-preventing technologies: How can countermeasures be built into the business case? Who will pay for distraction-reducing technologies?” Although many of these strategies are specific to the context of driving, researchers and practitioners should also consider the role of distraction among other road users such as pedestrians, cyclists, motorcyclists, etc. The impact of distraction on the performance and safety of other road users has been under-researched.
Road and traffic engineering and design	Identify which road and roadside objects, events, and activities distract drivers and other road users, and contribute most to crashes and crash risk. Design the road environment to prevent distraction-related crashes, including infrastructure that guides and nudges road users to stay focussed on the driving task. Design the road environment to provide opportunities for road users to recover from mistakes and noncompliance arising from distraction. Design the road environment to lower energy exchange through conflict points to within human tolerances. Develop and implement guidelines and standards for the design of the road and traffic environment to reduce distraction. Develop and implement criteria and test methods for rating the road and traffic environment for its potential to distract drivers that could be incorporated in road safety audits and roadway star rating systems (e.g., IRAP).
Roadside advertising	Promote independent research on the impact of roadside advertising on the safety of all road users. Develop standardized criteria and methods for assessing the suitability of a road site for the erection of advertising signage. Develop standardized criteria and research methods for evaluating the impact of advertising billboards on driver performance and safety. Develop guidance for planning authorities for assessing development applications for advertising on private premises

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Table 5 (continued)

	Strategies
	adjacent to roads to ensure greater consistency with advertisements in the road corridor. Proactively evaluate the impact of new advertising models and technologies on road safety.
Stakeholder coordination	Promote cross-sectoral stakeholder cooperation and coordination led by national and international bodies. Guarantee active participation of major stakeholders such as government, industry, drivers, technology developers, etc. Recognize the role that non-transport stakeholders such as the healthcare system or entertainment industry have in distracted driving. Adopt Human Factors Integration processes to ensure that products and systems are user-centered designed to prevent and mitigate distraction
Technology design	Persuade companies that already develop technologies to use smart phones in vehicles more safely to adopt common HMI design guidelines to further reduce road user distraction. Promote standardization of interfaces for the secure placement, mounting, and powering of nomadic devices on vehicle dashboards to prevent distraction induced by sliding and dislodgement of devices. Develop and implement mobile and wearable design guidelines, standards and features that facilitate safe interactions and prevent unsafe ones. Stimulate demand for other technologies (such as phone blocking, distraction warning systems, and workload managers) where proven to prevent and mitigate (directly) the effects of distraction. Develop and implement technologies that support police enforcement of regulations relating to driver distraction.
Vehicle design	Provide incentives for manufacturers to equip vehicles with technologies that prevent and mitigate the effects of distraction. Stimulate societal demand for advanced driver assistance systems already known to prevent and mitigate the effects of distraction. Develop and implement guidelines and standards for minimizing distraction in current and future generation vehicles. Develop assessment protocols for rating vehicles for their potential to distract drivers that could be incorporated in new car assessment programs (e.g., NCAPS) to encourage improved human-machine interface design.

Cross-References

► Automated Vehicles: How Do They Relate to Vision Zero
► Vision Zero: How it All Started

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Appendix

A Review of countermeasures against distracted driving hazards following the "Hierarchy of Controls."

Level of control	Countermeasure	Description	Evidence of Effectiveness
Elimination	Fully Automated Vehicles (FAV) SAE Level 4–5	FAV use sensors and software to drive the vehicle. Drivers are not required to take control or monitor the vehicle.	As drivers are not required to take control, this raises the question as to whether or not drivers can engage in distracted driving (e.g., eating, mobile phone use, etc.) without any repercussions. Automated vehicles are already being used in controlled road networks such as mining sites (Gershgorn 2016). Projected benefits from such vehicles are only likely to be observed in 25–30 years, mostly due to challenges in infrastructure, legislation, etc. (Dia 2015; Clark et al. 2016)
Substitution	Workload managers	Presenting driving and non-driving related information in such a way that road users are not distracted. Workload managers help drivers to focus on driving when it is needed.	Experimental research has shown that the technology could have a positive impact on safety in reducing distraction from ADAS (driving-related information) (Teh et al. 2018). The effectiveness of this approach to manage non-driving related information is unknown.
Engineering controls	Partially Automated Vehicle SAE Level 3 (also known as autopilot)	Partially automated vehicles involve automation of key vehicle control tasks, e.g., lateral and longitudinal vehicle control. However, drivers are supposed to maintain their hands on the steering wheel and be supervising the	Drivers are likely to engage in distraction while driving partially automated vehicles (Lin et al. 2018), which could result in road crashes.

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Level of control	Countermeasure	Description	Evidence of Effectiveness
		vehicle. Also, drivers must be available to take over control of the vehicle at all times.	
Engineering controls	Advanced driver-assistance systems (ADAS) including crash warning system [available in SAE Level 1–2 vehicles]	ADAS support drivers with features such as cruise control, blind spot monitors, lane centering, etc. ADAS also include systems that provide warnings for upcoming collisions.	Early warnings helped decrease drivers' reaction times, thus avoiding more conflicts and collisions (Lee et al. 2002; Bao et al. 2012). However, ADAS might not compensate for the effects of distraction on drivers' performance (Sieber et al. 2015). ADAS could increase distraction by means of poorly designed warnings/alarms (Biondi et al. 2014; Thompson et al. 2018; Li et al. 2020b). The spread of in-vehicle information systems (IVIS) increases the capabilities and often licit means to engage in non-driving tasks (Oviedo-Trespalacios et al. 2019f). IVIS are often used as an interface for ADAS.
Engineering controls	Blocking technology for mobile phone distractions	There are two main technologies: mobile phone applications and hardware which seek to block mobile phone use while driving (Oviedo-Trespalacios et al. 2019d)	Mobile phone applications and hardware-based technologies to block mobile phone technologies are effective in reducing mobile phone use while driving (Oviedo-Trespalacios et al. 2020a; Albert et al. 2019). However, there are concerns that some applications will not fully prevent high-risk mobile phone interactions. A field study using

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Level of control	Countermeasure	Description	Evidence of Effectiveness
			hardware-based blocking technologies in Australia showed a reduction on mobile phone use while driving (Ponte et al. 2016). Acceptance of blocking technologies is low among drivers which limits adoption of the technology (Oviedo-Trespalacios et al. 2019e, 2020c; Ponte et al. 2016; Reagan and Cicchino 2018).
Engineering controls/ administrative controls	Feedback systems [*Targeting young drivers*]	Feedback systems deliver information to drivers on their performance. Three main different feedback systems have been established (Merrikhpour and Donmez 2017): Social norms feedback that provided a report at the end of each drive on teens' distracted driving behavior, comparing their distraction engagement to their parents. Post-drive feedback that provided just the report on teens' distracted driving behavior without information on their parents Real-time feedback in the form of auditory warnings based on eyes-off-road time	Feedback systems that consider parental norms and real-time feedback are associated with a smaller duration of off-road glances, with parental norms feedback outperforming real-time feedback (Merrikhpour and Donmez 2017). Post-drive feedback showed no significant effect (Merrikhpour and Donmez 2017).
Administrative controls	Legislation	Legislation banning the use of mobile phone devices while driving	There are mixed reports about the effectiveness of bans across jurisdictions. In the USA, universal handheld calling bans are associated with lower self-reported

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Level of control	Countermeasure	Description	Evidence of Effectiveness
			handheld conversations for adult drivers (Rudisill et al. 2019b) as well as a reduction in motor vehicle crash (MVC)-related emergency department (ED) visits (Ferdinand et al. 2019). Alternatively, Rudisill et al. (2019b) found that universal texting bans were not associated with lower texting. A US literature review found that nearly none of the restrictions targeting young distracted drivers sustainably prevented mobile phone use while driving (Ehsani et al. 2016). In Europe, Jamson (2013) found that drivers in the most highly regulated country (Italy) reported texting while driving as frequently as those in countries with no legislation.
Administrative controls	Police enforcement	Police operations to increase compliance of legislation banning different forms of mobile phone use while driving.	Reductions of mobile phone use while driving are observed with resource-intensive police operations (McCartt et al. 2010). However, there are doubts of the long-term impact of the bans on safety (McCartt et al. 2014). The effect of police enforcement of mobile phone bans is limited. Research has shown that police officers are unable to correctly enforce legislation in many circumstances due

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Level of control	Countermeasure	Description	Evidence of Effectiveness
			to lack of resources, poor visibility inside vehicle, unenforceable legislation, among others (Rudisill et al. 2019a; Nevin et al. 2017). Additionally, drivers can engage in police-avoidance strategies such as concealing their mobile phone which further reduce effectiveness of police operations (Oviedo-Trespalacios 2018).
Administrative controls	Organizational procedures/ policies *[Targeting driving for work]*	Implementation of Workplace Health and Safety (WHS) organizational procedures/policies to reduce distracted driving and enhance safety of drivers.	Truck and bus drivers working for organizations that enforced texting bans have lower texting and driving prevalence in comparison to companies without bans (Hickman et al. 2010). Participants in Swedler et al. (2015b) study emphasized the importance of implementing policies that are clearly and strictly enforced. In addition, a participant in the study mentioned that a texting ban would help create an organizational safety culture that does not normalize distracted driving. Truck drivers in Swedler et al. (2015b) study listed the following examples that could be effective in reducing distracted driving: Better procedure for communicating with driver – delivering a noninvasive signal over dispatch device to

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Level of control	Countermeasure	Description	Evidence of Effectiveness
			indicate that the driver received a message Enforcing bans on distracted driving activities Video-monitoring to observe drivers engaging in distracted driving Monitor cell-phone usage if driver is using a company-provided phone Locking out device while vehicle is in motion Automatically updating package delivery drivers' routes so drivers don't have to make scheduling/routing decisions while driving
Administrative controls	"It Can Wait" educational program	In 2010, AT&T launched the "It Can Wait" campaign across the USA to educate drivers on the dangers of texting and driving. The campaign involved: Signing an online pledge to encourage drivers to make a commitment to never drive distracted (e.g., "I pledge to always drive distraction free.") A mobile app called "AT&T DriveMode," which detects when a vehicle is moving more than 25 miles an hour. If a driver receives a text message or email when the vehicle is in motion, the app is capable of sending an automatic reply to notify them that the user is currently driving (AT&T 2012). A virtual reality experience on their	AT&T evaluated the program after its launch, and found strong, positive, relationships between the campaign activities, particularly social media sharing, pledging, and mobile apps, and the projected reduction in crashes that would have taken place across the USA over a 1-year period (Carter 2014).

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Level of control	Countermeasure	Description	Evidence of Effectiveness
		website that helps users experience the dangers of distracted driving	
Administrative controls	“Steering teens safe” educational program	Educational intervention targeting parents of teen drivers. The intervention included: Parents received a workbook that identified 19 safety lessons divided into 4 topics: basic safety principles (including distracted driving); safe driving skills; rural driving; and special situations. Parents were upskilled on motivational interviewing in an initial 45-minute session. Parents received three 30-minute follow-up phone calls to provide additional intervention support	The intervention had a weak but positive effect, enhancing risky driving and parent-teen communication about road safety (Peek-Asa et al. 2014).
Administrative controls	“Just Drive—Take Action Against Distraction” educational program *[Targeting driving for work]*	An education program designed to increase awareness of the dangers of distracted driving and to encourage employees to be safe and responsible drivers. The program included presentations, group activities, and a “pledge card” to document the planned behavioral changes. The target group were businesses and organizations in San Diego County as part of employee safety and wellness programs.	The program was well received among the participants and resulted in positive changes in short-term intention and medium-term behaviors. Additionally, participants showed increased knowledge regarding distracted driving legislation and risks (Hill et al. 2020).
Administrative controls	“FOrward Concentration and Attention Learning (FOCAL)” educational program	The FOCAL program is a research-led training that consists of three stages: Pretest: Trainees watch four video clips while	Driver who received the FOCAL training engaged in fewer in-vehicle glances longer than 2 s by roughly 25 percentage

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Level of control	Countermeasure	Description	Evidence of Effectiveness
		having to switch between viewing the forward roadway and a map via keyboard. Trainees were asked to find the location of a street while also limiting glances away from the road to less than two seconds. Participants hit the space key on the keyboard to switch between the viewing the forward roadway and the map Training: This stage included feedback, timer, 3-second in-vehicle glance training, and 2-second in-vehicle glance training. Posttest: Trainees finished the program by watching four new video clips and completing the same task as in the pretest.	points when compared to the placebo group (Unverricht et al. 2019).

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Automated Vehicles: How Do They Relate to Vision Zero 34

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Abstract

The ideas to develop and introduce partially or fully automated vehicles are not recent but are not used on any larger scale at this moment. It is though likely that automating different functions, or moving vehicles driverless, will be common sooner or later. In this text, it is discussed how Vision Zero principles relate to the automation of the road transport system. Key findings are that automated vehicles

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will have to be better than human drivers and their safety system horizon will be key to limiting their functionality. The road transport system will have to be adapted to both failing humans and failing automated vehicles.

Keywords

Vision Zero · Automated vehicles · Model for safe traffic · Rules around automated vehicles

Introduction

Automation is entering the road transport system. This both as automated safety systems but also, being more challenging, as fully or partially automated vehicles. Vision Zero can be an important cornerstone when setting demands on automated vehicles. The safety requirements put on automated vehicles will probably be high, higher than the demands on human drivers. Models and approaches will have to be developed.

The ideas to develop and introduce partially or fully automated vehicles are not recent but not used on any larger scale at this moment. It is though likely that automating different functions, or moving vehicles driverless, will be common sooner or later. In this text, it is discussed how Vision Zero principles relate to automation of the road transport system.

Automation of vehicles can be seen as a stepwise migration of different driving tasks from the human driver to the vehicle. There is a migration of both normal driving tasks and driver actions in crash-related critical situations. There are several scales, but the Society of Automotive Engineers (SAE) seems to have developed the most widespread definitions of the levels between no automation and full (autonomous) automation (SAE 2018). A more simplified scale is a to go from "feet off" via "hands off" to finally "eyes off" representing the steps from automation of longitudinal control of speed to control of lateral positioning to finally let the technology take over all strategic, tactical, and operational driving tasks. In the highest level, full automation, the vehicle is "driverless" and could drive without human interactions. In between the steps, we have temporary situations, from milliseconds to infinite time, when the technology control some functions of the vehicle. This could be triggered as a safety function, like electronic stability control (ESC) or autonomous braking (AEB). They could also be more comfort oriented like adaptive cruise control (AICC). We can also see remote control of vehicles like geofencing of speed or "radio control R/C" with remote driving as some kind of automation, i.e., taking control of the driving task from the driver in the vehicle. A second development route is the one where low-speed vehicles operate along predefined route. These vehicles are seen already today. As they develop they will be able to incrementally manage more complicated situations.

The Vision Zero Concept

When first introduced around 1994, the Vision Zero contained a shift in focus in many traffic safety areas. One important and significant shift was in the new responsibility balance between the road users and system designers. System designers were defined as the bodies in society that design, operate, and use the road transport system. Vision Zero is stating that the system should be adapted to the failing human – a relatively dramatic shift from the common approach that road users should take the burden of a dangerous and non-error-tolerant road traffic system.

1. **The designers of the system are always ultimately responsible for the design, operation, and use of the road transport system and thereby responsible for the level of safety within the entire system.**
2. **Road users are responsible for following the rules for the safe use of the road transport system set by the system designers.**
3. **If road users fail to obey these rules due to lack of knowledge, acceptance, or ability, or if injuries still occur, the system designers are required to take necessary further steps to counteract people being killed or seriously injured.**

Vision Zero's shared responsibility concept

Vision Zero is further focusing the road traffic safety challenge to the most severe injuries, the impairing injuries and the fatalities. The development and introduction of Vision Zero resulted in a change in the Swedish Road Administration that up until Vision Zero mainly used accident reduction as the key target. Shifting focus and targets from accidents to the most severe cases changes what solutions are prioritized.

Illustrations about 2+1 roads and roundabouts (Swedish Transport Administration 2019)

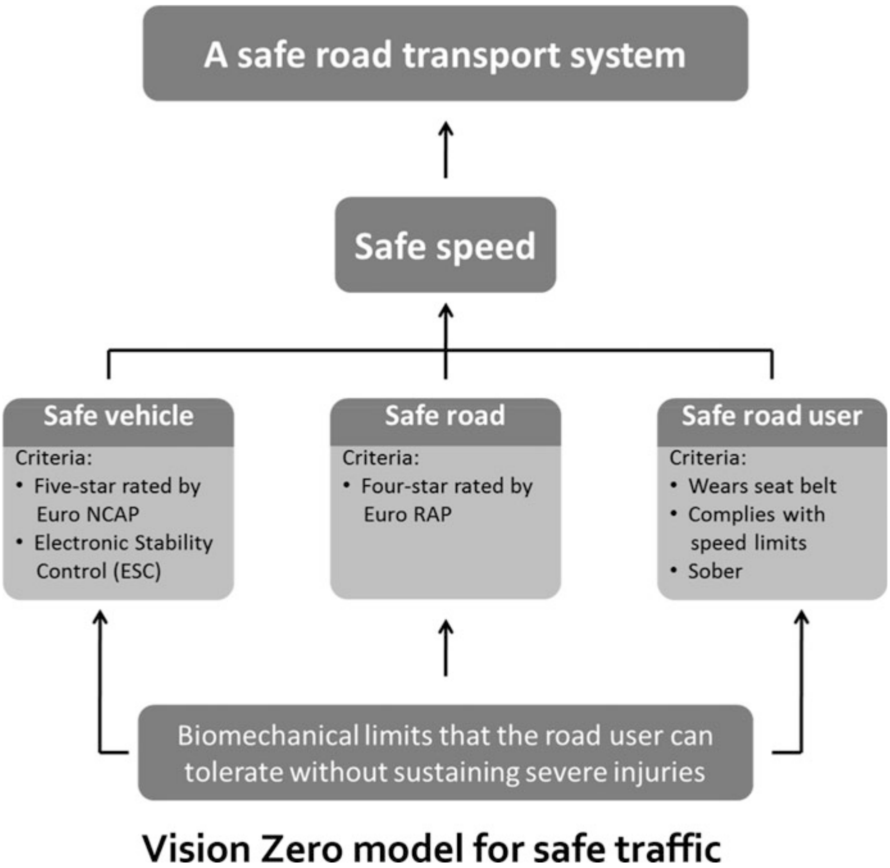
The safety core of Vision Zero is very much to design for the failing, non-perfect human – the human making misjudgments, errors, and mistakes. This is in strong contrast with the idea of perfect humans in traffic. The National Highway Traffic Safety Administration (NHTSA) in the USA finds that 94% of accidents are because of human error. This illustrates that the road traffic system is not designed for humans with the capabilities and weaknesses they have. The 94% human error problem, as described by NHTSA, can lead to the conclusion that we must develop driver further. In Vision Zero, the main focus is to develop the road transport system to absorb human failures to avoid fatalities and serious injury. However, we must bear in mind that humans are relatively good at driving.

As previously stated, Vision Zero is not aiming for a crash-free road transport system. It is aiming at a system without crashes that risk to result in loss of life or loss of long-term injuries. This is leaving the system designers with the possibility to manage the energy in crashes to levels that are survivable and not resulting in long-term harm. Energy control becomes essential and would include not only limiting kinetic energy but also using barriers, dampers, and filters outside and inside vehicles or directly protecting the human body through helmets and other protective gear.

Vision Zero Models for Safe Traffic

Vision Zero is using a holistic approach to road traffic safety. The capabilities of the road users and the performance of vehicles and roads together with the energy levels (speed) in the system can be balanced to deliver an efficient and safe system. High and safe travel speeds are possible with good cars on good roads and when no vulnerable road users are at risk in the system. With today's vehicle safety systems, speeds must be under 30 km/h when vulnerable road users and cars interact.

To illustrate how the components of the system interact, a Vision Zero model for safe traffic was developed. The Vision Zero model for safe driving can help in the planning process of a management system for traffic safety, especially in the design parameter setting and in the understanding of potential crashes.



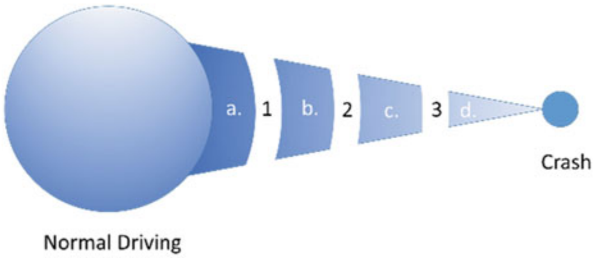
Vision Zero model for safe traffic

An example of the use of elements and criteria is how the factor "Safe vehicle" contains the element vehicle safety as measured by Euro NCAP and the criterion 5 stars. Another example is in the factor "Safe road user" that is having "Wears seatbelt" as element and 100% fulfillment as criterion. Stigson et al. have used this model to evaluate the safety on Swedish roads (Stigson 2009). By setting the criteria, a "safe" speed limit can be defined. Volvo Cars and the Swedish Transport Administration made a joint effort in 2011 to define "safe speed limits" (Eugensson et al. 2011). The basis was the existing levels of crash safety and accident avoidance technologies. The exercise indicated that at road without a median guard rail and safe management of the side areas, the maximum speed could be 80 km/h. The assumption was that the best cars could brake away 20 km/h before the crash and that a crash with a change of velocity of 60 km/h could leave the passengers without life-threatening injuries. The implication is that at speed higher than 80 km/h, significant investment in the road infrastructure is essential. At lower speeds much of the safety can be vehicle based. For vulnerable road users, a similar discussion was held and showed that travel speed of 40 km/h could be considered safe if the vehicles could brake 10 km/h before a crash and assuming a crash with a vulnerable road user is "safe" at 30 km/h. The numbers presented illustrate well how the human biomechanical limits, the protection in and of cars, the potential pre-impact braking, and the speed limit together can be used to calculate risk.

The reasoning above can be illustrated as a chain of processes potentially leading up to a crash and a serious injury or fatality.

The Vision Zero Integrated Safety Chain Model

To understand how crashes and injuries occur, the Vision Zero integrated safety chain model was developed (Tingvall 2008). It is describing crashes as a process spanning from normal driving to a crash and post-crash care and rehabilitation.



The integrated safety chain model

In the normal driving phase, most of the driving is done. The parameters from the Vision Zero model for safe traffic apply. The speeds should be at levels that ensure that potential crashes don't result in severe injuries of fatalities. If all drivers were perfect, the story would stop here. Everyone would be in the envelope of normal driving all the time. But when we design for failing humans, we must plan for events where road traffic users sometimes make errors, misjudgments, and mistakes. It is, however, important to remember that humans in a larger perspective are extremely good at driving and managing traffic. Most of us stay in the normal driving phase for hours and hours also in complicated traffic situations.

Even if normal driving is common and to a large degree regulated, human drivers often leave the normal driving and enters critical situations. Illegal speeding, driving too close, and not being able to stop in time are all examples of such situations.

For a multitude of reasons, drivers sometimes leave the normal driving or critical envelope and approach a critical situation (b). At this stage soft methods can be used to get the driving back into normal. This could be in the form of lane departure warnings, electronic stability control, or the warning element of emergency braking systems. In this early phase, the driver can still be part of the control and get the vehicle back into normal driving. One can expect that drivers are in these critical situations several times every year.

If the potential crash passes barrier level 2, one can no longer expect the driver to manage the situation. In phase c automated emergency braking is today such a system. In the future automated emergency steering can avoid potential crashes. In phase c reversible crash safety systems can also be activated. Reversible seatbelt pretensioners are one relevant example.

If the event is passing barrier 3, the crash can no longer be avoided. However it can still be mitigated by continuation of emergency braking in phase d. The consequences of the crash can in this phase be reduced by non-reversible crash safety systems.

In the crash more traditional safety systems such as seatbelts and airbags are active to protect the occupants. In a safe system, no energy can hit the human body at levels higher than the biomechanical tolerance levels for severe or fatal injuries. An ordinary driver can drive all the life without experiencing a crash going all the way to severe injuries.

In the integrated safety chain, one element is the frequency of cases going from normal driving and to a potential crash. One must be aware that very few crashes actually end up in severe and potentially life-threatening cases. An ordinary driver in a modern car can experience some ESC interventions and perhaps a few emergency brake warnings per year. Emergency braking or pre-impact deployment of safety systems is even rarer.

The integrated safety chain model is also an illustration of energy and can be read in reverse to establish safe travel speeds. Starting with the human tolerance, adding the crash safety system's performance and finally adding the crash mitigation and avoidance system's capabilities can result in a safe normal driving speed. A consequence of this is that cars with poor crash safety and few crash mitigation and avoidance safety systems have a lower "safe speed" compared to the best cars. This is what the above mentioned Volvo Cars study illustrated.

The Vision Zero work has developed two important models, the model for safe traffic and the integrated safety chain. Both models show how the human tolerance to crash impact, together with safety systems, can indicate safe travel speeds. The models also illustrate how different safety layers can support one another to generate safe traffic and that modifications would be directed to not only the vehicle but also the infrastructure.

In 1965 and 1966, Sweden had 1313 fatalities each year, the highest in Swedish history. This corresponded to around 17 fatalities per 100,000 inhabitants. Today Sweden has around 2 fatalities per 100,000 inhabitants. It is interesting to note that Sweden historically had about the same fatality rate as the world has today. According to the WHO's Global Status Report on road safety 2018, the global rate of road traffic death per 100,000 population was calculated to be 18.2 in 2016. The large reductions are a consequence of systematic work altering the components and interactions of the road transport system.

What About Automated Cars?

A question to consider is the relation between automated cars and Vision Zero. Do the Vision Zero models applicable for a fully or partially automated road transport system? There are reasons to believe so. Just as Vision Zero is defining possible speeds/energy levels based on the safety-related design properties of the road and the vehicles, an automated system must consider crash mitigation and avoidance safety properties, crash safety capabilities, and possible safe travel speeds. This approach is essential at least as long as the automated cars are used in traffic also containing manually driven vehicles and they have not proven to be crash- or incident-free.

In this paragraph the integrated safety chain will be used for a discussion about safety strategies for automated cars.

The normal driving of a fully automated car will be very different from the normal driving for humans. Automation and computers lack many of the human's weak spots. They don't get tired, they don't get drunk, they can have constant focus, etc. But potentially automated vehicles have in some aspects lower capabilities. The human eye and ear have dynamic ranges and capabilities that is a challenge to match. One can assume that the challenges for humans also are challenges for automated cars but also that automated vehicles will have unique challenges not yet well known. One can assume that humans have a unique possibility to act "approximately right" in complicated new and unexpected situations.

Sensors are very important elements since they are the basis for situational awareness. The situational awareness, mapping ego activities, the road properties, and the positions, speed, and intention of other road users are the bases for safety as the vehicle must operate in a dynamic surrounding. Humans have a very good capability when it comes to making decisions based on sparse information in a complicated situation.

Humans often bend or brake road traffic regulations. From an individual perspective, it can seem rational and beneficial. The perhaps most common is to travel faster than the regulated speed limit. But road users often break other rules and regulations as well. From a societal perspective, this is a problem and a reason for the significant road traffic problems we see. One must assume the fully automated vehicle will be law abiding, and therefore there is no variation in relation to rules and accepted practices in driving and therefore no need for bringing the car back to normal driving, i.e., the driving is always in the safe normal driving envelope. This makes the design of a safe system easier. However, for a long time we will have to design for both human driver partially automated and fully automated vehicles.

Automated vehicles will, just as human drivers, make errors and mistakes and misunderstand situations. As an effect of this, automated vehicles will at least initially need the same safety package as ordinary vehicles. If the fully automated vehicles should travel at speeds similar to vehicles driven by humans, the safety package must be the same. When designing a fully automated vehicle, there are good reasons to consider and design the safety systems as separate from the systems managing normal driving. This would add a much valued element of redundancy. A good side effect of automated cars having sophisticated crash mitigation and avoidance systems and crash safety system would probably also be further improvements to the safety pack of ordinary vehicles.

Is Performing as Good/Bad as Humans Good Enough?

The question above is probably one of the most challenging when discussing the introduction of fully automated vehicles. Here it will be discussed with an ethical approach, a legal approach, and an efficiency approach.

First of all we must define the objective of what potential outcome of incidents and unexpected events should be for a fully automated car. We could aim for the same safety ambition as Vision Zero, no fatalities or serious injuries. Or we might choose to move to “no crashes at all” or even further to avoid also incidents as to aim for security or rather the feeling of security. Cases that go beyond the target in Vision Zero would have major impact on the way a fully automated vehicle can operate. Using the chain of events approach where we limit the travel speed to what is possible to avoid fatalities and serious injuries and instead replace such a target with avoiding crashes means that we must reduce travel speed substantially. And if we would limit, say, braking to less than 0.2 g (normal and conformable braking), the travel speed would have to be further reduced. To some degree improved sensing and situational awareness could influence acceptable travel speeds but only marginally as long as errors do occur.

The road transport system kills about 1.25 million people every year. That is an alarming number, and as previously pointed out, the international society has taken action against road fatalities (United Nations General Assembly 2020). The situation has had a relatively low priority since our attitude to a large degree has been to blame the victim. An individual has done something “wrong” and is hence to blame. The fact that there is a guilty part has blinded many. The Vision Zero introduces the shared responsibility model. Road traffic users must do their best, but the system designers hold a high degree of responsibility for the design and usage of the system. It is more ethical to blame the ones having a real possibility to change the system (Hauer 2016).

Further it seems that we, both society and individuals, have a higher interest in protecting passengers than drivers. Being an innocent victim is significantly different from being an active agent, a driver. The effect of this is that safety in trains and planes is significantly higher than in cars. In aviation and for trains, there is virtually no balancing between safety and efficiency. Safety comes first. In the road transport system, such balancing is still common practice even if Vision Zero slowly is changing practice in many organizations.

For fully automated cars, it seems relevant to put the safety ambitions as high as the levels for aviation of train riding, a twentieth of the risk of today's car riding.

The Vienna Convention Article 13

The road transport system of today is running as it does, much because of driver not fully adhering to the rules. But taking the rules literary will probably be a prerequisite for partially or fully automated vehicle functions. The Vienna Convention of road traffic from 1968 is setting the framework for road regulation in most countries. One significant article in the convention is Article 13.

The key aspect is that the driver (or in the case of automated cars the control mechanism) always should adapt the speed so to be able to stop for any foreseeable obstruction. Even if the Vienna Convention isn't a regulation in itself, this article should be implemented in all national regulations in the contracting countries.

Human drivers are often not fulfilling the demand to be able to stop within the range of forward vision. This is clearly seen in the dark, rainy, or foggy traffic situations. We also often pass buses where it is well known that especially children can rush into traffic. Humans frequently take risks and bend rules in ways fully automated vehicles probably cannot accept. The risk taking of humans can to some degree make the system more efficient but at a high cost in insecurity, crashes, and severe or fatal injuries.

Combining the demands from the Vienna Convention, about being able to brake, with Vision Zero's chain of event model can reveal the new situation. The fully automated vehicle must always plan and act as to remain within the normal driving envelope. The energy level can never be higher than the allowed speed limit, but it is further restricted by the demand to be able to stop short of any foreseeable obstruction. The strict demand in the Vienna Convention about adaptation of the speed is often poorly understood or neglected by human drivers. Computer-driven vehicles should have less issues with this. The sensors and their limitations in combination with the systems situational awareness will restrict possible travel speeds. One must keep in mind that the Vienna Convention demands a crash-free system, not an injury-free traffic. The fully automated vehicle will therefore move slower than the rest of the traffic, and it may be sometimes a better idea to close off manually driven cars from some environments. The alternative is to change the rules and the behavior of the manually driven cars as well, to accommodate the principles of the Vienna Convention with regard to speed. Another alternative is to give the automated vehicles special infrastructure solutions to move within.

External or shared sensors could potentially expand the sensor horizon for automated vehicles. It can, however, be questioned whether external sensors can be reliable enough to base safety critical decisions on.

But, even if the energy levels are at the right, fully automated vehicles will be driving in environments with other vehicles and road users. Therefore it is probable that the fully automated vehicles also will crash and therefore need good systems to brake, steer, and protect in the crashes. Fully automated vehicles may be designed in ways where the passengers have seating postures different from the ones of today's vehicles. Safety demands and performance in these new seating positions must be considered. It is not likely that crash safety can be diminished for a long time to come. Further investment in crash avoidance and crash safety is an investment in higher speeds and better mobility.

Probably society will not accept fatalities and severe injuries in the fully automated transport system. As the safety demands increase, the most severe injury that is acceptable will be at lower levels than we see today. In the few and rare crashes that automated vehicles experience, the injury levels must be extremely low.

Very rare incidents and extremely few injuries are also a prerequisite for the acceptance for machine-driven vehicles from the general public. The new vehicles must act and feel like reliable and trustful traffic elements.

The demands regarding the impact of the road transport system will also gradually increase over time in such a way that even children should be able to walk or bicycle without risking any injury as a result of a conflict with fully automated vehicles. This will even more restrict automated vehicle to move in such a way that parents and the society feel secure. This means an even less obtrusive traffic.

Discussion

The development towards full or partial automation of driving functions will no doubt continue. Some of the safety technologies developed and introduced during recent years have been proven to be very effective. There are technologies available or under development that could significantly reduce illegal speeding and impaired driving, related to alcohol, fatigue, and distraction. Further, autonomous emergency braking and lane keeping aid systems have become common practice in modern cars. While these technologies do not have a 100% effect on the situations they address, they still seem to bring down the risk of fatalities to very low levels (Rizzi et al.). If they, hypothetically, would be 99% effective on fatalities, we would still have fatalities left but on a global basis go from, say, 1 million deaths per year to 10,000 deaths per year. That would be a giant step, but still not near today's safety level of rail or aviation (including only fatalities to those using train or regular aviation and excluding, for instance, car occupant fatalities in train to car level crossing crashes).

With these technologies within reach and more to come, full automation is probably not needed to solve today's safety challenges. However, regulation may be needed to ensure that all vehicles are equipped with these new technologies and that the systems are active when the vehicles are driven.

For railway, the acceptable risk for a jurisdiction is set to 10^9 fatalities per operating hours (Tingvall and Lie 2021). If we translate this level to the road transport system, the maximum number of fatalities for the European Union would be less than 185 fatalities per year which is 140 times less than the actual number (in 2018). For the USA, the corresponding figure would be 300 times lower than today's fatality number.

The risk of a fatality in a country like Sweden is already quite low on an individual basis. Calculated on cars (passenger cars, trucks, etc.), we have 200 fatalities linked to these annually, with 5 million cars exposed. This would equate on average to 1 fatality per 25,000 years for a car exposed. For serious injuries the corresponding figure would be 1 case per 2500 years. This tells us that the risk per individual car is low, but on a country level, it still becomes a large health problem.

For cars with a complete set of safety systems, much like a Volvo car of year model 2020 studied in the report by Rizzi et al., we could expect at least a 50% reduction compared to the estimates above. That would equate to 1 fatality per 50,000 years per vehicle and year and 1 per 5000 years for a serious injury. But a serious injury or a fatality would only be a tip of an iceberg, and the number of crashes with/without an injury would be many times more. While crashes without a serious injury or fatality would not be seen as a traffic safety problem, it is likely that they would constitute an unacceptable event for a fully automated car. This could be seen as the main issue surrounding the expectations for a fully automated car in comparison with a car driven by a human.

Many crashes (Rizzi et al. 2019) would be avoided or mitigated if the driver was brought to drive in accordance to general traffic rules. Driving sober, not exceeding the speed limits, and with a distance to the car in front of at least 2–3 s would no doubt have a large effect on the number of killed and serious injury. The figures given above would be significantly reduced when basic rules are followed. If every driver in Sweden did not speed, the number of fatalities would drop by at least 25%. And if no one was driving under the influence, another 25% would not be killed. If we would also add fatigue and distraction as examples, it is likely that we would end up with very few cases of fatalities. A fully automated car would not act as if the driver was intoxicated or fatigued nor drive too fast. But the technologies to detect and limit the driver to act and drive within the legal frameworks exist already. It can be seen as surprising that drivers today are given possibilities to break so many rules when there are technologies available to almost eliminate many offenses.

Given the above logics, it is hard to argue that the safety gains as they are expressed in Vision Zero would be substantial with fully automated cars. On the contrary, it might be a larger challenge to replace the human during normal driving than to only use technology when the driver is acting unsafe and/or a hazardous situation occurs. There are significant benefits in using the capabilities of human drivers and complement these with partially or fully automated functions, without making the entire driving process fully automated.

What seems to be more challenging with the fully automated car is the expectation that it would not only avoid any serious harm to a human but also not crash. It would probably even be expected to act in a nonaggressive way, meaning no harsh braking, etc. This would in turn reduce speed and increase distance to other vehicles and humans. The consequence of the fully automated car would therefore be more of a mobility issue or comfort rather than a safety issue. Furthermore, significant modifications to the road infrastructure would have to be made to improve effectiveness that otherwise would have to be solved by low travel speed. For low-speed fully automated vehicles, this could be more straightforward, especially if they only travel along predefined routes. This seems to be an issue not discussed to the extent that is needed (Sternlund 2020).

In summary, it does not seem adequate to claim that fully automated driving is the way to improve traffic safety to the level of Vision Zero. The combination of the driver and the technology of a vehicle could under certain conditions be as safe as, or even safer than, the fully automated car. But these conditions would no doubt put the same type of restrictions on the driver as we put on the automated car. Speed, fitness to drive, and distance to other road users should be the same for the car driven by a human as it would be on the fully automated car. The main difference between the automation and the manually driven car would be what we aim for – a road transport system free of death and serious injuries or a road transport system free of crashes, incidents, or fear of technology. In the end, it would be the effectiveness of the road transport system that would be the real challenge.

As human drivers will continue to play active roles in driving their vehicles while managing an increasing array of new or newly configured technologies at their disposal, they can expect to encounter more situations when they must consider, or have embraced and trusted a priori, a mix between human and automated control. These questions become tangibly real for drivers of cars equipped with advanced systems. Millions of drivers over the next 10 years will not only have to ask what their vehicle is able to handle, but be prepared and comfortable answering them with literal life-or-death certainty. Democratizing safety technology so that it benefits the greatest number of people as soon as possible is a new way of looking at our journey to full automotive autonomy. We believe that such a development can be enabled by a scalable safety approach that puts each new safety innovation wherever it can work effectively (Veoneer 2020).

It should also be stressed that the safety modeling of Vision Zero is based on modifying the road infrastructure if the conditions does not fulfill the safety requirements given the safety level of the vehicles exposed. For fully automated cars, the modifications to the infrastructure should be brought up as well. Otherwise, the entire safety challenge would have to be solved by the vehicles, and this does not seem to be rational as the travel speed of the safe fully automated car would have to be very low. In summary, it would be a mistake to believe that no modifications would have to be done to the infrastructure or to the functionality of the road transport system if we fully automate the vehicles. However we can foresee focussed action in the infrastructure if they are limited and clearly defined. An open dialogue around demands and performance would help both vehicle and infrastructure designers. We still need to bring humans, infrastructure, functions, and vehicles into the design of the future safe and secure mobility.

Partially or fully automated vehicles will be common in the future. The full potential benefits can only be gained if we understand the potential and limitations of automation. There is also an urgent need to look at automation in the systems perspective that Vision Zero has developed.

Fully automated vehicles are probably not prerequisites to achieve Vision Zero, but Vision Zero or even higher safety levels are a prerequisite for fully automated vehicles.

Conclusions

- Safety, trust, and security are critical elements when introducing partially or fully automated vehicles.
- When machines are driving, the safety demands will increase at least tenfold compared to the expectations on human drivers. They must experience fewer and less severe crashes than what we see today.
- The fully automated vehicles will have to obey traffic regulation. As a result of this, the energy allowed will be restricted by their sensor horizon, sensor reliability, situational awareness, and their stopping distance.
- Even if machines can drive safely in an ego perspective, they will have to plan for crashes by having the same safety systems as human driven cars.
- The key element of Vision Zero, the road transport system must be adapted to the failing human, is valid also for machine-driven vehicles. The system must be adapted for the failing machines.

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Part V

Vision Zero in Other Areas

Vision Zero in Workplaces

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Abstract

Unsafe and unhealthy working conditions contribute to more than 2.3 million deaths globally each year. Vision Zero (VZ) in workplaces presents the challenge to prevent all serious accidents and work-related sickness and disease. Companies and other organizations play a key role, in the development and implementation of VZ, and are supported by international organizations such as the International Labour Organization and the International Social Security Association (ISSA). VZ in workplaces has a long history and several roots, which explain the variety in its application. It is both conceptually and practically closely associated with the development of a broad prevention culture, focusing on the safety, health, and well-being of the workforce as an integrated part of business. VZ in workplaces has developed quickly since the Seoul Declaration (2008), whereby global occupational safety and health leaders and representatives of national governments expressed their will to create a worldwide culture of prevention. In particular, the ISSA launched a global VZ strategy and campaign in 2017, which now (in 2021) runs in more than 80 countries. VZ policies and strategies for both road traffic and workplaces are overlapping and can strengthen each other, as roads are an important place of work in many jobs. The implementation of VZ in workplaces should be regarded as a commitment strategy, based on genuine commitment of both top leaders and all personnel. It is important that VZ in workplaces is understood as a vision and a long-term ambition, not as a target. Proactive leading indicators are therefore more important for VZ than lagging indicators, such as accident frequencies.

Keywords

Golden rules · Innovating to zero · Occupational health · Occupational safety · Prevention culture · Proactive leading indicators · Safety ethics · Total quality · Vision Zero fund · Well-being · Work environment · Workplace · Work-related fatalities · Zero accidents · Vision Zero criticism

Introduction: The Global Challenges Concerning Safety and Health in Workplaces

The focus in this chapter is on how Vision Zero (VZ) is applied in organizations and workplaces. From a global perspective, safety and health in workplaces still needs a lot of improvement, and recent threats to the way we work in times of economic and social crises (e.g., during the COVID-19 pandemic) reinforce this need. According to the International Labour Organization (ILO 2019), more than 2.3 million people die globally from work-related accidents and diseases every year, and it is estimated that road traffic incidents account for approximately one-third of all work-related fatalities (EC 2020).

Roughly speaking, around 7,500 people die every day due to unsafe and unhealthy working conditions. Around 6,500 of them die from work-related diseases, and approximately 1,000 from fatal accidents (see Fig. 1), whereas the numbers for nonfatal accidents and diseases are much higher.

There are great differences in the frequencies of work-related accidents and diseases per region, country, and sector. Figure 2 shows the accident fatality rates per 100,000 persons in the labor force of various continental regions. In Europe, fatal accident frequencies are considerably lower than in, e.g., Asia and Africa, yet meaningful improvements are still needed and possible in Europe.

The high numbers of work-related accidents and diseases do not only mean a high human toll, but also considerable economic losses. According to the ILO, the global economic loss has been estimated at 4% of the Global Gross Domestic Product. This is because millions of productive workdays are lost, there is material damage, and production processes are interrupted. At the same time, there are huge associated

Fig. 1 Deaths per day due to unsafe and unhealthy working conditions (globally) (ILO 2019)

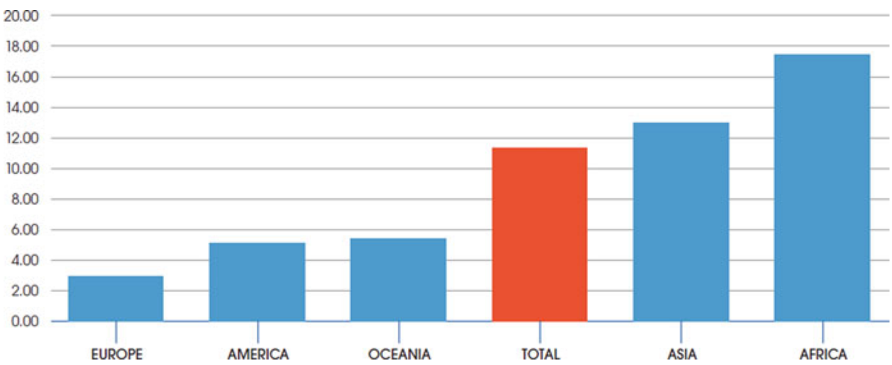

Fig. 2 Accident fatality rates per 100,000 persons in the labor force, 2014 (ILO 2019)

Fig. 3 The symbols of the United Nations Sustainable Development Goals no. 3, 8, 9, and 12, as relevant for Vision Zero in workplaces and road safety

costs for health care and worker's compensation. It is therefore not surprising that Decent Work and Economic Growth is one of the United Nations (UN) Sustainable Development Goals (SDG no. 8) for 2030 (UN 2015). SDG no. 3 – Good Health and Well-being – is also relevant to workplaces and road safety (e.g., SDG no. 3.6), as are SDG no. 9 – Industry, Innovation and Infrastructure, and SDG no. 12 – Responsible Consumption and Production (Fig. 3).

Vision Zero in Workplaces: Roots and Developments

Focus on safety in workplaces has a long tradition and is important in all parts of the world. Present practices with VZ in workplaces build, at least partly, on a range of historic experiences with accident prevention. In the remainder of this chapter, we follow the development of VZ in workplaces chronologically, paying attention at first to its main roots, and with examples of its relevance for road traffic safety.

The Origin of Accident Prevention (Early 1800s)

According to Eichendorf (2011), the roots of VZ for safety at work stem from E.I. DuPont who established a gunpowder mill near Wilmington (Delaware, USA) in 1802. Several severe accidents occurred, and on one occasion three wagonloads of gunpowder blew up, causing many fatalities and destroying many buildings in Wilmington. He realized that the disaster was not only a matter of bad luck. E.I. DuPont was one of the first to formulate safety rules, which he did back in 1811. He also realized that the lack of interest in safety of the managers contributed to the likelihood of accidents and disasters. He thus transferred responsibility to his managers, who were required to live on the site premises together with their families. In this way, he created a strong incentive for prevention. At that time, the understanding of safety and accident prevention was very limited, so DuPont's successes with accident prevention were limited. In the DuPont premises at Wilmington, 288 explosions took place during the period 1802–1921, causing the death of 228 people – including several members of the Dupont family (Hagley Museum

2020). However, E.I. DuPont's interest in safety formed the basis for the DuPont Company becoming a world leader in safety throughout the twentieth century.

Zero Defects (Since 1966)

In the 1960s, frontrunners in quality management were the defense and aerospace industries. In these industries, cooperation between various suppliers and industries in NATO countries implied a need to ensure that components, made in one country, matched perfectly with components from other countries and industries. To guarantee that products were "fit for purpose," quality management initially focused very strongly on "products meeting their specification" and inspection after production. Quality management gurus such as Edward Deming and Joseph Juran had clarified that in order to deliver quality products, organizations had to plan and control their production processes adequately, and they emphasized that quality had to be a top management priority.

The Total Quality philosophy enlarged the focus, from "products meeting their specification" and "being fit for purpose," to all aspects of production. In Total Quality Management (TQM, in Japan known as Total Quality Control, TQC), the general idea was that for delivering excellent quality, it was not sufficient to just control the production process, but that quality management also should comprise the quality of the organization and the quality of its personnel.

James Halpin was director of quality at Martin Company (now part of Lockheed-Martin), and responsible for the quality and performance of Martin's defense products, including missile systems, weapon systems, and communication systems. He was the first to develop a Zero Defects program. Under his guidance, hundreds of groups, also in related industries, developed, implemented, recognized, and sustained Zero Defects programs. In 1966, he published about the Zero Defects approach, to make it more widely available (Halpin 1966). In it, Halpin addressed the "double standard" workers may have: "If our 'everyworker' demands perfection from his mechanic, doctor, dentist, lawyer and all the rest, why doesn't he demand the same of himself in his own job?" (Halpin, p. 4). Zero Defects requires getting rid of this double standard: "The Zero Defects concept promotes a constant, conscious desire to do a job (any job) right the first time" (p. 5). Doing things right the first time eliminates the necessity of rework, reinspection, and retest and, in this way, saves a lot of costs.

Halpin saw the relationship between management and the individual employees as the key to achieving industrial excellence and described the Zero Defects program as ". . .a management technique beamed at getting the employee to think – getting him to think positively about each and every task" (p. 8). This could only be achieved by recognizing the importance of the dignity of the individual worker. Halpin also stated it was ". . .absolutely necessary that the unions be asked to join the ZD team" (p. 33). Though Halpin's program for Zero Defects was later criticized by other TQM experts for focusing too much on "creating a Total Quality Culture" and for "not paying sufficient attention to process controls," the impact of the Zero

Defects movement was great. The landing of the first man on the moon (1969) showed that with involvement of many stakeholders and a quest for prevention, it was possible to achieve unprecedented successes.

Zero Accidents (Since 1970)

When Zero Defects programs began to spread in industries, the path was paved for translating it to zero accident programs. Zero accident programs and campaigns were started in a number of countries and industries in the early 1970s. An example was the “Zero in Safety” or “Focus on Safety” campaign by the National Safety Council in the USA (US Department of Labor 1970). These early zero accident programs focused on promoting the state of the art in accident prevention; however, most of these campaigns lasted for only a few years.

Japan’s Zero Accident: Total Participation Campaign (Since 1973)

The zero accidents campaign of the Japan Industrial Safety and Health Association (JISHA), which was launched in 1973 with support of the (former) Ministry of Labor, demonstrated to be sustainable and is still running today. The campaign elaborated explicitly on activities, for quality control (QC), and also referred to the US National Safety Council campaign.

Similar to Halpin’s Zero Defects program, the Japanese Zero Accident campaign focuses strongly on participation of the workers, with the basic philosophy of respecting human life. They put a strong emphasis on Hazard Prediction training of workers (in Japanese KTY), and the technique of “pointing and calling.” Pointing and calling is a method whereby the workers collectively check the safety of the workplace and each other (e.g., use of personal protective equipment) before work is started. They point to (potential) hazards, and if it is OK, this is called out loudly by the workers. If is not OK, then measures are taken to rectify them. The method emphasizes that safety is a collective responsibility, and by using different senses (vision, sensing, hearing, and smelling), it is expected to have maximum impact on the workers’ awareness. In addition to this, meetings are held to discuss near-miss incidents.

The Japanese campaign is built around three basic principles (JISHA 2020): (1) a zero accident principle: achieving accident-free workplaces (including industrial accidents, occupational illness, and commuting accidents) by detecting, understanding, and solving all hazards (problems) in everybody’s daily life, as well as potential hazards existing in workplaces and work; (2) the principle of preemptive action, i.e., to prevent all accidents and industrial accidents by detecting, understanding, and solving all hazards (problems) in everybody’s daily life, as well as potential hazards existing in workplaces and work in order to create a brighter and more vigorous workplace with zero accidents and zero diseases as an ultimate goal; (3) participation, meaning managers, supervisors, staff, and workers making a concerted effort to detect, understand, and solve potential hazards (problems) existing in workplaces and work. It requires the voluntary effort and commitment of all those involved in actions for problem-solving, and a positive attitude and engagement of top management, safety management, leadership by managers and supervisors, and the voluntary participation of every worker.

From Safety Culture to Prevention Culture (Since 1986)

One of the first references to the term occupational "safety culture" was made in the 1980s after disasters with: (1) the Chernobyl nuclear power plant in 1986 (INSAG 1986), (2) the space shuttle Challenger in 1986 (and Columbia in 2003 – CAIB 2003), and (3) the Piper Alpha oil production platform in 1988 (Cullen 1990). In the analyses, intangible factors such as information difficulties, violations, failure to recognize emerging danger, role ambiguity, management complacency, poor communication, and low prioritization of safety were mentioned (Cox and Flin 1998).

There is no generally accepted definition of safety culture, and there is no universally accepted method of assessment. Many definitions of safety culture can be found in the literature, with at least four issues underlying the variety of definitions (Table 1).

Each of the four "issues of debate" seems relevant for a more broad "prevention culture," encompassing the prevention of injuries, illness, and disease, at the organizational level, wherein there is sufficient trust between management and workers, and wherein open communication is very important for the development of a

Table 1 Main issues in defining "safety culture" (Zwetsloot et al. 2020)

Issue of debate	Examples of definitions
Is safety culture an aspect of the broader organizational culture?	Safety culture is "a specific aspect of organizational culture regarding the organization's shared beliefs, values, and attitudes that contribute to ensuring safe operations" (Morrow et al. 2014)
Should safety be defined normatively (i.e., as a positive concept)?	Safety culture is an "enduring characteristic of an organization reflected in its consistent way of dealing with critical safety issues" (Wiegmann et al. 2004)
Are deeper layers, such as values and implicit assumptions, the "heart" of a safety culture (or are practices most important)?	Safety culture are those aspects of the organizational culture which will impact on attitudes and behavior related to increasing or decreasing risk (Guldenmund 2000)
Are the interactions with safety management systems essential for safety culture?	Safety culture refers to the interaction between the requirements of the safety management system, how people make sense of them, based on their attitudes, values, and beliefs and what they actually do, as seen in decisions and behaviors (ERA 2018)

prevention culture. The concept of a prevention culture does not have to be normative by definition. However, prevention cultures can be well developed or less well developed, and for distinguishing between them a normative framework (e.g., Fig. 4) is always needed. While the direct impact of a prevention culture on safety and health stems from practices and behavior that can be directly observed, these factors are certainly partly determined by "deeper layers," such as underlying values, attitudes, and implicit assumptions. Finally, while a safety and health management system represents the formal rules, the culture represents the informal rules. Formal and informal rules can strengthen each other, or conflict with each other. In the latter case, the culture tends to undermine formal safety management, while in the former culture and systems strengthen each other.

Prevention culture also has a business ethics dimension associated with corporate social responsibility (CSR). Avoiding "shifting consequences" (to others, to society, and to future generations), including the prevention of accidents and harm, is the key principle (Zwetsloot et al. 2013).

One popular and practical way of portraying safety culture in workplaces and organizations involves five levels of maturity or development in regard to companies' approach to health, safety, and the environment (Parker et al. 2006). This is often portrayed as progressive steps of safety maturity, with gradually increasing trust and accountability, from a pathological to a generative culture (Fig. 4; Hudson 2007).

VZ in workplaces is a process, and most reflective of the proactive and generative strategy steps of the ladder (Fig. 4), and it is this that many VZ companies around the world attain to follow.

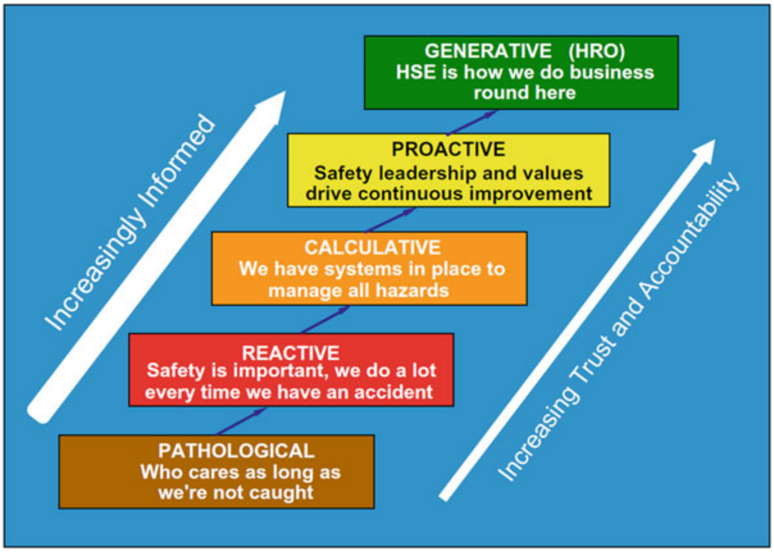

Fig. 4 The health, safety, and environment (HSE) culture ladder. (Source: Hudson 2007)

National Vision Zero Networks (Since 2003)

The Finnish Institute of Occupational Health and a group of Finnish companies started a Zero Accident Forum in 2003 with Professor Jorma Saari, who had picked up the zero "accidents" concept in Canada and the USA. The Finnish forum initially had 21 member companies in 2003 and, in 2021, counts more than 400 member organizations, representing various sizes and sectors. In 2019, the forum redefined itself as the Finnish Vision Zero Forum to reflect a broader application of the VZ concept to safety, health, and well-being. The management and staff of its member organization are committed to improving occupational safety and sharing good practices, in order to learn from each other, across industries and sectors, according to the following principles (Zwetsloot et al. 2017c):

- We commit ourselves to sharing information on best practices with other workplaces.
- We will improve our workplace safety in cooperation with our employees and management.
- Health and safety are an integral part of our workplace's successful business operations.
- We commit ourselves to annually providing the Vision Zero Forum's project team with information on occupational safety.

Similar VZ accident networks were started in the Netherlands in 2011, and in Germany in 2013.

Social Accident Insurance Policies (Since 2008)

In Germany, the national social accident insurance (DGUV) adopted the principles of VZ in 2008. They explicitly explicitly referred to these VZ principles as the basis for their strategy for accident prevention (at work, in schools, and on the road), as well as the prevention of occupational diseases and work-related illnesses (DGUV 2008). DGUV sees VZ as very closely related to the goal to achieve a comprehensive culture of prevention. According to Eichendorf (2011), there are four basic principles underlying VZ:

- Life is not negotiable.
- People make mistakes.
- Tolerance limits are the physical load limits of humans.
- People have a basic right to a safe working environment.

The DGUV regards VZ as a strategic and comprehensive approach. They also underline the ethical aspects of VZ, which implies that safety and health at work be regarded as human and societal values that provide direction to organizational and national preventive efforts. The DGUV also organized three international occupational safety and health strategy conferences, whereby the second strategy conference (2011) focused on a Preventive Occupational Safety and Health Culture (2nd Strategy Conference 2011). In the conference, five pillars were regarded as essential for attaining such a culture of prevention:

1. Vision Zero: Reducing work accidents and occupational diseases
2. Raising awareness, developing competencies and capacity building
3. Cooperation between public health and occupational safety and health
4. Health and safety as an integral part of lifestyle
5. Integrating prevention into the social security system

VZ as pillar no. 1 was regarded as the basis for the other pillars, which prepares the foundation (the strategy) and forms the roof (the objective) for a culture of prevention. The pillar considered to be most relevant for a culture of prevention by the conference participants was pillar no. 2 – raising awareness.

National and International Policies for Vision Zero in Workplaces (Since 2008)

The relevance of VZ for national and international occupational safety and health policies is increasingly acknowledged, explicitly or implicitly, by an increasing number of governments and institutions. A key event for VZ and the development of a prevention culture was the signing of the Seoul Declaration on 29th June 2008, by 46 global occupational safety and health leaders, including 33 representatives of national governments at the occasion of the XVIII World Congress on Safety and Health at Work in Seoul (South Korea) (ILO, 2008). It elaborated on the ILO Convention No. 187 on the Promotional Framework for Occupational Safety and Health, wherein the concept of a culture for prevention was first introduced (ILO, 2006). It was a collaborative effort involving the ILO, the International Social Security Association (ISSA), and the Korea Occupational Safety and Health Agency (KOSHA), as well as representatives of national governments, social security providers, and professional organizations and associations representing employers and employees. They jointly expressed their will to create a worldwide culture of prevention. It broadened the term prevention culture beyond the workplace, by stating that "worker" health was the responsibility of society as a whole. By 2013, 379 institutions had signed the Seoul Declaration, demonstrating a shared will to establish a world-wide culture of prevention with human beings as it hearts (Eichendorf and Bollmann 2013). The Seoul declaration states that a prevention culture implies the right to a safe and healthy (working) environment, which is respected at all national levels. The signatories of the Seoul Declaration committed to actively participate in securing a safe and healthy working environment through a system of defined rights, responsibilities, and duties, whereby prevention was to be accorded the highest priority.

A “Prevention Culture” was defined as a culture in which society as a whole promotes high levels of safety and health at work. “A national preventative safety and health culture is one in which the right to a safe and healthy working environment is respected at all levels, where governments, employers and workers actively participate in securing a safe and healthy working environment through a system of defined rights, responsibilities and duties, and where the principle of prevention is accorded the highest priority.”

With the Seoul Declaration, the focus in prevention was widened from work safety to a broader health and safety prevention approach:

> The steady increase in mental health issues and musculoskeletal diseases is an example, indicating that the borders between workers’ health and public health are dissolving and the links between work life and private life become more fluid. (Treichel 2013, p. 55)

In 2011, the Istanbul Declaration elaborated and built on the commitments of the Seoul Declaration and was signed by 33 countries (30 Ministers of Labor) (ILO, 2011). It recognized a healthy and safe working environment as a fundamental human right, as well as a societal responsibility. It was recognized that building and promoting a sustainable national preventive culture should be ensured through a system of defined rights, responsibilities, and duties. The countries that signed the declaration committed themselves to building sustainable national preventive cultures, and to taking the lead in promoting a preventive culture worldwide.

To foster a prevention culture, both prevention and promotion measures are need that align with values, norms, actions, policies, customs, and beliefs. To help achieve such alignment, six seem essential (Schulze et al. 2013):

1. Reduce the tendency to compartmentalize work from the rest of life.
2. Understand the value of good jobs to a culture of prevention.
3. Integrate into educational systems a focus on career and job readiness that promotes skills for risk prevention.
4. Advance evolved notions of work, health, and prevention.
5. Advance a preventive approach to chronic (physical and mental) disease.
6. Identify the means to make both prevention and promotion integral parts of a culture of prevention and well-being.

The main drivers of societal change are the recognition of safety and health as important human and social values. Recognizing these values implies intrinsic motivation for promotion and prevention in the area of safety and health at work. Yes, there are rules and regulations:

> But people live prevention because they believe in it, they are intrinsically motivated for it, they are convinced of the benefits, they have positive associations with prevention and finally, because they have successfully applied prevention principles at work and in their free time as part of their lifestyle. (Treichel 2013, p. 57)

The benefits of a prevention culture are: fewer health and safety problems and associated costs, and more productive employees; fewer quality and delivery problems, higher reliability, flexibility, and productivity in production and work processes; a better status in society and attractiveness in the labor market, greater profitability, and several social and economic benefits for society at large (Zwetsloot 2014).

In the USA, the National Institute of Occupational Health and Safety (NIOSH) defined a "Total Worker Health" trademarked strategy in 2011. Total Worker Health is defined as policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being. It focuses on four fundamental areas: safety first, well-being, leadership, and empowerment (NIOSH 2016). Another example is the Swedish government who explicitly referred to VZ in 2016 in their occupational safety and health strategy, which was focused on VZ for fatal accidents and other work-related injuries, sustainable working life, and a sound psychosocial work environment (Kristianssen et al. 2018).

Innovating to Zero (Since 2012)

A well-known business analyst and strategist, Sarwant Singh (2012), identified "innovating to zero" as one of the (ten) megatrends that was likely to greatly influence business, work, and life in the years to come. According to Singh, "innovating to zero" is a special kind of mega trend, as:

> It is more a concept than a real happening. It implies the desire for perfection in our society: a 'zero concept' world with a vision of zero carbon emissions, zero crime rates, zero accidents, carbon-neutral cities. (Singh 2012, p. 46)

> Although this seemingly perfect world sounds almost impossible, the point is that governments and companies today are moving towards this 'picture perfect' vision of eliminating errors, defects and other negative externalities, and along that very journey creating for themselves huge challenges and opportunities. (Ibid., p. 46)

Singh regards innovating to zero as a way of running and innovating one's business.

> It is not a trend that is incorporated by individuals or companies overnight. It is a gradual process, a journey that will create opportunities, demand investments, and yield long-term returns. The most remarkable feature of this Mega vision is that the ultimate opportunity lies not in attaining the actual goal itself, but in capitalising on the opportunities that would lead to it. Success in innovating to zero requires an innovation agenda that bravely talks of breakthroughs in the face of radical goals – goals that intend to create a better world, a zero concept world, which is free of unhelpful externalities and defects. It also needs a strong culture from people within that ecosystem. (Ibid., p. 59)

It is important to realize that VZ in workplaces and VZ for road safety, etc., are not unique concepts, but are all part of "a family of Vision Zeros" (Zwetsloot et al. 2013). Many leading companies have committed themselves to several applications of VZ (quality, sustainability, safety, etc.). Initially, each of these visions was criticized for being unrealistic, or too expensive, yet in actual practice they triggered inspiring innovations and contributed to good business cases.

The Global Vision Zero Fund (Since 2015)

It was thanks to the good relationship of the DGUV with the German government that in June 2015, when the World Leaders of the G7 came together in the South of Germany, VZ was discussed at the global top level. VZ was agreed to be the leading concept for improving safety and health (G7 2015a). On that occasion, a "Vision Zero Fund" was established to promote prevention around the world, with the goal of seeing as few serious work-related accidents as possible, or none at all (ILO 2015a). The fund is implemented through the ILO (ILO 2015b), with the aim of supporting low-income-producing countries in improving occupational safety and health (G7 2015b).

Implementation of Vision Zero in 27 European Workplaces (2017)

The Partnership for European Research in Occupational Safety and Health (PEROSH) is a partnership of 14 occupational safety and health institutes in 13 - European countries. The PEROSH "Working Group on Safety Culture and Accident Prevention" generated a discussion paper entitled "The Case for Research into the Zero Accident Vision," which was published in the journal *Safety Science* (Zwetsloot et al. 2013). In the paper, it was emphasized that many companies with a good safety reputation had adopted a zero accident vision (ZAV), while very little scientific research on VZ had been carried out. It referred to the success of the Finnish "Zero Accident Forum," which had supported its member companies in realizing significant safety improvements over time. In the paper, a call was made to the safety research community to undertake empirical research to better understand and support safety strategies based on ZAV.

The next step for the PEROSH-working group was to initiate a multinational (seven countries) study involving 27 European-based companies that had adopted a ZAV. The research focused on their implementation of ZAV, and particularly on the roles of ZAV commitment, safety communication, safety culture, and safety learning (Zwetsloot et al. 2017b). It was a mixed method study involving a survey among managers and workers, as well as workshops at company and country level. A common characteristic of all the companies was the high commitment of their managers and workers to their ZAV, which often were embedded in the companies' business strategies. This commitment was regarded by the researchers as the main driver for long-term safety improvements. Safety communication, safety culture, and safety learning (from incidents and good-practices) were also found to be relevant factors in ZAV implementation. It was concluded that ZAV is the basis for inspiring and innovative approaches to improve safety, as an integrated part of doing business.

The PEROSH research project also formed the inspiration for a second discussion paper, focusing on the innovative strategies of the companies committed to ZAV (Zwetsloot et al. 2017c). The researchers found that merely promoting traditional safety management or accident prevention will not necessarily lead to significant new improvements in safety. Six innovative perspectives associated with VZ were identified and presented:

1. A commitment strategy
2. Aiming for a culture of prevention
3. Mainstreaming VZ into the business processes
4. VZ as trigger for innovations in safety, health, and well-being
5. The combination of a strong ethical and rational basis
6. Networking and cocreation

Finally, the PEROSH research project also formed the basis for a third paper focusing on the broadening of VZ from accident prevention to the promotion of safety, health, and well-being (SHW) at work (Zwetsloot et al. 2017a). In the paper, the consequences of a genuine commitment to VZ for addressing SHW and their synergies are discussed, with special attention paid to the synergy between safety and well-being at work. One of the conclusions was that even with a strong focus on preventing accidents, health and well-being should also be addressed. The relevance of the above six innovative perspectives for SHW was further clarified (Table 2).

The ISSA's Global Strategy for Vision Zero (Since 2017)

The International Social Security Association (ISSA) launched a VZ strategy for workplaces in 2017 based on the assumption that all (serious) accidents, harm, and work-related ill-health are preventable (ISSA 2017). VZ in this context is the ambition and commitment to create and ensure safe and healthy work while preventing all (serious) accidents, harm, and work-related diseases. This requires a process of continual improvement, aiming at excellence in safety, health, and well-being (SHW). The ISSA global strategy is associated with a global VZ campaign, which (in 2021) is running in more than 80 countries, and where more than 11,000 organizations have associated themselves with the campaign and strategy.

VZ is not a target; it is a "Vision" and a process, a journey toward the ideal. VZ is something you do, not something you have. It is associated with ethical values, and it implies that work should help workers to maintain and improve their SHW, and develop their self-confidence, competences, and employability. Genuine commitment to VZ can initiate and sustain the process and social support necessary for the VZ process. Organizations, both large and small, can commit themselves to VZ independent of their performance in SHW.

A Vision is associated with a mindset, a mental image of what the future will or could be like. It requires attention to SHW in the design stage, in planning, procedures, and practices. The three aspects – "Safety, Health and Wellbeing" – are

Table 2 Vision Zero (VZ) for safety, health, and well-being – six innovative perspectives. (Elaborated on Zwetsloot et al. 2017a)

VZ theme	Traditional safety approach (accident prevention)	Zero accident vision (ZAV)	Zero harm for safety, health, and well-being (SHW)
Commitment strategy	Safety **control** strategy	Safety **commitment** strategy	SHW are a **long-term commitment** strategy
	Safety is a **priority**	Safety is a **value**	SHW are a **value**
	Safety (0 accidents) is an (unrealistic) **goal**	Safety is a **process**, a journey	SHW are a **process**, a journey
	Safety and health are in practice two **distinct** worlds	Safety and health are ethically and practically closely **interconnected**	SHW are ethically and practically closely **interconnected**
A way of doing business	Safety improvements stem from **safety** programs	Safety is an integrated part of doing **business**	SHW are an integrated part of doing **business**
	Safety is mainly a **tactical** and operational challenge	Safety is a **strategic** challenge	SHW are a **strategic** challenge
	Risk **management**	Safety **leadership** and business excellence	SHW **leadership** and business excellence
	Safety is perceived as a **cost** factor	Safety is perceived as an **investment**	SHW are perceived as long-term **investments**
	Safety is only relevant **internally** (and for the authorities)	Safety is also relevant for business partners and **external** stakeholders	SHW are also relevant for business partners and **external** stakeholders
Innovation	The workplace is more or less a **static** environment wherein safety management will lead to continuous improvement	The workplace is a **dynamic** environment wherein technological and social innovations are important for significant improvements in safety	The workplace is a **dynamic** environment wherein technological and social innovations are important for significant improvements in SHW
Prevention culture	**Preventing** accidents	**Creating** safety	**Creating** SHW at work
	Compliance – "We have to" (external motivation)	**Participation** – "We want to" (intrinsic motivation)	**Participation** – "We want to" (intrinsic motivation)
	Incidents are **failures**	Incidents are **opportunities** for learning	SHW events (incidents, cases) are **opportunities** for learning
	Safe behavior is **desirable**	Safe behavior is the **norm**	SHW promoting behavior is the **norm**
	Workers' behavior (human error) is part of the **problem**	Workers are empowered to come up with solutions – they are part of the **solution**	Workers are empowered to come up with solutions – they are part of the **solution**

(continued)

Table 2 (continued)

VZ theme	Traditional safety approach (accident prevention)	Zero accident vision (ZAV)	Zero harm for safety, health, and well-being (SHW)
	Safety is designed or prescribed by **experts**	Safety is cocreated by experts and **all** members of the organization (having a questioning and learning approach)	SHW are cocreated by experts and **all** members of the organization (having a questioning and learning approach)
	Focus on management **systems**	Focus on **culture** and learning	Focus on **culture** and learning
	Safety culture is important	Safety culture and “**just**” culture are important	SHW promoting a “**just**” culture are important
	Focus on accident **prevention**	Focus on accident prevention and safety **promotion**	Focus on prevention and the **promotion** of SHW in work and **life**
Ethics and CSR	Safety management is always **rational**	Safety management is rational but also founded on **ethics**	SHW leadership is rational but also founded on **ethics**
	Safety is associated with prescriptions, paper work, and owned or placed upon only by a **few** leaders or workers	Safety is inspiring, “alive,” and “owned” by **all** members of the organization	SHW are inspiring, “alive,” and “owned” by **all** members of the organization
	Transactional leadership	**Transformational** leadership	**Transformational** leadership also paying attention to job demands and resources
	Safety policy **implicitly** based on values	Safety policy **explicitly** based on values	SHW policy **explicitly** based on values
Networking and cocreation	Safety improvement is triggered by **internal** processes (Plan, Do, Check, and Act)	Safety improvement is triggered also by learning from the experiences of others in and **outside** the organization	SHW improvement is triggered also by learning from the experiences of others in and **outside** the organization
	Benchmarking on **lagging** indicators (like injury rates)	Benchmarking on **leading** indicators and good practices	Benchmarking on **leading** indicators and good practices
	Safety improvement is triggered by **best** practices in the sector	Safety improvement is triggered by adopting and adapting **good** practices from other (ZAV) organizations and sectors	SHW improvements are triggered by adopting or adapting **good** practices from other (VZ) organizations and sectors

interacting and can strengthen each other – thus implying opportunities for synergy. As a result, the consequence of commitment to zero accidents is to create these synergies by simultaneously dealing seriously with health and well-being (Zwetsloot et al. 2017a). By focusing on not just safety, but also health and well-being, the VZ strategy builds on emerging initiatives in policies and practice to prevent, e.g., workplace stress, terror, violence, bullying, and harassment, as well as ergonomic issues such as heavy lifting and repetitive strain in the workplace.

The ISSA has developed a guide for organizations that want to implement or further develop VZ. The guide has been developed in close interaction with many organizations and practitioners and is structured around seven "Golden Rules" for VZ for SHW at work (ISSA 2017):

1. Take leadership – demonstrate commitment
2. Identify hazards – control risks
3. Define targets – develop programs
4. Ensure a safe and healthy system – be well organized
5. Ensure safety and health in machines, equipment, and workplaces
6. Improve qualifications – develop competence
7. Invest in people – motivate by participation

The guide for the 7 Golden Rules, which addresses employers and managers, can be downloaded from the ISSA website visionzero.global and is available in many languages, and there are also several sector-specific versions available. In addition, a "Seven Golden Rules ISSA" app can be downloaded (currently in English and Spanish), and it is also available via the website: www.sevengoldenrules.com.

Examples of the Implementation of Vision Zero in Workplaces

Although there are many organizations that have adopted VZ (Zero accidents, Zero harm, etc.), there are not yet many well-described case studies performed on the implementation of VZ. The two examples below illustrate some variety and potential.

Case 1 Implementation at the New Zealand Aluminium Smelter

Young (2014) described and analysed 25 years of experiences and interventions at the New Zealand Aluminium Smelters Limited (NZAS), which was named the safest aluminium smelter of its class in the world in 2007. A Zero Accident Vision was introduced in the company in 1990, using the slogan "Our Goal is Zero." Young evaluated the activities and success factors of their sustained effort, one of which was the importance of recognizing innovations as opportunities for safety improvement. The most important success factors

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over the years were: (1) automation (thereby eliminating hazardous work); (2) transformational leadership (which enabled the application of resources toward goal-oriented interventions); (3) an ergonomic strategy focussing on the hierarchy of controls; and (4) a focus on environmental conditions, instead of trying to influence individual behaviour directly. There was an emphasis on eliminating hazards or risk scenarios and improving ergonomic system design, and as such, individual behaviour was generally regarded as less important.

Case 2 Implementation in a Large Steel and a Large Construction Company in the Netherlands

Twaalfhoven and Kortleven (2016) carried out empirical research in the largest steel company and the largest construction company in the Netherlands, both of whom were committed to zero accidents. In both companies, the attitude and behaviour of employees were seen as important for achieving zero accidents. In their research, Twaalfhoven and Kortleven focused on how the companies managed human errors and the use of sanctions. Both companies had a three-step approach for dealing with unsafe behaviour: Step 1, the behaviour of an employee is addressed by the supervising manager; he/she explains what behaviour is expected from the employee and why. When the undesirable behaviour persists, step 2 follows. The manager has to ensure that the employee fully understands what is expected and why and an official warning is given. If necessary, step 3 implies an intervention to ensure that the undesirable behaviour stops. The intervention may include additional training or allocating the employee to a different task. In the two organizations, employees were seen as individuals who intrinsically wanted to work safely. External factors were regarded as the prime causal factors of unsafe behaviour, which were regarded as the responsibility of management. They also found that sanctions were used more frequently toward employees from external contractors than toward their own personnel.

The ISSA's Proactive Leading Indicators for Vision Zero (Since 2020)

Many companies and organizations have been inspired by the ISSA VZ strategy, yet one of the challenges and traps that organizations fall into when implementing and evaluating the effects of VZ strategies is, as mentioned above, their sole reliance on measuring "reactive" (*after incidents have occurred*) and "lagging" indicators, such as accidents, fatalities, injuries, harm, sickness absence, and disease. So the question is: What else can they measure which will help them steer in the right direction, which can pinpoint areas for preventive and promotion action, and which can be used as "proactive" and "leading" indicators?

To support the ISSA VZ strategy and the seven Golden Rules, a set of 14 proactive leading indicators were developed in 2020 through an interactive and collaborative process involving researchers, organizations, and companies. There are two proactive leading indicators for each of the 7 Golden Rules as outlined in Table 3. There is also an ISSA Guide available for the use of the indicators, as well as a fact sheet for each of the indicators. The fact sheets comprise aims, key concepts, good practice, limitations, and options for measuring the indicator.

The guide provides three options for using the proactive leading indicators:

- Option 1: A Yes/No Checklist, focusing on the key activities for good processes in each facet of safety, health, and well-being.
- Option 2: A Frequency Estimation addresses the frequency with which key activities for good SHW processes are carried out in a systematic and consistent manner. The degree of systematic action and consistency can be estimated using, e.g., five broad semiquantitative categories: Always or almost always – Frequently – Occasionally – Rarely – Very rarely or never.
- Option 3: A Quantitative Measurement, wherein the key activities are quantitatively measured with either frequencies or percentages. The outcomes thereof can be used for benchmarking.

Vision Zero in Workplaces and Road Traffic

Workplace and road traffic safety are more closely related than is often realized. Roads are the workplace for: Truck, bus, and taxi drivers; emergency, health care, and law enforcement personnel; salespeople, mail, food, and package delivery; and road construction and service workers. Their health and well-being are central to strategies to ensure excellence in workplace and road traffic safety. In addition, for many people commuting to and from work is a daily routine, which is also relevant for both road and workplace safety. For a wide variety of professions and many people, workplace safety and road safety go hand in hand. Many jobs, professions, and workplaces are influenced by the VZ policy implementation in road traffic, from the construction and service of the roads, to commuting and transport of goods and people. It is estimated that up to one-third of all work-related fatalities occur in work-related motor vehicle crashes (EC 2020). VZ in workplaces is therefore relevant to all organizations that deal with traffic safety, most prominent with organizations involved in the construction and maintenance of road or rail infrastructure.

Workplace Vision Zero and Road Traffic Policies

Two of the fields where work-related fatalities and injuries occur most frequently are in the construction and use of roads. A recent study of roadway work zone fatalities in the USA revealed that 76% of fatalities involved “transportation events” (CDC 2020), such as when construction workers are struck by vehicles entering work

Table 3 Overview of the 14 proactive leading indicators for safety, health, and well-being at work (SHW) (ISSA 2020)

No.	ISSA Vision Zero Golden rule	No.	Proactive leading indicators	Aims
1	Take leadership – demonstrate commitment	1.1	Visible leadership commitment	Through visible leadership commitment and being exemplary role models, leaders demonstrate their commitment to SHW and actively promote and support SHW improvement processes and the development of a prevention culture
		1.2	Competent leadership	Committed and competent SHW leadership is essential to drive the development processes of VISION ZERO. Such leaders are intrinsically motivated to improve SHW and promote SHW as personal and organizational core values. Leaders then regard SHW as integrated parts of business processes, and support processes of continual improvement of SHW, while creating a strong prevention culture
2	Identify hazards – control risks	2.1	Evaluating risk management	Evaluation of the effectiveness of SHW risk management shows leadership focus and commitment to improving SHW and stimulates active participation and influence of workers. It allows leaders and workers to improve the effectiveness and sustainability of SHW promotion measures as an integrated part of business. In addition, it allows for organizational learning and continuous development
		2.2	Learning from unplanned events	Learning from unplanned events (incidents, events, and cases) is necessary to prevent similar undesirable events from reoccurring, and to create a culture of SHW prevention and learning. Adequate follow-up of reported unplanned events will increase reporting and learning
3	Define targets – develop programs	3.1	Workplace and job inductions	Integrating SHW in induction (onboarding) processes demonstrates that SHW are an integrated part of each job and each business process. SHW are an essential part of leaders and workers' new job in a workplace. It can be both a formal and informal way of welcoming new personnel to an organization, group, and/or job function and highlights SHW purpose, values, and goals

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Table 3 (continued)

No.	ISSA Vision Zero Golden rule	No.	Proactive leading indicators	Aims
		3.2	Evaluating targeted programs	Evaluating targeted programs (e.g., temporary campaigns) that integrate SHW in work processes helps to verify that they are implemented as intended, and that the improvement goals for SHW are met
4	Ensure a safe and healthy system be well organized	4.1	Prework briefings	Integrating SHW in prework briefings allows leaders and workers to identify context-specific hazards, risks, and prevention measures. This shows leadership focus and commitment to SHW, and a commitment to stimulating the active participation and influence of workers
		4.2	Planning and organization of work	Planning and organization of work are essential for the success of every organization and for ensuring SHW. This is because planning can make an organization competitive and efficient. Several issues need to be considered in effective planning and work organization in order to promote SHW. Good planning and work organization promote good morale and a healthy organizational culture
5	Ensure safety and health in machines, equipment, and workplaces	5.1	Innovation and change	Technological, organizational, and personnel changes occur frequently in organizations. Instead of assessing SHW risk after the changes, these changes should be considered proactively, and to utilize innovation to improve SHW right from the start in the design phase
		5.2	Procurement	The indicator aims to trigger the systematic use of procurement for SHW improvement Procurement, particularly of hardware, can determine SHW risks for a long period, while procurement of services, such as maintenance, is often associated with increased SHW risks
6	Improve qualifications – develop competence	6.1	Initial training	Competence is key to ensuring good SHW. Being proactive requires training/qualifying leaders and workers in advance, before they start their job. It also shows that no job or task should be carried out without the relevant SHW competences, and that SHW are an integrated part of any job or profession

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Table 3 (continued)

No.	ISSA Vision Zero Golden rule	No.	Proactive leading indicators	Aims
		6.2	Refresher training	Developing SHW competence should be an aspect of continuous professional development. Refresher training ensures that leaders and workers' knowledge and skills on SHW remain up to date and include new SHW insights
7	Improve qualifications – develop competence	7.1	Suggestions for improvement	In the development of a prevention culture and the active involvement of workers, it is important that suggestions of workers for SHW improvements are welcomed and taken seriously. This will stimulate workers' active commitment to SHW and demonstrates their leaders' commitment to improving SHW
		7.2	Recognition and reward	Providing timely, proactive, and relevant recognition and reward for excellent SHW performance to both leaders and workers is essential for fostering a SHW culture that is based on trust, respect, participation, and cooperation

zones. Likewise, employees travelling the roads as part of their work or commuting also suffer fatalities, including crashing into roadway work zones. Designing, planning, training, and building safe work zones for construction workers are therefore crucial aspects of VZ strategies in this sector, focusing on proper work-zone layout, signage, high-visibility apparel, concrete barriers, speed-reducing measures, etc.

Companies have developed road traffic policies for their employees regarding their use of vehicles and the roads, which deal with a number of safety, health, and well-being issues that can be applied to a VZ strategy, including:

- Type of vehicle or mode of transport – truck, car, motorcycle, bicycle, scooter, etc.
- Vehicle exterior and interior design and configuration – mirrors and cameras, suspension seating (ergonomics), noise reduction, etc.
- Placement and securing of cargo – people, machines, tools, goods, etc.
- Planning tools – GPS-routing, global tracking of goods, etc.
- Behavior in traffic – speed limits, use of mobile phones, seat belts, helmets, alcohol, drugs, rest breaks, working hours, etc.
- Technical assistive devices – tail lift, forklift and crane for heavy lifting, etc.
- First-aid and fire training
- Vehicle inspection – check before each trip, etc.
- Vehicle maintenance – consistent with manufacturers' recommendations
- Incident reporting and investigation

- Travel management – weather, use of public transport, etc.
- Routine and nonroutine trips – knowledge of routes and locations, etc.

Case: Shell's Lifesaving Rules

More than 350 employees and contractors of Shell International were fatally injured worldwide in work-related incidents between 2000 and 2008. The company regarded the frequency of fatalities and serious accidents of people working for them (employees and contractors) as far too high. Shell analyzed the fatalities and serious accidents in their company (including accidents involving non-Shell employees working for them), and in response defined, introduced, and implemented 12 so-called Lifesaving Rules (Peuscher and Groeneweg 2012), which were in line with their safety strategy to pursue "Goal zero." The Lifesaving Rules were not new rules but were selected as they target activities where failure to comply with the rules had a high potential for serious injury or death. The Lifesaving Rules have since 2008 been mandatory for everyone while on business or on Shell sites. Consciously breaking safety rules was already never acceptable, and in the case of Lifesaving Rules, the Shell philosophy is that it is totally unacceptable: Failure to comply with any Lifesaving Rule, or encouraging or tolerating rule-breaking, results in disciplinary action. Breaches in these situations mean that Shell applies the principle that: "If you choose to break these rules, you choose not to work for Shell." All reported breaches are investigated thoroughly, fairly and on an individual basis in line with the established local policy and practice. Complying to the Lifesaving Rules is not only an individual responsibility, but it is also the responsibility of everyone to intervene in case someone else is breaking one of these rules. Four of the twelve Lifesaving Rules are explicitly aimed (fully or partly) at decreasing serious road accidents, e.g., involving trucks with Shell products (Table 4).

In the period 2008–2011, Shell's fatal incident rate dropped by 71%, while in other oil and gas companies the average decrease was 39%. In the same period, the Lost Time Injury rate at Shell dropped by 40%, while the average decrease in the sector was 21% (Peuscher & Groeneweg, 2012).

Pitfalls in the Implementation of Vision Zero in Workplaces

The research on the implementation of VZ in workplaces has also identified a number of pitfalls in the implementation process, one of more of which can seriously hinder successful implementation of VZ. The pitfalls do not imply serious challenges for the implementation, when the organizations fully understand VZ. However, when VZ is only used as a slogan, without real commitment to the long-term process, and without realizing that it should be based on genuine commitment of leaders and workers, implementation may fail to be successful (Table 5).

Table 4 Shell's Lifesaving rules that are also relevant for road safety

Lifesaving rule	Sign	Reason
While driving, do not use your phone and do not exceed speed limits		Speeding or using your phone while driving increases the risk of losing control of your vehicle
Wear your seat belt		A seatbelt protects you from injury in the event of an incident while driving and keeps you safe
Follow prescribed Journey Management Plan		A Journey Management Plan is a plan for you as a Driver that will help you to travel and arrive safely
No alcohol or drugs while working or driving		Using alcohol, illegal drugs, and misusing legal drugs or other substances will reduce your ability to do your job safely

Table 5 Pitfalls when considering Vision Zero in workplaces. (From Zwetsloot et al. 2017a)

Vision Zero used inappropriately	Vision Zero used appropriately
Applying Vision Zero as a **target** and making people accountable for realizing it (perhaps even strengthened by economic incentives)	It is a **process** that requires commitment from all leaders and workers in an organization
Focusing strongly on incident rates (and other **lagging** indicators)	Using **leading** indicators
Assuming that more safety rules, **management** systems, and behavioral control will help to go from good to excellent safety performance	Focus on **leadership**, being innovative, and promoting (collective and individual) learning
Assuming that **one** approach is able to improve different types of safety (e.g., process and personal safety)	Using a **variety** of approaches and adapting them where appropriate

Vision Zero Criticism and Response

VZ in workplaces is regularly criticized as being only based on simple slogans, leading to counterproductive results (Dekker et al. 2016; Dekker 2014; Long 2012). The main criticisms are that VZ: is unrealistic and naïve, denies the realities of risk, and is a fundamentalist ideology; in short, VZ is a dangerous idea (Long 2012), and VZ companies pursue safety through bureaucratic safety systems and bureaucratic accountability (Dekker 2014). According to the critics, VZ focuses on lagging indicators (such as injury rates) only, leading to underreporting of incidents, and is associated with trickery and fraud with numbers. The critics also state that ZAV drives a safety culture characterized by skepticism, and cynicism. VZ would also drive a punitive mindset, while positive goals and targets are said to be much more effective than avoidance goals such as zero accidents (Long 2012).

The VZ criticism is more often based on anecdotal evidence than on empirical research. It does confirm the pitfalls in implementation. Rather than being fundamental criticism, the criticism mostly highlights failures in implementation and proceeds to generalize such cases to criticize VZ in general. It is also striking that the critics all stem from the safety area, and do not pay any attention to other members of the family of VZ, e.g., zero defects, zero downtime, etc.

Conclusion: Key Messages

1. Globally, more than 7,500 people die each day due to unsafe and unhealthy working conditions.
2. Vision Zero in organizations is applied to several areas, e.g., zero defects, zero downtime, and zero emissions, as well as on workplace strategies targeting worker safety, health, and well-being, and the prevention of workplace accidents and work-related diseases.
3. Vision Zero in workplaces has a long history. Its roots go back to the beginning of the nineteenth century when E.I. Dupont formulated the first industrial safety policy. It also builds on the Zero Defects approach for Total Quality Management developed in the 1960s.
4. The concept of Vision Zero in workplaces is closely related to the concept of creating a prevention culture.
5. For many professions, the road is an important workplace. Vision Zero for road traffic and workplaces are overlapping and can strengthen each other. This is most relevant for employees who use roads as part of their work, for commuters, and for the workers who build and maintain the roads.
6. The implementation of Vision Zero in workplaces should be regarded as a commitment strategy, as it is based on genuine commitment of top leaders as well as the personnel. It is associated with five other innovative perspectives: Safety, health, and well-being as way of doing business, using opportunities for innovation, the development of a prevention culture, as an ethical basis linked to corporate social responsibility, and networking.
7. It is important that Vision Zero in workplaces is understood as a vision and a long-term ambition, not as a target.
8. Proactive leading indicators, such as those reflecting ongoing processes for ensuring safety, health, and well-being, are more important for Vision Zero in workplaces than lagging indicators, such as accident frequencies.
9. Vision Zero in workplaces is relevant on many levels, from workplaces and organizations, to national and international policies.
10. In 2021, more than 80 countries and 11,000 organizations are participating in the ISSA's Vision Zero strategy and campaign.

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Suicide in the Transport System

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Abstract

The Swedish Transport Administration (STA) work to reduce the number of suicides in the transport system. Fatalities, i.e., on roads, railways, and bridges, originate from either accidents or suicides, natural death excluded. Knowing the correct manner of death is needed to work with optimal prevention strategies. The aims are to separate fatalities due to suicides, follow the development, and implement measures for suicide prevention. Methods are developed for suicide classification and criteria for the selection in which suicides were suspected. Fatalities in level one and two of five were classified as suicides. Data from the STA's databases are used and so are data from the psychosocial investigations done by a trained investigator in the topic and with clinical experience from counselling at hospitals. 2129 persons died on the roads in Sweden, 10% (206 persons) were classified as suicides. 336 persons died after being hit by trains, 85% (284 persons) were suicides. 130 persons died by jumping from bridges.

The number of suicides increases with population density. Suicide in the transport system is a major problem; firstly personal tragedies, it is also a work environment problem for truck and train drivers and for the emergency staff. It generates delays and costs for passenger and cargo transport. By analyzing the results of countermeasures in the form of obstructive barriers, the physical environment can be improved and high-risk areas can be accentuated. Restricting access to the means of suicide is important in suicide prevention. Strategies for the STA include suicide prevention in the design of new roads, railways, and bridges, as well as by identifying and reducing existing high-risk locations. Sharing the results with other authorities and organizations and cooperation within suicide prevention missions are vital for the enhancement of the overall suicide prevention work in society.

Keywords

Suicides · Suicide classification · Transport-related · Transport system · Suicides on roads · Suicides on railways · Suicides on bridges · Jumping · Psychosocial examination · Countermeasures against suicides · Physical barriers · Suicide prevention · Multidisciplinary collaboration

Introduction

In September 2016, the Swedish government relaunched the Vision Zero initiative (Renewed Commitment to Vision Zero), which states that suicide in the transport system is a problem that also must be addressed within the traffic safety work. Preventive measures in order to reduce fatalities in road traffic, intentional or accidental, are in line with Vision Zero. The Swedish Transport Administration (STA) works actively to reduce the number of suicides in the transport system, i.e., in roads and railways, including suicide preventive measures on bridges.

Suicide is a major health problem and affects a large part of the population. In addition to the personal tragedies, suicide also affects professional working groups and imposes costs on society. In Sweden, approximately 1200 persons per year die due to suicide by intentional self-harm and about 300 persons by undetermined intent (The National Board of Health and Welfare). Some suicide means can be more difficult to classify, if it has been with intention or if the person died unintentionally. Examples can be drowning oneself or drowning by accident, jumping from a high height or falling by accident, suicide by burning oneself to death or being burned to death by accident, and poisoning by purpose or unintentional overdose. Some people use the transport system to take their lives, and it can be hard to assess if the fatality was a suicide or an accident.

The Swedish Parliament decided in 1997 that Vision Zero should serve as the basis for traffic safety activities in Sweden. In 2010, the Swedish government decided that fatalities in road traffic due to suicides should be reported separately from fatalities due to accidents. Since then Sweden has been presenting statistics on suicides in road traffic separately from fatalities caused by accidents, using a specially developed method (Swedish Transport Administration 2017; Andersson and Sokolowski 2022). Suicide accounts for a significant proportion (10%) of road traffic fatalities. Since the year 2015, the method was adjusted to classify the fatalities on railway, and a majority of them are due to suicidal actions (85–90%). It can be difficult to assess whether a fatality is due to suicide or accident. Reporting statistics about suicides is a complex task due the hidden cases. A method has been developed for classification of road traffic fatalities in order to determine if the fatality was caused by accident or suicide. This method has been adjusted for suicide classification for fatalities on railways.

Suicides in the Transport System

The Public Health Agency of Sweden is a national expert agency striving for better public health. In order to prevent suicide, broad collaboration is needed between the Swedish government and the Swedish Parliament, authorities, municipalities and county councils, universities and colleges, voluntary organizations, and organizations that support bereaved families (Public Health Agency of Sweden 2016). The STA is one of the authorities that cooperate with the Agency. The national action program adopted by the Swedish Parliament in 2008 contains nine strategic areas of action to reduce the incidence of suicide. According to these nine actions, the Swedish Transport Administration works directly or indirectly with the strategies.

1. Promote good life opportunities for less privileged groups
2. Reduce alcohol consumption in the population and in groups at high risk for suicide
3. Reduce access to means and methods of suicide
4. View suicide as a psychological mistake
5. Improve medical, psychological, and psychosocial initiatives
6. Distribute knowledge about evidence-based methods for reducing suicide

7. Raise skill levels among staff and other key individuals in the care services
8. Perform “root cause” or event analyses after suicide
9. Support voluntary organizations

Promote Good Life Opportunities for Less Privileged Groups

Promoting good life opportunities by providing safe and secure traveling communications contributes to social sustainability.

Reduce Alcohol Consumption in the Population and in Groups at High Risk for Suicide

Demanding drivers not to be influenced of alcohol, e.g., by technical systems and behavioral impact, reinforces the second strategy. SMADIT (cooperation against alcohol and drugs in the traffic system) is a cooperation between different authorities with the aim to support persons who are reported for driving drunk or influenced of drugs (The Swedish Transport Administration 2012). The procedure is based on being able to offer help from the health care as quickly as possible, preferably within 24 h. The STA supports technical development for sober driving in vehicles and implementation of alcohol interlock devices. The STA also works on an information assignment to citizens, where sobriety is one of the areas, and cooperation with the police is another important area in the field.

Reduce Access to Means and Methods of Suicide

The third strategy is the action most often associated with the work of the STA. Restricting access to means of suicide is effective in preventing suicide, and suicide prevention measures on roads are beneficial for all road users. Collision at high speed against a solid object in the roadside area can be avoided by putting up guardrails or by removing the solid object. Rebuilding roads to the so-called 2+1 roads will reduce the number of fatal head-on collisions. Erecting fences or barriers along high-speed roads in urban areas will make it harder for pedestrians to carry on with a suicidal attempt and can prevent persons from being tempted to take a dangerous shortcut. Installing high fences on bridges and viaducts will increase the safety for all pedestrians and may prevent sabotage in the form of throwing down objects. The Swedish road and bridge design guidelines have been updated to make sure those suicide preventive measures are included in the design of new roads and bridges.

To reduce access to the railway system, different measures are to prevent people from intruding on the tracks at distances between stations on suicide- and accident-prone routes. Measures such as barrier fences, intermediate fencing between tracks, anti-trespass panels, alarming cameras that monitor the track areas, and platform screen doors are examples of physical barriers. Other important actions are functioning communication between the STA and emergency services when someone is on or close to the tracks as well as designed environments, which promote safety and security.

View Suicide as a Psychological Mistake

Suicide can be seen as a psychological mistake or mental accident (Beskow 2008, 2010), where the deliberate self-destructive act can lead to death, as the individual experiences a situation that seems impossible to change. The "solution" to take one's own life can be impulsive, and in those situations, protective barriers can prevent the act, by disturbing the impulse.

Improve Medical, Psychological, and Psychosocial Initiatives

On rare occasions, the STA can take the initiative to alarm the police, psychiatric care, and the municipality to report that a person is recurrently located in a risky place in the transport system. This action can be lifesaving as the psychiatric care and the responsible municipality can provide focused support to the person in an ongoing crisis.

Distribute Knowledge About Evidence-Based Methods for Reducing Suicide

Sharing the results from the suicide classification in the transport system to other authorities and organizations with suicide prevention missions is vital for enhancement of the overall suicide prevention work in society.

Raise Skill Levels Among Staff and Other Key Individuals in the Care Services

By analyzing the results from the systematic suicide classification, countermeasures in the form of obstructive barriers in the physical environment can be improved, and high-risk areas can be accentuated. The facts of the psychosocial contexts and patterns of transport-related suicides are important to share with other stakeholders. The exchange of information from the STA to responsible authorities is also a part of the total activity against suicides.

Perform "Root Cause" or Event Analyses After Suicide

Methods have been developed for suicide classification of fatalities on the roads (Swedish Transport Administration 2017; Andersson and Sokolowski 2022) and the railways. Criteria for the selection of fatalities in which suicides were suspected were compiled, and a classification scale with five levels was defined. Fatalities in level one and two were classified as suicides. Data from the STA's databases (Trafikverket 2012) have been used together with data from psychosocial investigations performed by a trained investigator and with clinical expertise through counselling at hospitals. The suicide classification method will be described below.

Support Voluntary Organizations

Different research grants are given to nonprofit organizations with the aim, e.g., to reduce alcohol consumption in society and to work in the field of traffic safety, where reducing suicide is a part.

Suicide Classification Methodology and Psychosocial Factors

Not all fatalities in road traffic are accidents, some are suicides. Since 2010 Sweden has been presenting suicides in road traffic separately from fatalities caused by accidents. To undertake this, a method has been developed for the classification of road traffic fatalities (Swedish Transport Administration 2017; Andersson and Sokolowski 2022) based on whether the fatality was caused by accident or suicide. It can be difficult to assess whether a fatality is due to one or the other. Reporting statistics about suicides is a complex task and the choice of method can make a substantial difference. Data showing that the fatality was an accident are as relevant as data speaking for a suicidal act.

Vision Zero is the ethical standpoint that no one should be killed or suffer lifelong injury in road traffic. The Swedish Parliament decided in 1997 that Vision Zero should serve as the basis for traffic safety activities in Sweden. In 2008 the Swedish Parliament also stated in a new health policy that no person should end up in such situation that suicide is seen as the only way out. In connection with the introduction of Vision Zero, in-depth studies were carried out on all fatal accidents in road traffic in Sweden by investigators at the STA. The in-depth studies (Trafikverket 2012) are stored in a database at STA. In each case information on the vehicle, the road and event, and the road user are collected.

Already in 2001, a group of well-informed scientists wrote about the problem that statistics about road traffic fatalities contained at least three groups: "accidental" fatalities, suicides, and natural deaths. They also requested criteria for the classification of manner of death in "borderline" cases (Ahlm et al. 2001). According to Värnik et al. (2010), there is an underestimation of suicides, due to shortage of necessary information for determining the manner of death.

The work with the classification method has been carried out in cooperation between the STA, the Swedish Transport Agency, the National Board of Forensic Medicine, and Suicide Prevention Western Sweden. This method was developed to be used for road traffic, but with suitable modification, it can also be used for other modes of suicide. Since 2015 a revised method has been used to classify suicides on the Swedish railway system.

The study about suicide classification method (Andersson and Sokolowski 2022) has been approved by the Central Ethical Review Board in Gothenburg.

Criteria to Undergo the Classification Process

Criteria for selecting fatalities, which were to undergo the classification process because of a significant suspicion of suicide, were determined and are shown in Table 1. The criteria were influenced by a list developed by the European Rail Agency (ERA 2004) of factors that may indicate that a death is a deliberately act. That list is based on the so-called Ovenstone criteria (Ovenstone 1973). Criteria for cases that were to undergo the classification process in 2012 included the traffic event; the vehicle; together with a knowledge of psychosocial factors, such as prior suicide attempts; indirect suicidal communication and knowledge of ongoing depression, and so forth.

Classification Scale

A classification scale was developed and is shown in Table 2. The scale for assessing suicidal diagnosis by Lönnqvist (1977) influenced the assessment tool (Lönnqvist 1977). The classification harmonizes with the National Board of Forensic Medicine for assessment of the manner of death, but only a five-point scale is used, instead of a nine-point scale (Rättsmedicinalverket 2014).

Table 1 Criteria for selecting fatalities, which might be suicides and are to undergo the classification process

Criteria
1. Farewell message, oral or written, where intention is clearly communicated and where the traffic event supports a suicide
2. A traffic event that indicates a suicide in combination with knowledge of a) Recent known suicide attempts b) Recent indirect suicidal communication c) Communication about committing suicide or having no reason to live d) Ongoing prolonged depression or mental illness e) Previous severe emotional or stressful life event
3. A traffic event that strongly indicates a suicide

Table 2 Classification scale for fatalities in the road traffic system

Grade	The result of the examination
1	Shows that manner of death was suicide Requires farewell letter or equivalent
2	Strongly supports that the manner of death was suicide Almost certain suicide, but the intention is judged primarily on the basis of evidence in the surroundings
3	Cannot determine whether the manner of death was suicide or the result of an accident The information is not sufficient to determine whether an event was a suicide or accident
4	Strongly supports that the manner of death was accidental Almost certainly an accident
5	Shows that the death was accidental way Surely accident

Data Collection and Psychosocial Examination

The investigators from STA and the police collected the primary data at the scene of the fatality. The investigator at STA gathered important documents such as the autopsy report, photos, information from the police, press clippings and details of the technical investigation of the car, and information about the road environment. The material was registered in the STA's database, the so-called in-depth client.

When the STA's investigators suspected that the fatality was due to a suicide, they reported this to the psychosocial investigator, who from the year 2012 conducted an expanded psychosocial data collection. The psychosocial investigator also attended the monthly review of the previous month's fatal accidents in road traffic to detect suspicious cases. Reports from the police, written and oral, information from relatives, and witnesses of the accident scene, as well as information from autopsy reports, were used. When possible, medical case records were collected as primary data. The psychosocial investigation was conducted by an investigator with education in behavioral and medical sciences and with experience from counselling at hospitals and trauma care. The psychosocial investigation (Andersson and Sokolowski 2022) is a working routine similar to, but not the same as, a "psychological autopsy" (Cavanagh et al. 2003). The most common reason to conduct a psychological autopsy is to determine the mental state of someone who is already deceased to determine the cause or nature of death, whether it be by natural causes, suicide, homicide, or an accident.

The review of the deceased was performed regarding data about socioeconomic background factors, as well as data about the life situation earlier and at the time of the traffic event. The review could include marital status, education, gainful employment and working situation, health, economy, residence, alcohol, and drug or medicine abuse.

Information such as suicide notes, previous suicide attempts, suicidal communication, recent suicide threats, long-term mental illness, use of psychopharmacologic drugs, or neuropsychiatric diagnoses were noted. Other important information was triggering factors as separations or recently revealed "socially unacceptable behavior."

Expert Group

An expert group of five experienced professionals with knowledge in forensic medicine, behavioral and medical science, counselling, and traffic safety classified the suspected suicides using the classification scale in Table 2. During the first years, complex cases were discussed in a special referee group. The expert group and referee persons contributed over time to more comparable assessments. The cases classified as suicides were reported to the Swedish government agency for transport policy analysis, Transport Analysis, which compiles and publishes the official statistics on road traffic injuries. In 2013 Transport Analysis approved the method with data from the STA's database and the psychosocial investigations for delivery of the official Swedish statistics of suicides in road traffic.

Data on Suicides in Road Traffic 2010–2018

During 2010 and 2011, no psychosocial investigations where done, since these started in 2012. Results of the distribution of suicides and accidents in road traffic during 2010–2018 are shown in Table 3. The validation of the method is reported in a manuscript (Andersson and Sokolowski 2022) comparing results when the suicide classifications are conducted, without and with psychosocial investigations as a ground.

Data on Suicides on Railway 2010–2018

During 2015 and 2018, the suicide classifications were made using the adjusted method from road traffic for the fatalities on railway (Table 4).

Table 3 The official statistics for fatalities in road traffic, 2010–2018

Fatalities in road traffic	2010	2011	2012	2013	2014	2015	2016	2017	2018
Suicides	16	23	36	28	25	23	31	29	35
Accidents	266	319	286	260	270	259	270	253	324
Total	282	342	322	288	295	282	301	282	359
Percentages of suicides %	5,7	6,7	11,2	9,7	8,5	8,2	10,3	10,3	9,7

Without psychosocial examinations, 2010-2011
With psychosocial examinations, 2012-2018

Table 4 The official statistics for fatalities on railway, 2010–2018

Fatalities on railway	2010	2011	2012	2013	2014	2015	2016	2017	2018
Suicides	66	57	84	93	78	87	68	50	79
Accidents	45	25	15	18	25	16	13	14	9
Total	111	82	99	111	103	103	81	64	88
Percentages of suicides %	59	70	85	84	76	84	84	78	90

Before the adjusted suicide classification started, 2010-2014
After the adjusted suicide classification were used, 2015-2018

Data on Suicides by Jumping from Bridges 2010–2017

Earlier there has not been any collected or reliable data in Sweden about how many people take their own lives by jumping from bridges. In collaboration with the National Board of Forensic Medicine, data from 2010 to 2017 was collected (Riesenfeld 2020). In total 130 people died in this way during 2010–2017, distributed on 61 different bridges, whereof 8 bridges had 3 to 20 suicides, and the rest of them, 1 or 2 each. Physical barriers have been installed on some of the bridges during this time and positive effects have been noted. Analysis of the data has started and the effects of erecting fences will be studied. The most affected places are the bridges in or near urban areas with large populations. During the observation period, 2010–2017, no reduction in total was noted in Sweden, but the survey showed fewer suicides by jumping from bridges than expected. Riesenfeld (2020) points out that to make the data collection more effective, it is important to have high quality of documentation from different authorities and a simpler coding method for the certificate of cause of death. The National Board of Forensic Medicine and STA will further develop the suicide classification method.

How Do We Address the Problem of Suicides in the Transport System?

Suicides are a major health problem which affects a large part of the population. According to the World Health Organization (WHO), nearly one million people take their own lives in the world every year. Suicides in the transport system cause personal tragedies and loss for relatives and affect the working environment for truck and train drivers, as well as for operational and service personnel. Suicides cause delays of goods and passengers and impose costs for society.

Suicide is the result of complex interactions between genetic, individual, and social factors. The most effective way of approaching this complex topic is through interdisciplinary research (WHO Library Cataloguing in Publication Data 2010).

The same principle should be used when assessing the manners of death in the transport system. The combination of different competences in the classification group has been successful. The safety analysts take into account the road, bridge, or railway environment and the factors concerning the vehicles or trains. The forensic doctor interprets the autopsy report and contributes medical knowledge. The psychosocial investigator has competence in behavioral, psychological, and clinical sciences and from practice counselling patients, as well as next of kin to persons who died because of suicides. The ordinary road user data like gender, age, influence, etc. are not enough; it has to be complemented with additional complete psychosocial information.

Suicide Prevention in the Society

Suicide prevention provided by the health-care system should contain early diagnosis and customized treatment, which is individualized to the person suffering from mental illness. The level of knowledge in the government, municipalities, and authorities about suicides must be increased. Another important task is to restrict means and methods of suicide.

Strategies for the STA comprise suicide prevention in the design of new roads and by identifying and reducing existing high-risk locations. Key preventing strategies include building intrusion protection and middle separation as well as clearing the side region of the roads to protect people from taking their lives in road traffic.

Besides roads and bridges, people use the railway system for suicidal acts. To prevent suicides on the railways the systematic work with creating barriers between people and tracks is important. The number of suicides increases with population density. Building barrier fence, intermediate fencing between tracks, anti-trespass panels, alarming cameras that monitor the track areas, and platform screen doors is vital.

Designing an environment that promotes safety, which makes people feel secure, can reduce suicidal thoughts. Other important actions are functioning communication between the STA and emergency services. This is important in situations when someone is near or on the railway tracks and needs to be taken care of by the police or emergency units. The STA can order the train to stop or run at reduced speed, so that the rescue staff can manage to help the suicidal person. Rapid alert chains and cooperation between the STA and the emergency services also guarantee a safe working environment for the staff. Suicide prevention is a multidisciplinary commitment, and collaboration with emergency services and highlighting good examples of alert chains and cooperation are crucial.

Other measures that can be used against suicides in the transport system are analyzing the suicide events with a uniform method and discussing the psychosocial contexts and patterns with responsible authorities. Strategies against suicide should be developed continuously based on the best research knowledge available and the cooperation of all stakeholders in the community. According to the WHO, suicide prevention programs should be multidimensional (WHO Library Cataloguing in Publication Data 2010).

Conclusions for the Future

There are several important pre-crash factors determining whether an injurious or fatal event occurs in the transport system (Andersson 2003). There are material factors, such as the condition of the road, vehicle status, the weather, etc., and there are psychosocial factors, such as mental illness, abuse, socioeconomic problems, etc. An accident or a suicide often depends on a combination of factors, the latter especially in case of a suicide. To improve prevention, knowledge regarding the importance of psychosocial factors is required and should be a part of the work.

Good-quality data are needed for the analysis of the incidence and patterns of suicides in the transport system. A uniform method of suicide classification for all modes of transport should be used. Nevertheless, the method must be adjusted to the different challenges and circumstances of roads, bridges, and railways. The systematic suicide classification methods and the analysis concerning suicides should be used in the prevention work in the transport system. They should also be used in collaboration with other organizations and authorities. The countermeasures against suicide should be intermodal for the systems of roads, bridges, and railways. Suicide-preventive measures are important variables in the design of new roads, railways, bridges, platforms, etc. Already existing exposed places and stretches can be located and remedied.

Many countermeasures against suicides require the same types of mind-sets regardless of means of suicides. By working with countermeasures and in collaboration with other responsible authorities to reduce the total incidence of suicides in the society, the transport-related suicides can decrease.

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Vision Zero in Suicide Prevention and Suicide Preventive Methods

37

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Contents

Abstract

According to the World Health Organization (WHO), suicide is a global public health issue, and countries need to be working toward a comprehensive and holistic response to prevent suicide and suicidal behaviors. Vision Zero for

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suicide is an aspiring goal that aims to lower suicide occurrence through a combined action of public health and healthcare sectors. Vision Zero for suicide has a multilevel and multidisciplinary approach that intends to provide a systemic change in society to facilitate and put suicide prevention on the agenda. This chapter explores the origins of Vision Zero for suicide by first presenting theoretical models that influenced suicidal behavior preventive programs. Then, Vision Zero for suicide goals, advantages, challenges, and examples of implementation in some countries will be presented. Further, evidence-based suicide prevention programs in existing public health and healthcare settings will be described as they support the Vision Zero aims. Vision Zero is an ambitious goal, but one that is worth aspiring to achieve, as the potential outcomes for suicide prevention implementation and research are very worthwhile.

Keywords

Vision Zero · Suicide · Suicide attempts · Suicidal behavior · Suicide prevention · Healthcare approach · Public health approach · Evidence-based · Multilevel interventions · Strategies · Mental health

Introduction

Suicide is a significant public health issue with over 800,000 people worldwide dying by suicide each year (WHO 2016). At least 20 times as many attempt suicide. These figures have increased globally in the last decade by 4% (Brodsky et al. 2018). Suicide impacts every age group. Despite various national suicide prevention strategies which have been established to address this problem in countries around the world, suicide is the third leading cause of death globally in adolescents aged 15–19 years after road injuries and interpersonal violence (WHO 2018). A 10-year systematic review compiling almost 1,800 studies (Zalsman et al. 2016) highlighted that increasing and coordinating the application of evidence-based suicide prevention strategies is crucial. Zalsman et al. (2016) also emphasized the importance of implementing suicide prevention programs both across public health and mental healthcare systems. Vision Zero for suicide with a multilevel and multidisciplinary approach to drive evidence-based suicide prevention has been introduced in some countries. Suicide prevention relies on suicidal behavior research to implement the most accurate evidence-based programs. Knowledge about suicidal behavior, risk, and protective factors is paramount to ensure good practice in implementation. Therefore first, we provide an overview of models for suicide prevention; second, we present Vision Zero; third, we offer reflections on the advantages and challenges in the implementation process in some countries; and last, we describe public health and healthcare prevention programs which are recommended to be used in obtaining Vision Zero for suicide.

Models for Suicide Prevention

Suicide prevention strategies have been continually studied and developed over time. Understanding the complexity of suicidal behaviors and their multifactorial dimension is important when establishing effective suicide prevention strategies. Various theories – or models – explain the suicidal process and which factors lead an individual to develop suicidal behavior (Sisask and Kõlves 2018). Models and understanding their evolution, as well as theoretical influences, are crucial, when designing suicide prevention programs (Cramer and Kapusta 2017).

Below is a summary of important models which have influenced and continue to influence suicide prevention programs today.

Sociological Theory

Emile Durkheim, in his sociological investigation of suicide, stated that suicide is the result of society's strength or weakness of control over the individual (Durkheim 1897). Suicide is thought to be a result of an interaction between low and high levels of social regulation and moral integration. Social integration describes bonds with other members in society, while moral regulations are the adherence to existing norms in society. According to his theory, suicide occurs "when the level of social integration is too high (leading to altruistic suicide) or too low (leading to egoistic suicide) and when the level of social regulation is too high (leading to fatalistic suicide) or too low (leading to anomic suicide)" (Lester 1999). This contributed to the understanding of societal and community influences on suicidality. But the theory failed to consider individual variations in suicidal behavior (Mäkinen 2009).

Hopelessness Theory

The hopelessness theory by Beck highlights the notion of hopelessness as a psychological factor that has a central role in suicide (Beck et al. 1985). Hopelessness is defined as the fatalistic expectation of an individual. Nothing the individual wants or wishes for will happen, and there is nothing one can do to change it. Since the development of the model, research has shown that hopelessness is an important predictor of future suicidal behavior (Wolfe et al. 2019). However, this theory does not account for other factors contributing to suicidal behavior (Aish and Wasserman 2001).

Psychache Theory

Schneidman defined psychache as intense psychological pain. He emphasized that psychache is a necessary condition for suicide to occur and that this pain can overpower any other protective factor (Shneidman 1998). Schneidman further asserts that the only solution to stop the psychache is suicide.

Escape Theory of Suicide

The escape theory of suicide highlights the role of failure, disappointment, and setback (Baumeister 1990). Suicide is thus viewed as an escape from existential problems. Feelings of failure are a necessary but insufficient condition to attempt suicide. In addition to feelings of failure, the six-step process when considering suicide includes escape motivation, self-blame, depression, cognitive deconstruction, and disinhibition (Tang et al. 2013).

Emotional Dysregulation Theory

According to Linehan, emotional dysregulation is a process relating to the incapacity to adjust to and manage emotions. Emotion dysregulation is a risk factor predictive of suicidal behavior (Ammerman et al. 2015). This model was originally geared toward borderline personality disorder and was used to develop dialectical behavioral therapy (Hogan and Grumet 2016). There is strong evidence supporting this model.

Stress-Diathesis Model

This model takes into consideration that suicidal behavior is influenced by both individual biological/psychological predisposition (diathesis) as well as the surrounding environment (environmental stressors) (Mann 2003; Wasserman 2001). Although suicidal behavior is heterogeneous and varies between individuals, this model provides an explanation as to why some commit suicide and why others do not. The causes of suicidal behavior are complex with many interacting contributing factors (Sokolowski et al. 2015). Many factors can lead toward a predisposition for suicide diathesis such as genetic makeup, exposure to psychological stress, and adverse environmental conditions, especially in the developmental stages of childhood and adolescence (Mann 2003; Wasserman 2001). There are strong associations between suicide and inequity, social exclusion and socioeconomic deprivation which are all causes of stress.

Interpersonal-Psychological Theory of Suicide

This theory considers suicide to be the interaction between two states: (a) *Thwarted belongingness* is feeling that one does not have connections with others; (b) *perceived burdensomeness* is feeling that one is a burden for those around them. A*cquired capability* described as diminished fear of pain and death due to repetitive experiences with painful and fear-evoking life events leads individuals to getting used to self-harm, suicidal behavior as response to risk (Ribeiro and Joiner 2009). The strength of this theory is that, contrary to previous theories, it differentiates between suicidal ideation and suicidal behavior (Van Orden et al. 2010). The interpersonal-psychological theory of suicidal behavior still has some unanswered gaps, such as the threshold for acquired capacity to lead to suicide attempts and death by suicide. However, evidence-based research shows the potential of this theory, for understanding pathways to suicide from risks for suicidal behavior (Barzilay et al. 2015).

World Health Organization (WHO) Socioecological Model

The WHO report *Preventing suicide: A global imperative* (2014) offered evidence-based recommendations and actionable steps to improve suicide prevention, as well as to support countries within public health strategies. The WHO used a socio-ecological model, built on risk and protective factors identification of socio-ecological contexts, to help build resilient suicide prevention.

This theory assumes that the cause of suicidality is multifactorial, and that the accumulation of risk factors increases suicide as a potential outcome. Risk factors are grouped into the following categories: systemic (society and health system), community, relationship, and individual. Suicide prevention needs to address these risk factors while strengthening protective factors through effective suicide prevention programs.

The aforementioned models highlight that suicidal behaviors are multifactorial; thus, to reduce them, there is a need for a joint effort from public health and healthcare strategies which are described later in this chapter. Vision Zero for suicide is influenced by the theoretical models and uses multidisciplinary and multileveled approaches to combat suicidal behaviors.

Vision Zero for Suicide

Definition of Vision Zero for Suicide

Vision Zero for suicide is an approach emerging in the last two decades that aspires to bring suicide prevalence as close as possible to zero. It assumes that no one should end up in a situation where suicide is the only option. Considering that suicidal behaviors, as previously explained, stem from biological but also social, environmental, and cultural factors, Vision Zero initiatives look to bring resources together in a multiphased plan that uses evidence-based knowledge to cause a system change (Kristianssen et al. 2018). Vision Zero can be implemented through policies on nation-, region-, or organization-based levels. Vision Zero is more than an approach guiding suicide prevention initiatives; it is an aspirational goal bringing healthcare and public health sectors together to decrease suicide rates.

When countries or regions implement Vision Zero policies, initiatives need to first involve programs not only at the public health level (policy-makers, politicians, research centers, and advocacy groups) but also at the community level (community-based organizations, NGOs, and minorities advocates), and then at the healthcare level. Developing a Vision Zero approach thus needs a multidisciplinary effort from fields such as political, policy, economics, public health, psychiatry, psychology, sociology, anthropology, education, and religion. Even when Vision Zero is implemented in smaller settings, such as in a hospital, the different departments need to work together to organize procedures and communication that involve all staff members.

Advantages and Challenges of Vision Zero for Suicide

Advantages of Vision Zero for Suicide

Vision Zero provides a general goal to focus and gather resources (funding, research, monitoring, and evaluation). Implementing Vision Zero as a suicide prevention approach, rather than a mental health policy in general, provides a platform to allocate more funding focused primarily on suicide prevention. Similarly, this gives incentives as well as financial means and frameworks to organizations to commit to strategies and goals for suicide prevention and to pool resources to tackle suicide. Thus responsibility for suicide prevention will be shared with multidisciplinary approaches that have proven to be successful in many instances (Brooks et al. 2019; Kim et al. 2019).

Vision Zero also aims to decrease stigma about suicide by putting into practice a systemic approach and improved communication around suicide. Vision Zero strategies have been described as shifting the focus of policies from suicidal individuals and those bereaved by suicide to combating social determinants of suicide and improving protective factors (Swedish Legislation of 2007 translated by Kristianssen et al. 2018). This shift puts a stop to the blaming of suicidal individuals, their families, and medical practitioners to build a general understanding that suicide is due to the entire failure of the system. Tackling stigma is additionally linked to improved communication. Communication increases understanding of suicide, mental health disorders as well as bringing into light the work of public health and healthcare services to combat suicide. An additional perk of raising awareness with safe and positive messaging is that it promotes and increases help-seeking behaviors (Sisask and Kõlves 2018).

Vision Zero for suicide contributes to a broader understanding of suicidal behaviors and preventive measures, by giving more resources and opportunities (due to the increased number of programs) to accumulate evidence-based information. This has enabled researchers to better understand not only the course of mental disorders, the impact of risk factors, but also which protective factors work best to prevent suicides from happening. Initial organizations and healthcare systems that have started a Vision Zero initiative, such as the Henry Ford Health System in the United States, have inspired further programs. Similarly, the *Lex Maria* legislation in Sweden recommends investigations of all suicides that occur in relation to healthcare practices to learn from medical errors.

Challenges of Vision Zero for Suicide

The main challenge to Vision Zero for suicide is that this approach is interpreted differently and at different scales depending on the countries (this is further illustrated in section Vision Zero in the world). This has led to some criticisms which are addressed below.

For example, Karlsson et al. (2018) interviewed Swedish psychiatrists to identify their arguments for and against Vision Zero. They found that most participants, although being able to list some advantages, considered Vision Zero to be unachievable and leading to incentive-oriented practices toward patients with mental disorders and could lead to increased involuntary admissions. Similar arguments highlighted that this approach would take the focus away from learning to live with mental disorders to only preventing death by all means.

First, the findings of the Swedish study might be an artifact of the researcher's methodology which allowed respondents to themselves define Vision Zero for suicide rather than using the official parliamentary document describing the different strategies that should be implemented. Second, in Sweden, a study by Roos af Hjelmsäter et al. (2019) describing the results of healthcare provider examination after suicides evaluated that the state of healthcare, the treatment given to patients, and suicide risk assessments were deficient. These deficiencies occur at the organizational microlevel, and the authors called for sustainable improvement of healthcare (Roos Af Hjelmsäter et al. 2019). This is exactly what Vision Zero aims for. The goal of Vision Zero is to implement system responsibilities and healthcare practice improvements that would provide resources for public health and healthcare programs to tackle suicidal behavior and stigma. Thus, Vision Zero initiatives raise awareness of the magnitude of mental disorders in society and call for providing financial resources to tackle suicide.

Funding for an initiative of this capacity can be considered as a challenge. In national health policy, practice change in addition to training is costly at every scale, from a public health policy scale to a hospital department scale. Taking the Henry Ford Health System as an example, data showed that even though initial loans were required at the beginning of the initiative, the impact of Vision Zero reduced the cost from the burden of suicide in recent years (Hampton et al. 2010; Coffey 2015).

There has also been a debate on whether aiming for zero suicide would hinder ongoing discussion about euthanasia and physician-assisted suicide (Holm and Sahlin 2009). The authors consider that having a goal of zero suicide would make it difficult to enable euthanasia (2009). Although others would argue that physician-assisted suicide and suicide decided independently by an individual are different and thus should not impact the target number of Vision Zero policies.

In summary, Vision Zero for suicide drives suicide prevention policies through a multidisciplinary approach by directing awareness, training, and resources toward a concrete goal of having zero suicide. It teaches and empowers individuals in all of society – not just suicide survivors, victims, and medical practitioners – as well as removing guilt and responsibility by proving that suicide prevention needs the support of the entire system to be effective (Mokkenstorm et al. 2018a). Vision Zero is also a support and provider of evidence-based research which improve suicide prevention programs.

Vision Zero in the World

Vision Zero for suicide approaches has been implemented at different scales, i.e., national, regional, and organizational levels. Initiatives share common approaches, such as using evidence-based information to raise awareness, support and guide individuals, families, medical workers, and in some cases public health practitioners. Approaches are systematic and aimed at improving suicide prevention at multiple levels and often through a healthcare approach.

Vision Zero in Sweden

Sweden has a national countrywide approach to Vision Zero. In 2008, the Swedish Parliament launched the *National Action Programme for Suicide Prevention* which presented Vision Zero for suicide approach. Many of the documents were inspired from Vision Zero for road traffic that Sweden successfully implemented by aiming to reduce the road toll to zero (Kristianssen et al. 2018). Vision Zero aims to implement a systematic approach based on preventive measures with the aim that no one should be in a situation where suicide is the only solution (Karlsson et al. 2018; Kristianssen et al. 2018). Vision Zero targets individuals using healthcare services, and also the wider populations to encourage stakeholders to create supportive environments.

The plan is based on nine main areas of action (Folkhalsomyndigheten 2016):

- Promote good life opportunities for less privileged groups.
- Reduce alcohol consumption in the population and in groups at high risk for suicide.
- Reduce access to means and methods of suicide.
- View suicide as a psychological mistake.
- Improve medical, psychological, and psychosocial initiatives.
- Distribute knowledge about evidence-based methods for reducing suicide.
- Raise skill levels among staff and other key individuals in the care services.
- Perform “root cause” or event analyses after suicide.
- Support voluntary organizations.

As mentioned previously, Sweden has a legislation entitled the *Lex Maria* about the healthcare system’s responsibility to investigate incidents to improve patient safety (Karlsson et al. 2018). Vision Zero emphasized (2008) the current usage of this legislation and recommended that if a suicide occurs due to a medical error in the healthcare setting, the case should be evaluated under the *Lex Maria* legislation. This would then allow these suicides happening in healthcare setting and during outpatient procedures to be further studied for future prevention (Hadlaczky et al. 2012). However, *Lex Maria* application to suicides happening within a short time after a healthcare contact was mandatory until 2017 and is presently only implemented based solely on the healthcare provider’s decision.

Vision Zero in the United States

Several Vision Zero initiatives are implemented in healthcare systems in the United States. In 2000, the first United States national suicide strategy was launched, and in 2010, the National Action Alliance for Suicide Prevention was created. National Action Alliance for Suicide Prevention (NAASP), a public-private partnership, identified healthcare systems as paramount for suicide prevention and launched several task forces focusing on a comprehensive system approach to detect and manage suicide in the healthcare setting (Labouliere et al. 2018). To reach the aspirational Vision Zero goal, the National Institute of Mental Health and NAASP committed to reduce suicide by 20%, a first step in the joint effort to prioritize research and resources to lower suicide in the United States (Gordon et al. 2020). The implementation of Zero Suicide practices is recommended by both national governmental offices such as the United States Office of the Surgeon General (2012), and countrywide nonprofit organizations such as the Joint Commission, a United States healthcare accreditation program (2016). Initial data from studying Zero Suicide initiatives in the United States show that these initiatives are effective and should be replicated more widely (Hogan and Grumet 2016; Brodsky et al. 2018).

One example of large-scale prevention program under Zero Suicide in the United States is the Perfect Depression Care program at the Department of Psychiatry at the Henry Ford Health System, launched in 2002 in Detroit, Michigan (Hogan and Grumet 2016). The program focused on evidence-based approaches to improve healthcare chain of care: effectiveness, safety, patient-centered, timeliness, efficiency, and equity among patients (Hampton 2010). One of the key approaches to minimize suicide has been to increase screening of patients that enter the healthcare system for suicide (Coffey 2015). Another component is to tackle concerns from primary care physicians when it came to treating suicide, such as providing guidelines on how to deal with potentially suicidal patients and direct access to knowledgeable psychiatrists (Coffey 2015). The system has been deemed a huge success, with a 75% reduction in suicide rates in the first 4 years of implementation, and has been sustained each year since 2001 (Hampton 2010; Covington and Hogan 2019).

Vision Zero in the United Kingdom

The United Kingdom has also embraced the Vision Zero approach for healthcare practice. The United Kingdom government launched across the National Health Service (NHS) a zero-suicide ambition in January 2018 targeting mental health patients in care and aiming to expand to all mental health patients (Department of Health 2019). This led to two international conferences on zero-suicide where some of the programs launched by the NHS were presented (Henden 2017).

The Mersey Care NHS Foundation Trust, for example, aims toward zero suicides inspired by the Henry Ford Hospital system in the United States. The core strategy lies in quality improvement, universal staff training, and support for victims of suicide. Mersey Care established several public campaigns to tackle stigma and funded digital innovations to improve health outcomes. The program is also being scientifically evaluated, and future results will direct both subsequent improvements of the system and adaptions of their approach to other systems (IIMHL 2016). Additionally, the NHS trust launched the Zero Suicide Alliance which is supported by and partnered with many organizations. The alliance plans to both raise awareness and promote accessible training in suicide prevention. According to them, if the general public learns to identify signs of suicidal behavior and how to direct the individual to services and care, then everyone can be empowered to help prevent suicide (Zero Suicide Alliance 2020).

Vision Zero in Other Countries

In several countries, most of the Vision Zero projects target healthcare settings and follow the example of implementation of the United States framework titled Zero Suicide. In the Netherlands, mental healthcare institutions were targeted by the Dutch National Prevention Strategy to investigate and assess the practice and variation of suicide prevention strategies. The study highlighted that several institutions gathered together under the name SUPRANET Care and publicly announced pursuing a Zero Suicide aim (Mokkenstorm et al. 2018b). Additionally, the New South Wales (NSW) state in Australia launched an initiative called Zero Suicides In Care to create a blame-free working environment in addition to several other initiatives such as postvention service for people bereaved by suicide, resilience building in local communities, or gatekeeper training (NSW Ministry of Health 2019). This NSW program combines both public health and healthcare initiatives which demonstrate that the objective of Vision Zero for suicide needs a consensus of actors to be reached.

Toward a Vision Zero for Suicide Label?

The above-mentioned examples on Vision Zero for suicide initiatives show that most of the existing implementations of Vision Zero revolve around healthcare prevention in hospital settings. This can be explained by the influential Zero Suicide organization and its framework used worldwide (in the United Kingdom, Netherlands, Australia, and more) after proving successful in the United States. This even led to the international declaration for better healthcare signed by Australia, Canada, China, Denmark, French Polynesia, Hong Kong, Japan, Malaysia, the Netherlands, New Zealand, Taiwan, the United Kingdom, and the United States (IIMHL 2016). This declaration provides a strong action plan implementable in any organization wanting to reach zero suicide in healthcare. Healthcare-setting improvements are a crucial interpretation of the systemic approach to improve suicide care in the medical system. However, the general aim of Vision Zero for suicide calls for more implementation in the public health system.

There are many suicide prevention programs, presented in the next section, built on evidence-based approaches that reduce suicide in societies worldwide. These interventions involve multidisciplinary actors and not only target at-risk groups but also target society as a whole, in addition to often being implemented at different levels (Zalsman et al. 2016). This resonates with the Vision Zero aim described earlier, but they are not labeled as such.

An example of what can be called international aspirational label is the Sustainable Development Goals (SDGs), a high-level concept to enable coordination between governments and international organizations and place emphasis on partnerships in implementation (Nilsson et al. 2018). Although criticized about their indicators, top-down approach, and feasibility, the SDGs, once adapted locally and taken as a general guideline for development institutions to create policies and attribute funding to local initiative, are impactful. Judging by the number of projects and papers published in relation to the SDGs, the use of the SDGs as a label stamped on papers, funding proposals, media communication, and policies improves society's awareness and increases communication about a much-needed field of intervention.

Like the SDGs, Vision Zero for suicide could be an overarching label by which programs and organizations can identify themselves with the aspirational goal of zero suicide, even though their strategies and scales of operation may differ. This would improve the visibility of such projects, would create a strong link between international programs, and would create a research consensus among multi-disciplinary actors, as well as provide a clear funding platform to catalyze efforts from governments and funding bodies.

What Does the Evidence Say about Suicide Prevention

Evidence-based suicide prevention programs are often organized around the conceptual framework called the Universal, Selective, and Indicated model (USI) (Wasserman and Durkee 2009). This framework is used internationally, especially by the WHO for its suicide prevention activities (Cerulli et al. 2019; World Health Organization 2014; Wasserman 2019).

These three strategies are aimed at target populations. Universal prevention is aimed at general population. Examples of strategies could be increasing access to mental health care, restricting access to means of suicide, or encouraging responsible reporting of suicidal behaviors. Selective prevention is aimed at groups who have an above-average risk to develop disease or risk behavior (for example, immigrants, substance users, or children coming from at-risk families). A selective strategy would focus on community support and strengthening protective factors, such as building strong personal relationships or teaching positive coping strategies. Indicated prevention is directed at persons who have already experienced symptoms of a disorder. These strategies target specific risk groups, such as individuals with mental health disorders and substance use, individuals who are bereaved by suicide, or individuals who have experienced some form of trauma or use.

Suicide prevention requires a multiphased and multilevel approach, drawing strategies from both the healthcare and public health perspectives (Hegerl et al. 2009; Zalsman et al. 2016). Preventive intervention strategies can be implemented according to the healthcare approach and the public health approach which are complementary of each other (Wahlbeck et al. 2017; Wasserman and Durkee 2009; Wasserman 2019; Zalsman et al. 2016, 2017). The public health perspective focuses on population-based initiatives and aims to decrease risk factors and strengthen protective factors (Wasserman and Durkee 2009). The healthcare perspective targets patients, relatives, and healthcare professionals, as well as different healthcare settings and fields. A comprehensive overview of all evidence-based strategies is published in *Suicide: an Unnecessary Death* (Wasserman 2016) and *Oxford Textbook of Suicidology and Suicide Prevention: a Global Perspective* (Wasserman 2009, 2020) presently updated. A summary of the evidence-based strategies is presented below.

Public Health Approaches

Public health prevention strategies target the general public and draw resources from governmental bodies as well as nongovernmental organizations. These strategies with strong scientific evidence include increase in public awareness, restriction of access to lethal means, and school-based universal prevention. Strategies that need more research are gatekeeper training, media guidelines, internet-based interventions, helplines, and indigenous preventive programs.

Increase Public Awareness

Public information campaigns are aimed at the whole population to promote health and prevent suicide. Public information campaigns disseminate knowledge about mental health, about the treatable aspects of suicidal behavior and depression, and about the importance of communication about these issues. Information campaigns also provide crucial information on helpline numbers and who to contact. Many Vision Zero for suicide initiatives described earlier, such as the NSW one in Australia, have programs including the raising awareness approach. The NSW Australian initiative aims to build resilience to support the suicide prevention of local communities including people with lived experience, health organization, and others to raise awareness (NSW Ministry of Health 2019). Awareness campaigns can be shared through several media platforms such as television, newspapers, radio, YouTube, advertising posters, social media, brochures, websites, etc., in order to increase public awareness (Barker et al. 2017; Kreuze et al. 2017; Zalsman et al. 2016). Campaigns that were part of a larger multicomponent approach, with other public health interventions, produced better and more lasting results than campaigns implemented without complementary interventions.

Restrictive Access to Lethal Means

Limiting the availability of means by which a person can commit suicide is supported by strong evidence in many studies in suicide prevention. A means restriction is a preventive approach adapted to different lethal means and several environmental and cultural contexts. The restricting access to lethal means' methods that have the strongest evidence of efficacy is: limiting access to medication, restricting firearms, and limiting pesticide access; barriers implementation; and control of carbon and gas, preventing hanging, and alcohol restriction (Värnik et al. 2007; Barker et al. 2017; Das et al. 2016; Dodd et al. 2016; Gunnell et al. 2017; Pirkis et al. 2015; Riblet et al. 2017).

The theoretical standpoint for this approach is that the longer it takes and the more difficult it is for a person to access means to commit suicide, the more time there is for the person to be interrupted by others or to change their mind (Zalsman et al. 2016). For the same reason, these restrictions have a greater chance of decreasing the mortality rate in impulsive suicide attempts compared to the planned ones.

Medication

Self-poisoning via medication is often a lethal mean of suicide (Ho et al. 2016; Sinyor et al. 2019). Restricting access to medication (analgesics, barbiturates, opiates, and caffeine tablets) is linked to a reduction in the number of deaths by suicide. Methods for restricting access to medication include restricting and monitoring prescriptions, prescribing alternative medication, taking precautions against forgery, recalling unused drugs, and creating blister packs (reducing the size of the packaging of drugs) (Zalsman et al. 2016; Hawton et al. 2018).

Firearms

Firearms are a fatal mean of suicide in countries where they are easily accessible. Restrictions of domestic firearm availability with control legislation have mostly positive results. Regulations of firearms have also resulted in a decrease of suicide by firearms in Norway, Switzerland, Israel, New Zealand, and Australia (Zalsman et al. 2016).

Pesticides

In low-income and middle-income countries, pesticides are a common means of suicide (Eddleston and Gunnell 2020). Therefore, governmental actions aim to remove dangerous pesticides from agriculture practice (WHO 2019). Measures to restrict pesticides include reducing their toxicity, controlling sales of pesticides, raising awareness toward safe management and storage practices, and improving healthcare practices of pesticide overdoses (Mann et al. 2005). Such policies to control toxic pesticides have shown to be successful in suicide reductions in Sri Lanka, India, and Western Samoa (Gunnell et al. 2017; Zalsman et al. 2016).

Barriers

Suicide by jumping plays an important role in urban societies (Hemmer et al. 2017). Barriers to jumping sites, as well as railways and subways, have strong evidence in reducing suicides (Zalsman et al. 2016). For bridges, installing high altitude barriers or safety nets has proven effective, with little evidence of substitution to other jumping sites (Perron et al. 2013). For subways, restricting access to railways, installing platform doors, creating “suicide pits” (areas with suspended rails resulting in trains passing above a person fallen on the rails without risk of hurting them), and increasing surveillance systems can prevent suicide (Ratnayake et al. 2007).

Control of Carbon Monoxide: Charcoal and Gas

Detoxification of domestic gas and restricting the purchase of charcoal are effective in preventing suicide (Zalsman et al. 2016). Suicide by poisoning from car exhausts decreased due to the push for cleaner air, leading to the introduction of catalytic converters and suicide with domestic gas decreased due to its detoxification (Mann et al. 2005). Charcoal burning has been a suicide method especially carried out in Asia (Wong et al. 2009; Yip et al. 2010). Limited access to charcoal for the general population was highlighted as an effective way of preventing charcoal-burning suicide (Yip et al. 2010).

Hanging

Only a small amount of evidence exists regarding prevention of hangings (Zalsman et al. 2016). Controlled environments and institutions, such as psychiatric hospitals and prisons, can enforce the implementation of hanging prevention because of the supervision occurring there. Proposed implementations are safe clothing that cannot be used as means of suicide, windows adjustment, and installation of antisuicide shower heads (Reisch et al. 2019).

Alcohol

Alcohol generally increases impulsiveness and aggression which can lead to premature or rash decisions in a crisis. In addition, alcohol use is particularly common in many cases of suicide among men (Gvion and Apter 2011). Drinking habits are embedded in the culture as well in society. In some societies where alcohol consumption is not culturally acceptable, restrictions may not have the same effects as in countries where alcohol consumption is pervasive. Some examples of legislations and policies aimed at reducing alcohol consumption of the population are increased taxes, ban on alcohol imports, decreased availability of alcohol through alcohol license sale restrictions, and zero-tolerance when driving (Xuan et al. 2016).

Several examples of significant decrease of suicide rates due to alcohol reduction include the prohibition in the United States in 1910–1920 (Wasserman I 1992), price increases in Denmark in 1911–1924, and restriction of sales in Sweden starting in the first part of the twentieth century (Norström 1988). However, one of the best-studied examples of alcohol restriction on suicide rates can be found during 1984–1990 in the former Union of Soviet Socialist Republics (USSR), during the time of the *perestroika* (Wasserman et al. 1994).

Perestroika was a period of major political change, which developed into a time of increased freedom. Policies limiting the sale of alcohol were administered, which resulted in an attitude that also encouraged the restrictive consumption of alcohol in the population. It was also around this time that the USSR national archives were opened, making them available for research to study topics such as societal factors that may affect suicide rates (Wasserman and Värnik 1998). Studies of the archives showed differences of suicide within the country. The Slavic (25.6 per 100,000) and Baltic (28) region had higher suicide numbers than the Caucasian states (3.5); this is understood to be due to the cultural differences between these populations (Wasserman et al. 1998a, b). Even so, after the introduction of the *perestroika* movement, all states witnessed a fall in suicide rates, with a decrease among men approximatively by 40% for suicides from 1984–1988, in comparison with the decrease by 3% in 22 European countries at the same time (Wasserman and Värnik 1998). Further, a study that examined the alcohol levels, at the time of death in suicide victims before, during, and after the launch of the antialcohol movement during *perestroika*, confirmed that the use of alcohol consumption was a common precursor to suicide and that strong alcohol restrictions were accompanied particularly by a decrease in suicide mortality among persons of both sexes who screened positively for alcohol (Värnik et al. 2007).

School-Based Universal Suicide-Prevention

Suicide is the second leading cause of death among young people of age 15–29 years, globally (WHO 2016). School-based suicide-prevention programs can be used as an important tool to support vulnerable people and provide them with education on how to effectively cope with stress and mental health issues. In general, research shows that school-based interventions are effective concerning increased knowledge and changes in attitude (Zalsman et al. 2016). Moreover, evidence shows that some school-based mental health and suicide awareness programs are followed by a reduction in suicide attempts and ideation. The three universal school programs with the strongest evidence which are briefly described are Good Behavior Game, Signs of Suicide, and Youth Aware of Mental Health studied in the Saving and Empowering Young Lives in Europe (SEYLE) study (Zalsman et al. 2016).

The Good Behavior Game (GBG) was developed in 1969 in the United States and is designed as team-based behavior management to control aggressive and disruptive behaviors in the classroom setting. With the design of the game, the pupils are being taught two important skills: learn what maladaptive behavior is, and how to be part of a social setting and work toward common goals (Wilcox et al. 2008). The GBG program, although not primarily developed as a suicide prevention program, was successfully linked to lower suicidal behavior from childhood to young adulthood. This is believed to be related to the decrease in aggressive and disruptive behavior, as both these behaviors are correlated to suicidality (Newcomer et al. 2017). The program has primarily been linked to a long-term impact in lowering alcohol and substance use.

Signs of Suicide (SOS) is a school-based universal intervention aimed at secondary school pupils and was successful in reducing self-reported suicide attempts. The program was designed in relation to the theoretical standpoint that suicide is the outcome of mental illness and not solely a response to life stressors and emotional distress (Aseltine et al. 2004). The program aims to communicate knowledge of the warning signs of suicide risk and what to do if they are discovered by others or oneself. The intervention, however, was not followed up after 3 months and was limited by follow-up dropout (Schilling et al. 2016).

Saving and Empowering Young Lives in Europe (SEYLE) project was implemented in 11 European countries with Sweden as a scientific coordinating center. Its goal was to study the mental health of 15-year-old school-based youth and to evaluate three different school-based suicide-prevention programs compared to a control group (Wasserman et al. 2010). The project included three programs: *QPR* (Question, Persuade, and Refer), *ProfScreen* (the Screening by Professionals), and *YAM* (Youth Aware of Mental Health). Of the three SEYLE programs, YAM was the most effective in reducing the number of suicide attempts and suicidal ideation (Wasserman et al. 2015).

- The QPR program is designed by Paul Quinnett to train teachers and other school staff to act as gatekeepers (Quinnett 2007). The goal was for staff to learn how to identify risk and suicidal behavior in students and to motivate them to help students seek professional help if in crisis. Teachers also distributed contact information of local healthcare services to students who seemed to be at risk (Wasserman et al. 2015).

- The ProfScreen program screens and identifies at-risk students through the SEYLE baseline questionnaire. This enabled referral to clinical services if needed (Kaess et al. 2014).
- The YAM program is a 5-hour universal intervention targeting all students in the classroom. This program consists of interactive role-play workshops teaching skills to cope with dilemmas in life, stress, anxiety, depression, and suicidal behavior. A booklet regarding these topics with contact information to local healthcare services is also provided (Wasserman et al. 2010).

The YAM program decreased by 50% severe suicide ideation with plans and suicide attempts. This program was unique in that it not only provided knowledge on how to cope with stressful life events but also gave the students the chance to verbalize a variety of different issues concerning mental health and suicidal behavior (Wasserman et al. 2018). Additionally, it was also effective in diminishing impulsiveness as a coping strategy (Kahn et al. 2020). The YAM program is currently being culturally adapted and implemented in Australia, England, India, Norway, the United States, and Sweden. The cultural adaptation is pursued by the local researchers in collaboration with the founders of the YAM program. The adaptation is based on a back-and-forth translation of the materials, linguistic adjustments, and on the results of qualitative research using focus groups with young people, instructors, and facilitators. This procedure feeds in the program materials and aims to ensure the fidelity of the original YAM program, quality insurance, and outcome improvement for the schools (Lindow et al. 2019).

Gatekeepers

Gatekeeper training aims to increase knowledge of suicide prevention as well as the response and identification of at-risk individuals for people with a high chance of being in contact with at-risk population. They may be from the general population, or specific professionals (e.g., teachers, police officers). The training activities are focusing on warning signs, risk factors for suicide-related acts, and how to assist or refer a person in need to appropriate assistance. Quinnett with the QPR program highlighted that in addition to such activities, training should also aim to enhance mental health literacy and decrease stigma (Quinnett 2007). Examples of existing training activities include 113 Suicide Prevention, a Dutch gatekeeper training (Terpstra et al. 2018) and Mental Health First Aid (MHFA) training launched in Australia and adapted worldwide (Kitchener and Jorm 2002; Hadlaczky et al. 2014; Jorm et al. 2019).

Media Guideline

Media reporting of suicide-related events may have negative consequences if done incorrectly. The WHO published guidelines on how suicide should and should not be reported (WHO 2017). For example, Guidelines suggest avoiding sensational descriptions of suicide as well as not providing information about the means of suicide, location, or suicide notes, and to avoid the inclusion of pictures. Media outlets should focus on educating the population about suicide (facts and myths), and their reporting should always include visible contact information to crisis helplines for people in need. Implementing such guidelines for media has a strong positive impact on the population (Torok et al. 2017). Additionally, media reporting may have a protective factor on the general population due to an emphasis on coping with suicide.

Internet Initiatives for Suicide Prevention

The Internet can be seen as a source providing counseling and psychological help that is accessible for everyone (Gilat and Shahar 2007; Lester 2008). Internet and Internet-based applications (on smartphones and computers) are increasingly utilized for suicide preventive programs (Perry et al. 2016). Internet-based information has several advantages regarding the low-cost of building Internet prevention and accessible nature of such media (Perry et al. 2016). It nonetheless is challenged by the uncontrolled nature of the Internet, the mental health impact on users, and the fact that only a few programs are systematically evaluated (Hökby et al. 2016; Larsen et al. 2016; Zalsman et al. 2016). The Internet is all-encompassing, but research has highlighted that search engines should, and can, improve their algorithms with a more positive and tailored approach to suicide prevention (Arendt and Scherr 2016).

The Suicide Prevention through Internet and Media-Based Mental Health Promotion (SUPREME) project was aimed to develop, share, and evaluate a web-based intervention on adolescent mental health and suicide prevention. The website was designed to increase knowledge and awareness of mental health and to offer direct professional support to users. The research had strong evidence that all mental health-related outcomes declined. The study revealed that participatory designs are paramount for Internet-based interventions to meet the preferences of the users (Carli 2016).

Another example of initiative implementing Internet initiative to pursue the Vision Zero for suicide aim is the Netherlands consortium of organizations called SUPRANET which launched 113Online program to empower and improve suicide prevention action network (IIMHL 2016).

Helplines

Telephone-based helplines for suicidal people are available in many countries. The aim of these helplines is for the suicidal, or otherwise concerned, person to feel heard, talk about their problems, and be encouraged to find constructive solutions to their problems and to, ultimately, continue being alive. Since many suicidal people avoid seeking formal help, this may be the only opportunity for some to talk to someone. Crisis centers have been involved in national strategies to tackle suicide (Gould et al. 2012; Gould et al. 2016). Challenges exist to gather evidence on the effectiveness of helplines, as these services are anonymous and there are no possibilities to follow-up with the user (Nelson et al. 2017; Zalsman et al. 2016).

Indigenous Suicide Prevention

Indigenous communities have a significantly higher rate of suicide than other communities (Pollock et al. 2018). Indigenous suicide prevention programs are unique because they need to be culturally responsive to be efficient (Wexler and Gone 2012; Charlier et al. 2017; Allen et al. 2019). Most culturally responsive programs are multilevel, multidisciplinary, and include projects on community prevention, gatekeeper training, school-based programs, media, helplines, primary care providers training, etc. (Kirmayer et al. 2009; Wexler et al. 2015). All public health and healthcare initiatives described in this section can be adapted for indigenous populations. Challenges for indigenous suicide prevention, as highlighted by some systematic research (Clifford et al. 2013; Harlow et al. 2014), are that usual suicide program designs (randomized-control trials with large population), and their evaluations do not fit the needed approach for indigenous communities (holistic approach, community-level factors, suicide considered as a social issue, etc.) (Wexler et al. 2015; Hatcher 2016; Allen et al. 2019). However, some programs on quasi-experimental designs (based on strengths-based assessment and community-level variables) have seen an increase of protective factors and reduction of suicidal behavior (Kirmayer et al. 1999; Allen et al. 2009; Allen et al., 2019). Indigenous suicide prevention programs, in addition to following a similar holistic approach as Vision Zero, highlight the strengths of community-based prevention programs.

Healthcare Approach

Healthcare approach aims to improve healthcare services, early diagnosis, and identification and treatment of suicidal behavior, as well as training healthcare staff toward better practice and follow-up for suicidal patients. These prevention strategies target patients, families, and others affected by suicide in addition to healthcare setting (Wasserman 2004; Wasserman and Durkee 2009). The initiatives with the strongest evidence are treatment of depression and chain of care. Others with mixed-result evidences are education of primary care physicians and screening in primary care (Zalsman et al. 2016).

Treatment of Depression

Psychiatric disorders are a major risk factor for suicidal behavior; therefore, their treatments are essential to suicide prevention (Zalsman et al. 2016). Improvement in depression screening and recognition by general practitioners, as well as depression campaigns, have strong evidence on suicide prevention (van der Feltz-Cornelis et al. 2011; Hegerl 2016). Various medications and psychotherapies are effective and recommended in suicide prevention (Zalsman et al. 2016).

Chain of Care

The chain of care revolves around the idea that care must be consistent and coherent at every level during the screening, diagnosis, treatment, and follow-up of a patient. It is particularly important for serious mental illnesses and suicidal behavior, which usually require longer treatment and follow-up. The chain of care needs structural (internal communication and information sharing) and follow-up improvement.

Some interventions consist of phone-based patient follow-up (Noh et al. 2016) or crisis-coping cards (Wang et al. 2016). Crisis-coping cards have shown positive results in reducing suicidal behavior and severity of suicide risk (Wang et al. 2016). Evidence for chain of care is quite heterogeneous (Zalsman et al. 2016). In the United Kingdom, the NHS launched a plan for Zero Suicide which includes engaging staff through the creation of a Safe from Suicide Team comprising representatives from local services. This team monitors and ensures the implementation of the program through all services to strengthen the chain of care regarding suicide prevention (Public Health England 2016).

Education of Primary Care Physicians

Zalsman et al. (2016) highlighted that the training of primary care physicians is effective in preventing suicide. For example, studies have shown that primary caregivers face several challenges when working with mentally ill patients (i.e., lack of training on suicide management, competing health issues, and brief and inconsistent visits) (Jerant et al. 2019). As such, programs and guidelines need to support primary caregivers on how to talk about suicide and develop contact with suicide specialists and psychiatrists (Hogan and Grumet 2016).

Screening in Primary Care

In order to prevent suicides, screening must be combined with an effective response for those individuals who screen positively for suicide risk. Considering the cost of screening, and the insufficient evidence of its benefits in primary care populations, it is judged not to be the most effective strategy for suicide prevention (Zalsman et al. 2016). In the United States, the Henry Ford Health System to implement their Zero Suicide program first assessed and screened every patient going through the Behavioral Health Service. This first step enabled the prioritization of care and contributed to the improved communication between services by creating a targeted profile of patient accessible through shared records (Hampton 2010).

Conclusion

Like all Vision Zero policies, Vision Zero for Suicide should be seen as an aspirational goal bringing together several sectors at all levels of society. But in order to succeed, it must be ambitious. It aims to not only diminish the stigma around mental health and suicide but to also bring about systematic changes. Working toward this goal for zero suicide enables multiscale and multidisciplinary suicide prevention interventions as a label for stakeholders to rally together and pool resources. Despite criticisms, successful programs worldwide guide future Vision Zero implementations for suicide.

To achieve the goal of Vision Zero for suicide, evidence-based suicide prevention strategies need to be widely implemented, in both public health and healthcare settings. Substantial financial support is a prerequisite for the success of Vision Zero. These strategies need to be catered to the respective contextual environments and regularly evaluated to improve their quality and effectiveness.

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Vision Zero on Fire Safety

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Ragnar Andersson and Thomas Gell

Contents

Abstract

Since 2010, Sweden has a Vision Zero policy on fire safety: no one should die or be seriously injured as a result of fire. Compared to the traffic safety model, however, the preconditions for successful implementation appear more immature and less convincing in the fire area. The purpose of this chapter is to illustrate, using the Vision Zero policy on fire safety as an example, how a Vision Zero initiative in a new area, where the conditions for governance may differ significantly from the area of inspiration, can be dealt with as a dynamic process to gradually establish credibility and effectiveness.

Globally, fire is a significant cause of death and injury. The general trend is toward a slow decline, especially among middle-income and high-income

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countries. The decline may be due to successful fire safety efforts, but also to other conditions affecting it indirectly. Both risk-increasing and risk-reducing factors determine fire safety. Risk increasing factors include an ageing population, an increasing diversity of possible ignition sources, and a change in the composition and amount of combustible materials present in our homes. The risk-reducing factors include generally favorable socioeconomic and technological developments, including concrete societal actions directed against fire risks such as the promotion of smoke detectors and sprinkler systems.

Fire safety is one of the oldest documented examples of societal risk management. City planning and construction were early influenced by fire safety considerations, while in contrast, the legal responsibility for residential fire safety has largely remained a private and individual matter. The situation is similar to the one that for long prevailed in the traffic sector, that is, the primary responsibility rests with the system's users, not with its designers.

The launch of the Vision Zero on fire safety in 2010 represented a clear boost in ambition. Along with the vision, a strategy intended to guide the work toward the visionary goal was also presented. The strategy included four items: information, technical solutions, local collaboration, and evaluation/research. Several actions were taken in line with the strategy, including a significant research effort and the development of a set of indicators to monitor progress.

Ten years later, the research effort has brought new knowledge that puts previous perceptions into partly new light. The notion that survival depends on the individual's personal capacities is strengthened. Adverse outcomes such as death and serious injury appear mainly linked to specific vulnerabilities of certain groups for medical and social reasons. Most fires are handled by the residents themselves without injuries and without assistance from Rescue Services; on the other hand, even minor fires can be fatal for vulnerable residents. This turns the problem framing toward social aspects rather than technical, since broad groups of residents lack the capacities needed, conflicting with the prevailing view that the individual should bear the primary responsibility.

Other findings relate to the proven inefficiency of certain measures for groups at elevated risk and the need for re-thinking and innovations to meet the challenges ahead. This includes extended inter-sectoral collaboration on a broader spectrum of residential risks besides fire, threatening the same groups for similar social and medical reasons.

This updated state of knowledge is now being used as a basis for renewing current national fire safety strategies. With reference to general principles of systems control, this chapter will discuss obstacles and challenges to establish a more robust and systematic national control of the fire problem in line with the Vision Zero policy. The appropriateness of launching Vision Zero policies in fields that are not yet ripe for systematic governance is also discussed. It is concluded that a Vision Zero initiative can still be meaningful and successfully pursued, provided that limitations in the ability to influence crucial elements in the system are openly identified and systematically addressed in a process in

which strategical and policy developments interact with research and innovation.

Keywords

Vision zero · Fire safety · Systems approach

Introduction

Since 2010, Sweden has a Vision Zero policy on fire safety: no one should die or be seriously injured as a result of fire. Compared to the Vision Zero on road traffic safety, the Vision Zero on fire safety can be said to be less well known and less systematized in its implementation. It was launched as one among several Vision Zero policies in different areas where politicians and decision-makers became inspired by the Vision Zero on traffic safety and advocated similar approaches to meet other societal problems. Unlike the Vision Zero on traffic safety, where scientific and strategic progress can be said to have paved the way for the breakthrough and acceptance of a new paradigm (Belin et al. 2012), the Vision Zero on fire safety is still based on fragmentary scientific and strategic evidence. Rather, the Vision Zero on fire safety appears as an expression of decision-makers' desire to manifest will and determination before there is a clear picture of how the vision can be realized. Other Vision Zero policies have been established on similar grounds, which raise questions regarding the challenges involved in launching Vision Zero policies in new areas before they can be said to be scientifically and strategically mature for such a radical approach. The purpose of this chapter is to highlight these challenges, using the fire area as an example. More specifically, we wish to demonstrate how a long-term Vision Zero initiative in a new area where essential preconditions for adequate governance are still lacking can be dealt with as a dynamic and iterative process where such insufficient preconditions are systematically tackled along with more detailed solutions.

The chapter is structured as follows: first, we give a brief background on fire as a societal problem from Swedish and international perspectives, and how it has historically been managed. This is followed by a presentation of how the Swedish Vision Zero policy on fire evolved to the formal initiative that was presented in 2010. An essential part of the strategy associated with the policy was to initiate research in areas that were assessed to be of particular importance for the further implementation of the policy. The richer state of knowledge resulting from this research effort is summarized briefly, as well as its implications for the continued Vision Zero work. Emphasis is placed on achievements that can be judged of importance for a broader understanding of the nature of the fire safety problem, and how these achievements can be assumed to influence future strategic work. The chapter concludes with a discussion on the challenges a Vision Zero initiative can encounter when transferred to a new field where the preconditions for societal control may differ considerably, as compared to the traffic safety model.

Background

Globally, fire is a significant cause of death and injury. A total of about 120,000 people are estimated to die each year in fire (Ritchie and Roser 2018). Most of these deaths occur in low- and middle-income countries.

Reliable comparisons of the number of fire-related deaths between countries are largely lacking. In the EU, fires are estimated to be responsible for 2% of all fatal injuries (EuroSafe 2014). A report based on data from the International Association of Fire and Rescue Services shows steadily declining trends in countries such as Estonia, Germany, the United Kingdom, Latvia, Russia, and the United States since 2002 (Winberg 2016). Similar trends are shown in a Swedish study based on WHO data (Moniruzzaman and Andersson 2018). The latter research suggests socioeconomic development is the determinant that most clearly explains the differences between countries.

Sweden has documented a steady decline in fire mortality of about 60% from 1950s levels (Jonsson et al. 2016). Similar developments are observed in many comparable countries. Why this has happened remains largely unclear, but for Sweden, it is noted that the decrease has been most significant in children and younger ages. This has contributed to assumptions that expanded childcare and improved medical burn care may be important factors besides fire safety measures. Further, an ongoing shift in the medical cause of fire deaths, from burns toward intoxication, is observed, possibly due to changes in interior materials in Swedish homes. A vast majority of all fire deaths occur in residential settings.

Fire is a risk that accompanies people of all times, and fire safety is one of the oldest documented forms of societal risk management. For several centuries, many cities were ravaged by devastating urban fires (Garrioch 2019). As urbanization took off in the nineteenth century, Swedish cities grew rapidly, and a large number of them were hit by widespread fires (Bankoff et al. 2012; Schmaltz 1992). In 1874, the first Swedish national building and fire charter was adopted (Kongl Maj:t 1874). Rules on building height, firewalls, chimney-sweeping, and physical separation between buildings were introduced. Blocks with spacing between them replaced the previously clustered style of city planning. These measures proved effective; extensive urban fires ceased in the twentieth century and became limited to more finite block fires. This positive development continued, and the major fire problem then became fires in individual buildings. During the 1950s and 1960s, the concept of "fire cell" was introduced. A fire cell is a defined part of a building within which a fire can be confined for a given minimum period without spreading to other parts of the structure. This is achieved practically by requiring fire-resistant properties of the fire cell limiting surfaces – walls, ceilings, floors, doors, etc. This measure has been proven successful as well and has contributed to a deep reduction in fully developed fires in buildings. Most fires in apartment buildings are now limited to the fire cell where the fire started. The same applies to fatal fires; in a majority of residential fires with a deadly outcome, the fire is confined to the fire cell of origin (e.g., an apartment) or even to the single room of origin.

Besides regulations on construction and city planning, which impose certain obligations on industries, property owners, and municipalities, there is a strong tradition of responsibility of the individual in fire safety. According to the current Swedish legislation applicable to fire safety – The Civil Protection Act (Swedish Parliament 2003) – "the individual," whether human or legal, has a primary responsibility to protect life, property, and the environment and not to cause fires or other accidents. In the first place, it is the individual who should take measures to prevent accidents and limit the consequences of accidents that may yet occur. The individual – for example, a resident of a single-family house or an apartment – is therefore assumed to have both the knowledge and ability to prevent a fire. The individual is also expected to have the skills and equipment (e.g., smoke detectors) needed to be able to act properly if a fire nevertheless should occur.

The fire safety framework described above has largely grown through evolution. The legislation is developed reactively, usually adjusted only in the aftermath of major and devastating fire events (Ewen 2018). Fire research gained momentum in the second half of the twentieth century but remain mostly technology oriented. An exception is research on evacuation, where behavioral knowledge and related methodology play a significant role.

Another aspect that might, in part, explain the lack of proactivity and adaptation to the social aspects of fire prevention is to look within the rescue service's deeply ingrained culture. Most people choosing this career are focused on operational firefighting. Prevention tends to be regarded as an alternative or second-hand task. The strong internal professional culture, organized after military-type hierarchical models, with male dominance and a technical focus, probably makes it even harder to take on board knowledge and practices from non-fire science related areas such as public health or social care.

The Swedish Vision Zero Initiative

The first initiative toward a long-term strategical approach to reducing deaths and injuries in fires was taken by the then national authority having jurisdiction, the Swedish Rescue Services Agency, concurrently with the launch of the Vision Zero of road traffic in the late 1990s. At this time, it was primarily the ethical component of Vision Zero – it is hardly possible for a safety authority to argue for an ultimate visionary state other than zero – that was the motive. In 1997, the Swedish Rescue Services Agency submitted a fire prevention program to the government, proposing that "*The risks of fires should be continuously reduced. The numbers of deaths and injuries, as well as cases of serious damage to irreplaceable environment and property assets, should decline towards zero*" (SRV 1997). Partly as a result of this initiative, a systematic collection of facts about fatal fires and fire fatalities began at the Swedish Rescue Services Agency.

The current Swedish Vision Zero policy on fire safety was formally proclaimed by the succeeding nationally responsible sector authority, the Swedish Civil

Contingencies Agency (MSB[1]), in 2010. It was developed in response to a government initiative in which the Swedish government called for a national strategy on how fire protection can be strengthened by providing support to individuals (MSB 2010).

The initiative was motivated by an impression of slow progress and the recent occurrence of some high-profile fires with multiple fatal outcomes among immigrants. A supplementing strategy, intended to guide the work toward zero deaths and serious injuries, was formulated in four points:

Knowledge and communication
Technical solutions
Local collaboration
Evaluation and research

"Knowledge and communication" aimed at easily accessible and coordinated information for different target groups, such as those with special needs. Basic fire safety knowledge was judged essential to be included in schools and vocational training, as well as in training courses for newly arrived immigrants.

"Technical solutions" addressed technical innovations and the development of so-called forgiving systems that allow individuals to make mistakes without being seriously harmed or killed. Smoke detectors and extinguishing equipment in homes were particularly highlighted, as was the need to spread knowledge of other solutions. This point also underlined the need for strengthened fire safety in nursing homes.

"Local collaboration" addressed the importance of collaboration across sectoral boundaries to identify groups and individuals in need of special efforts and to reach out to property owners and insurance companies.

"Evaluation and research" was added as a final point to support future strategic development by bringing new knowledge. Among other things, a focused research effort on residential fires was proposed.

In support of Vision Zero for fire safety, a collaboration group and a campaign were launched (MSB 2020a). Further activities included the editing of a guide on "individualized fire safety," aimed at providing knowledge to, and guiding professional fire safety efforts toward, particularly vulnerable groups (MSB 2013a). In addition, an initiative on planned home visits was undertaken in 2016 (MSB 2020b). The latter activity was primarily inspired by the extensive home visiting activity in the UK, which is cited as an explanation of the substantial decline in death rates in fires there (Arch and Thurston 2013).

[1]MSB replaced the Swedish Rescue Services Agency in 2009, as a result of the Southeast Asian tsunami disaster in 2004, when more than 500 Swedes lost their lives. The intention was to create a broader national agency on crisis management and preparedness. MSB is the Swedish government's expert authority on fire safety and is responsible under the government for advice and support to the country's municipal rescue services and issues regulations and general advice to individuals and other actors.

Inspired by monitoring and follow-up routines employed in the traffic area in Sweden (Trafikverket 2020), nine indicators for fire safety were also developed (MSB 2013b). Four indicators related to outcomes (number of fatalities and serious injuries in fire per year, number of fully developed residential or fireplace-related fires per year, and societal costs of residential fires per year). The remaining indicators intended to reflect the implementation of fire prevention measures taken by society and individuals (presence of functioning smoke detectors, presence of extinguishing equipment, the proportion of municipalities with developed cooperation in the prevention of residential fires, knowledge of how to act in the event of a fire, awareness of fire risks in the housing environment). All indicators were intended to be regularly monitored, primarily through Rescue Services response records and complementary surveys.

Among these points, the proposed research effort has come to play a particularly important role in further strategic development for Vision Zero, as was envisaged when the proposal was presented in 2010. In 2013, three major research projects on residential fires were supported by MSB, all of them finalized and reported in 2017/18. The projects focused on different aspects related to fire safety, such as death and injury, social patterns, and technical solutions.

The Updated Status of Knowledge; What Is New, and What Are the Implications?

The aforementioned research has shed new light on residential fires in general, on contributing circumstances to deaths and serious injuries, and on the effectiveness of measures considered important for prevention. The research has also increased the awareness of remaining critical knowledge gaps, which consequently need to be addressed in further research efforts.

Residential Fires and How They Are Managed

In 2010, the state of knowledge was mainly based on data from Rescue Services call-out records collected through MSB. There was an awareness that these data might be skewed by underreporting, but in the absence of better data, generalized conclusions were nevertheless drawn on causes and consequences. In 2020, there is now a more complete picture of the total incidence of fire in Swedish homes based on complementary sources, leading to new insights and increased awareness of remaining uncertainties, such as:

There is more clarity on the fact that fires are frequent occurrences in Swedish homes, and that most fires are handled by the residents themselves. The total incidence of residential fires is estimated to be about four times the number to which the Rescue Services are deployed. Residential fires rarely lead to death or serious injury. This reinforces the image that fire outcomes primarily depend on the residents' own capacities.

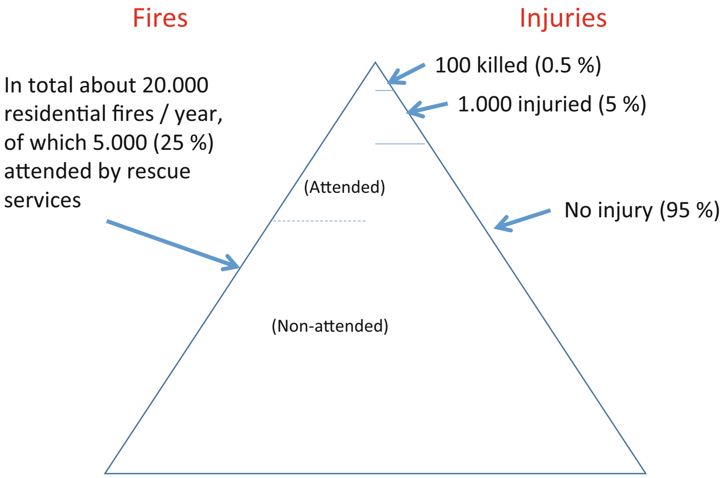

Fig. 1 Proportions between injury outcomes and rescue service attendance in case of residential fires in Sweden (derived from Jonsson 2018a, b)

The interest in creating an overall picture of the property damage caused by the large number of residential fires has increased.

The possibility of drawing conclusions about the causes of residential fires is surrounded by greater uncertainty, as most fires never come to the attention of the Rescue Services and thus are not subject to expert analysis. This also affects the state of knowledge regarding the relative danger of different fire causes, as current data collection does not capture information on the fires that residents handle themselves.

The updated knowledge status is summarized in Fig. 1.

Killed and Injured

One of the more important research efforts on fire fatalities, their circumstances, and the possibilities to assess the true number of fire-related deaths was carried out by Jonsson et al. (2015), by matching data derived from three separate sources. These were the National Board of Health and Welfare's cause of death register, the National Board of Forensic Medicine's register of autopsies, and MSB's fatal fire register. Through this matching, a validated and richer aggregate data set was created. From this work, it was possible to conclude that none of the registers alone gave complete coverage of fire fatalities and that the actual number of deaths was systematically underestimated by 20–25% in MSB's fatal fire register (Jonsson et al. 2015).

The understanding of fire-related deaths has thus developed considerably from 2010 to 2020. Data capturing from multiple sources is now secured, meaning that the previous under-reporting is under control. The statistics are now far more reliable. The importance of medical and social vulnerability among victims emerges more clearly. In the rare cases when a residential fire leads to death (<1%), the cause is usually the inability of the affected individuals to act appropriately in the acute situation, for example, for age reasons or because of illness, disability, or intoxication. There is no clear relation between the magnitude of the fire and the severity of the outcome in terms of death or injury. The majority of fatal fires are limited in size, with the victim most often found in the room of fire origin. Even very limited fires can be deadly for those who cannot help themselves, an insight that shifts the framing of the problem from a previously technically dominated perspective toward a more social one, including housing policy for people with special needs. Smoking, in combination with alcohol consumption, still appears to be a central problem among groups at risk. More in-depth analysis, however, reveals complementary scenarios, such as clothing fires, where influence of alcohol is rare. Medicines can also contribute to reduced alertness and ability in the aging population where prescribed drug consumption often is high (Sessing et al. 2017).

For the seriously injured, the knowledge is still very limited, but data from the national burn clinics, where the most seriously injured are treated, indicate a similar social profile as among deaths (Gustavsson and Nilsen 2018). The average age is slightly lower than among fatalities; on the other hand, a heavier social burden is indicated. In contrast, those with milder injuries and those who escape unharmed do not appear to differ significantly from the population average.

Although the Swedish Vision Zero on fire safety encompasses all types of fires, the policy has in practice been restricted to unintentional residential fires. While a clear majority (about 70%) of all fire deaths in Sweden result from such fires, a considerable proportion also relates to non-residential and intentional fires. For instance, around 10% result from post-crash fires in vehicles, and about 13% relate to intentional fires, mostly suicide (Jonsson et al. 2017). More study of this group is needed; currently no central measures to counteract these deaths or injuries appear to have been implemented, although some local Rescue Services in recent years have activated themselves in the field of suicide prevention (MSB 2009). It is important that future strategical developments also incorporate considerations on non-residential and intentional fires.

The toxicity of fire gases is the most critical factor from a survival point of view (Stec and Hull 2016). The majority of fatalities now die from poisoning (Purser 2010). In addition, toxicity contributes by incapacitating the victim before death occurs. The incapacitation process is comparatively less well studied in the published literature. Given that fire gases usually contain a mixture of very potent toxic gases such as cyanide and carbon monoxide, it is, however, reasonable to assume rapid impacts in those who cannot immediately escape the room of origin.

Fatalities and property losses from fires represent separate problems and should be understood from separate points of view. Deaths are caused by medical impacts on living organisms by the fire's by-products: gases and heat. Property damage, such as structural damage to buildings, is mainly caused directly by the oxidation process of the fire itself. Some property damage also results from smoke or extinguishing materials such as water. Costlier property damage is often caused by larger fires, while most fatal fires are limited in size. Deaths usually occur in the initial phase of the fire, while property damage culminates later as the fire grows in intensity. Thus, measures to prevent lives will also reduce the risk of property damage.

Effectiveness of Measures

In 2010, smoke detectors were highlighted as the single most important measure to improve safety. Ten years later, there is an increased awareness of the limitations of the effectiveness of smoke detectors in relation to vulnerable risk groups, with accompanying requirements for complementary individual and needs-adapted measures (Runefors 2020a). These include technical equipment such as detector-activated sprinkler systems, but also social initiatives such as the provision of adapted housing for those with special needs, meeting higher safety standards. The latter, in turn, raises a broader perspective on fire safety, including more factors and actors than originally considered.

Smoking is a leading source of ignition as regards fatal fires. Therefore, there were considerable expectations for the so-called self-extinguishing cigarettes as introduced in both the USA and the EU around 2010. The cigarettes were designed to stop glowing when left without active smoking. However, studies have shown that the cigarettes do not seem to fulfill this criterion in practice (Bonander et al. 2015), and that the testing method poorly reproduces real situations (Larsson and Bergstrand 2015).

A particular problem is the extensive introduction of various types of artificial materials in buildings, including dwellings, since the 1950s. Different plastic materials with the potential to emit highly toxic gases are present in many interior products and finishes (Seo and Son 2015). Energetic petroleum-based polyurethane foam has largely replaced natural materials in furniture upholstery. The above developments have led to the presence of significantly more flammable material in larger volumes inside an average dwelling. This has significantly shortened the time until very high temperatures (flash-over) are reached and also leads to a faster release of combustion gases with very high toxicity (Kerber 2012; Blomqvist 2005). The problem has been understood for a long time, and early attempts were made to counteract this by the addition of flame retardants. However, these agents, usually bromine compounds, have serious environmental and health effects and are in many countries banned or on the verge of being phased out (Chivas et al. 2009). Research to find environmentally acceptable alternative solutions are underway (Brandforsk 2019).

The Rescue Services annually rescue a number of people who would otherwise have died (Runefors 2020b). However, the ability to save more lives is strongly limited by their response time (Jaldell 2017). In practice, few can be reached as quickly as would be needed for rescue operations to be considered a reliable safeguard for those who cannot help themselves in case of a fire at home. Swedish standards for fire protection in dwellings still presuppose that residents can evacuate on their own (Boverket 2019). Yet those rescued by Rescue Services are, on average, younger, more often cohabiting, and more commonly found in spaces other than the room of origin as compared to those who die (Runefors 2020a, b). The gender balance is also more even. Those rescued generally seem more capable than those who die, perhaps by being able to move to a safer space while awaiting assistance. Trials with complementary semi-professional or volunteer response resources, which may arrive at the scene earlier than the Rescue Services, show some potential to increase the ability to rescue and thereby increase survival (Sund and Jaldell 2018).

Knowledge Gaps and Innovation Needs

Besides generating new knowledge that can be directly utilized in prevention work, research also helps to increase awareness on remaining knowledge gaps. As the research front moves forward, new issues are identified whose importance may earlier not have been fully understood.

For example, since most residential fires remain unattended by the Rescue Services, there is still insufficient knowledge about the total incidence of fire in Swedish homes, typical patterns and details of unattended fires, and how these fires are normally handled. It emerges now more clearly that death and serious injury from fire are among the exceptions, while the typical situation is that most fires are controlled by the residents themselves without serious consequences. This underlines the need for a wider comprehension of residential fires to better understand under which specific and exceptional circumstances a fire leads to serious consequences. In-depth studies and learning processes on fires with fatal or seriously outcomes need to focus more intensely on such specific conditions.

Further knowledge is also needed on the conditions that facilitate the successful rescuing of people who would otherwise die in life-threatening fire situations. The abovementioned circumstances, as indicated by Runefors (Runefors 2020a, b) and Sund and Jaldell (2018), need to be explored in more detail.

Those who incur serious injuries remain to be studied with the same depth and breadth as those who die. Some similarities are already indicated between the two groups. However, the fact that people in this group survived suggests that there may be significant differences as well, carrying potential information on protective factors critical for survival.

The knowledge is still sparse on the physiological effects of toxic fire gases. This knowledge is crucial for the understanding of the time available for rescuing helpless persons left in the room of origin, as well as the mechanisms and speed of incapacitation of the victim.

The contribution of pre-hospital and hospital care to reducing mortality and injury severity associated with fire needs to be further studied. Proper care of a seriously injured person at the fire scene and during transportation, such as adequate antidote treatment and breathing support, as well as the quality of the subsequent specialist care, is often crucial for survival and successful restoration. In contrast, incorrect pre-hospital diagnosis and treatment can further aggravate the harm.

The role and measures of the Rescue Services should be studied in a broader context. The social dimension of the residential fire problem calls for more extensive involvement from other societal actors to take the preventative work forward. At the same time, studies show that Rescue Services can make very cost-effective efforts outside their core area, for example, in cases of sudden cardiac arrest. The vulnerable target group identified here is surrounded by several other parallel risk and insecurity issues at home, all of them originating from similar vulnerability circumstances linked to age, ill-health, and disability. The time seems ripe to seriously explore broader models of cooperation around the wider risk spectrum shared across sectors.

Trends and Implications

In 2010, an aging population, combined with an increasing proportion of elderly remaining living at home, was assumed to pose the risk of a significant increase in the number of people dying in fire. Also, social and economic factors were judged to contribute to the risk of death, which called for actions targeting particularly vulnerable groups. Alcohol and drug prevention was also considered an essential part of fire safety work. These judgments remain in 2020 with increased weight. In addition, the knowledge of ethnicity as a possible contributing factor was in 2010 seen as necessary to strengthen. This assessment no longer seems as relevant, as additional studies do not support the assumption that an immigrant background is a significant risk factor for fire mortality. On the other hand, there has been rapid technology development that was not really predicted in 2010, but which in 2020 appears worrying from a fire safety point of view. Digitalization has led to a sharp increase in rechargeable electrical products in living environments. An increase in fire problems can also be foreseen due to the transition to a fossil-free society. This development is expected to lead to increased multi-dwelling construction in wooden materials, a sharp increase in rechargeable electric vehicles, local electricity production via solar cells and storage in lithium-ion batteries with a high energy content (Andersson et al. 2019).

Finally, the new state of knowledge brings new policy implications that need further study and development. These include housing policy, social services, home-based health care, and how society generally should provide safe, secure, and attractive housing for a growing elderly population, and other groups with limited abilities in the event of fire. What is the potential for initiatives such as changes in housing policy, a broadened content in social needs assessments, and home visits? What support in the form of amended legislation, directives, and resource allocation is needed to promote a more extensive and intensified development of societal fire safety? Preventative and Vision Zero approaches from adjacent areas suggest a need for a broader systemic approach to housing risks, in line with the principles adopted in traffic and occupational safety, where responsibility for safe conditions is seen to rest with several actors in cooperation.

Continued Strategic Development Work

The richer state of knowledge gained from research has created incentives for renewed strategical initiatives based on science rather than traditional experiential learning. First up was the Swedish Fire Protection Association (SFPA), a nonprofit organization working for “A fire safer Sweden.” SFPA is supported by a number of stakeholders in the field of fire safety, such as the insurance industry, and works with standard development, knowledge dissemination, and advocacy in the fire field. A parallel strategic update has been initiated by MSB. This work is ongoing at the time of writing, which means that we here limit ourselves to summarizing what we perceive as broader achievements and considerations that generally influence both processes.

One such insight concerns the need for a more comprehensive "systems" approach to the problem of residential fires, as indicated above. It is becoming increasingly clear that the risk of being killed or seriously injured in fire is due to several interlocking factors, which in turn link back to the responsibilities of many different actors. Another overall insight concerns the need for a systematized collaborative approach across sectors regarding all these factors and actors toward the Vision Zero targets.

An interesting model for describing and analyzing the possibilities of controlling a system, in this case reviewing the potential of a Vision Zero strategy, is the so-called GMOC model. GMOC is an acronym that stands for Goal, Model, Observability, and Controllability. According to general control theory (Kalman 1959), four criteria represent prerequisites for controlling any system. Although control theory is mainly focused on automated systems, GMOC has found applications in fields such as human decision-making and human-machine interaction (Tschirner 2015).

The four criteria include:

G: The need for an objective – the Goal criterion
M: The need for a model of the system – the Model criterion
O: Possibilities to determine the current states of the system – the Observability criterion
C: Opportunities to influence these states – the Controllability criterion

The goal criterion is about defining what is to be achieved; in this case, fewer deaths and serious injuries from fire. The goal should be directed toward the adverse end outcome (e.g., deaths and serious injuries) instead of focusing on single upstreams exposures or determinants (e.g., fire occurrence). There are many examples of the latter kind of policies that prove ineffective because they are based on simplistic and sometimes erroneous notions on cause-effect relations, such as zero tolerance on drug use to prevent drug-related mortality, to mention one.

The model criterion relates to the need for a commonly shared view of what the "system" looks like, who designs it, what it is aimed for, the relationship between inputs and outputs, and why, in certain circumstances, it also entails risks for its users. In this case, it is reasonable to consider housing as a system. The primary purpose of housing is to provide shelter and security for its users. Unfortunately, however, housing is also the arena where most injuries occur. It is necessary for the sake of prevention to identify significant circumstances contributing to these injuries and subject them to intervention with the involvement of those actors which directly or indirectly determine the related risks.

The observability criterion means that relevant system states and dynamics can be monitored over time by valid measures and indicators. If the goal is to reduce the number of deaths and serious injuries, monitoring procedures for these variables must be ensured to identify actual states and to follow and evaluate progress in the preventive work. The same applies to different determinants of need to influence, for example, smoking and alcohol habits, the presence of smoke detectors, the proportion of single residents, the proportion of residents with disabilities, etc.

The controllability criterion refers to the need for a preventative "toolbox," that is, access to evidence-based methods with credible ability to influence the outcomes targeted for change. If adequate tools are lacking, it does not matter how well a system is defined, and its mechanisms and determinants are modeled and understood. There is still no ability to influence the outcome of interest.

To the controllability criterion, we wish to add an aspect highlighted in the literature on "governance" on how to develop systematic societal control of broad and complex problems affecting several societal sectors (Hedlund and Montin 2008). It is not enough that control is technically possible; there must also be a governing system in place that ensures policy implementation. To a large extent, this is about providing policymakers and stakeholders at different levels of the system with the necessary information and ensuring their mandates and resources. Communication and feedback vital for a proactive safety control include objectives, priorities, actual status in relation to objectives, and awareness among involved actors of the potential safety effects of their decisions. A proactive governance strategy should aim at defining the boundaries of safe performance, making these boundaries visible to decision-makers, and counteracting pressures that drive decisions toward the boundaries (Rasmussen and Svedung 2007).

Table 1 represents an attempt to review the current fire safety work by employing the GMOC model's criteria. As can be seen, a great deal of work remains to be done before even elementary system control possibilities can be said to be in place concerning the prevention of deaths and serious injuries from fire.

Table 1 Illustration of prerequisites for systems control and actual status regarding fatal and serious injuries from residential fires

Criteria	Fatalities	Serious injuries
Vision/goal	Established by MSB at agency level	Ditto
Observability/ status monitoring	Ongoing data collection and analysis with good quality	Inclusion criteria and monitoring routines are still lacking
Model	Good problem comprehension on groups at risk, injury mechanisms, and significant risk- and protective factors from recent research The broader system including related actors remains to be modeled	Weak problem comprehension due to lack of research. Injury etiology largely unknown
Controllability/ governance	Major limitations: Lack of effective measures Lack of governing system Obsolete legislation Lack of political support	Ditto

The preconditions for a well-founded prevention strategy are undoubtedly better regarding fatalities, with adequate status monitoring and a growing understanding of relevant mechanisms and determinants (the model criterion). However, there is still reason for skepticism on effectiveness and success when it comes to the possibility of influencing the problem. The main obstacle is the lack of a politically supported governance system across sector boundaries, as many of the determinants, such as medical and social, lie outside the mandate of the expert authority itself (MSB).

In the case of non-fatally injured persons, primarily those seriously injured as are explicitly addressed in the vision zero policy on fire safety, the basic conditions for systems control are still largely lacking. There is no regular monitoring routine in place, leaving the knowledge-base for this group relatively unclear, including related determinants and potentially effective countermeasures. The lack of a national cross-sectoral governance system characterizes this category as well.

The same applies even more to property damage. However, as this aspect of the problem falls outside the objective of the Vision Zero policy on fire, it is not further commented on here.

This presents several fundamental challenges for the continued Vision Zero work on fire safety.

The provision of basic statistics and the use thereof need to be significantly developed, especially concerning serious injuries. Major determinants of deaths and serious injuries from fire should be monitored and followed up on a regular basis as well.

The modeling work needs to be intensified. Actors having an impact on housing safety need to be identified on a broader scale and assigned roles and responsibilities in the collective fire safety work. It is also crucial that the injuring process itself (corresponding to the impact from crash violence in traffic) is modeled to increase the understanding of the time interval for action that is available to a person left in the room of origin in the event of a fire. This knowledge is crucial for proper system measures aimed at improving the individual's chance to self-evacuate and the potential success of external rescue operations.

The "toolbox" needs further improvements with new and innovative methods of fire prevention, such as detection, alarming, extinguishing, evacuation, and rescuing. Not least, new forms of housing need to be considered for those who, despite supportive efforts in regular homes, are at risk of acute danger in the event of a trivial fire incident.

Societal governance in the fire safety area needs to be fundamentally upgraded. Like the traffic safety model, the Vision Zero policy for fire safety needs clear support from the top political level, mandating a national body to coordinate the work across sectors, and an obligation for other sectors concerned to participate in the work. The legislation needs to be reformed, supporting such a broadening of the fire safety work, including its approach to liability.

All these steps need to be underpinned by continued knowledge development and innovation. Research and prevention need increasingly to take the medical and social dimensions of the problem into account.

Conclusions and Future Work

Each risk area is unique in terms of context, typical sequences of events, and possible consequences. Therefore, it is not possible to merely copy models and measures from one area to another. On the other hand, there are often parallels allowing some generic lessons to be transferred, not least in terms of general procedures and approaches in safety work. Here, with the fire area as an example, we wish to discuss some more universal lessons learned on Vision Zero work in areas where essential conditions for systematic societal governance may remain weak. In such situations, we claim, the focus must be on establishing these conditions.

Fire and traffic share the feature that both areas entail injuries and deaths. In traffic, it is mainly the crash violence that harms and kills, while in the case of fire, the corresponding mechanisms are the exposure to heat and combustion gases. It has taken decades of research and development in the field of traffic to reach consensus on the crucial importance of controlling crash violence as a core strategy to improve road safety. In parallel, there is a persistent narrative on the role of human error. Crash violence is determined by the design of the traffic environment, vehicles, regulations, etc., that is, conditions determined by actors other than road users. The parallel focus on the responsibility of the road user thus tends to become an excuse for dangerously designed traffic environments and vehicles. The Vision Zero in road traffic can be said to represent the visible result of a paradigm shift in which policy-makers have decided to partly reverse the division of responsibilities: "responsibility for road safety is shared between those who design and those who use the transport system. The ultimate responsibility for safety rests with the designers" (Swedish Government 1997). Underlying this statement on the overall responsibility of system designers is a judgment that to err is human and that the transport system, therefore, needs to be designed in a way that compensates as far as possible for simple mistakes that anyone can make. The traditional idea of the individual's primary responsibility can thus be said to be abandoned in the current theory and practice of road safety work, even though this view is still apparent in legislation and law enforcement practices.

For the Swedish fire safety work, the Vision Zero policy on traffic and its indicator-based follow-up system has undoubtedly served as a source of inspiration since the late 1990s. There has been a genuine interest in establishing something similar. However, the analysis of the core contents of the Vision Zero philosophy in the fire area has remained relatively superficial, and the fire sector has not yet been able to take the full step toward a corresponding paradigm shift. The thinking has to a large extent remained inside the existing legal framework and the extensive work done in the field of road safety to identify and involve system designers does not seem to have been fully understood and replicated in fire safety.

There is a persistent narrative on the responsibility of the individual in fire safety as well. This view is reinforced by the fact that fires, in addition to having different injury causes (heat and toxicity), also differ from road accidents in terms of the time available for action while the accident happens. Traffic accidents usually cause instant harm, while hardly anyone is injured at the onset of a fire. A fire takes time to escalate, which means that the individual responsibility is seen as twofold; to ensure that fire does not occur, but also to extinguish or evacuate before the fire becomes critical. Rescue Services' response times are usually not short enough to guarantee safety for residents, which means that fire safety in ordinary homes is considered to rest on the premise that residents themselves are able to act appropriately in the event of a fire (Boverket 2019).

Thus, compared to the traffic area, the broader systems approach is still lacking in the fire area. Consequently, the Swedish vision zero initiative on fire safety cannot be described as a mark of a scientific and practical paradigm shift similar to that in traffic. The situation is therefore reversed in fire safety, leaving a flavor of wishful thinking. Instead of an emerging knowledge base forcing a new groundbreaking policy, the new policy comes first while the scientific foundation has to be constructed afterwards. The reversed approach may seem irrational, but can also be seen as a challenge and an incentive for further research, innovation, and policy development. It is this opportunity we wish to highlight here.

Another difference lies in the prevailing traditional intra-professional culture in the fire area, in contrast to the broader and more cross-sectoral approach of the transport area. Traditional exertion of authority, which characterizes fire safety, mainly consists of regulation and enforcement. The regulations issued, based on existing legislation, usually imply incremental improvements, reflecting traditional mental models of liability, of fire causation, and of measures to be taken. The rules tend to define minimum levels only, following the natural logic of formal rule-based processes. Unless such a process is complemented by initiatives relying on other drivers than compliance and also exploit, for example, the innovative powers of industry, there are reasons to be pessimistic about the potential for more significant changes in trends.

Again, the fire area here should be able to find inspiration from the traffic area's Vision Zero work. Several innovative solutions have been implemented in the road infrastructure, but the major leap in improvement is undoubtedly to be found in technological developments in the automotive sector. These achievements are not a priori driven by legislation, but by consumer demands and competition. Airbags and other safety systems are now standard equipment in every new car. But, for those buying a new villa, often at a cost that exceeds a car's manifold, few or no safety systems against fire or other accidents are included in the standard delivery.

The GMOC model presented above with its four criteria can serve as a theoretical framework for understanding what needs to be in place for a Vision Zero initiative to appear meaningful and practicable. The basics for controlling dynamic systems have been known since the steam engine's introduction in transportation and industry (Maxwell 1868). This theoretical framework has been further developed over time and led to applications in high-tech areas such as aviation, nuclear power production, and space expeditions. Those are areas where high values are at stake, and where all related risks, therefore must be meticulously controlled. These applications are all characterized by interactions between human, technological, and organizational components, so-called sociotechnical systems (Rasmussen and Svedung 2007). The principles have been subsequently disseminated to broader areas of risk management already in the 1970s and 1980s, first to the field of occupational health and safety, with its industrially dominated culture and understanding on issues like organization, reliability, process control, and quality assurance, and then further to areas such as product safety and patient safety. In these areas, risks are commonly understood as the result of an interaction between people, technology, physical environment, and organization where all components contribute and where weaknesses in one element, for example, the human part, can be compensated by other parts of the system. The notion that risks can be systematically controlled is fundamental. The Vision Zero policy in traffic safety was the result of a breakthrough for a systems control approach to traffic safety as well. It became increasingly clear that accidents are not just to blame on road users. Infrastructure, vehicle standards, regulations, etc. play fundamental roles in addition to human behavior. Therefore, road safety also more clearly emerged as controllable by society. The scientific achievements came first, and the policy innovation Vision Zero was prompted as the logical result. The goal criterion could be formulated based on confidence in the possibilities of long-term systems control. The model criterion was already met through a thorough conceptualization of the interaction between road users, traffic environment, vehicle technology, regulations, and monitoring, combined with an in-depth understanding of the crucial importance of crash violence in the severity of outcomes in the event of an accident. Observability was enhanced by improved data collection on outcomes and major determinants (indicators). With broad top-level political support and supervision, better conditions for controllability were created and further strengthened through systematic feedback to the various system sub-designers and other actors involved.

The fire area differs considerably from the aforementioned situation. A Vision Zero policy was launched without a corresponding scientific underpinning that preceded the Vision Zero on traffic. Through the GMOC model, it is possible to identify that more development is needed to establish a controllable system on fire safety, and it is these needs that ongoing strategy work now aims to meet. The goal criterion (no one should die or be seriously injured) remains fanciful as long as data capture on deaths and seriously injured, and evidence of prevalent types of societal interventions, is not secured. Hence, there is still a lack of credibility in both the long-term vision and the milestones set. The model criterion is the weakest point. Housing is a system that is still waiting for its modeling. It should be seen as a socio-technical system in the same way as working life and transportation, with a spectrum of associated risks, including fire. Risk levels in housing are, to a large extent, determined by system designers such as property owners, the construction industry, social services, regulatory designers, licensees, and manufacturers and suppliers of installations and movables. As far as fire is concerned, it is evident that significant responsibilities fall on these different system designers, especially as it is becoming increasingly clear that a growing proportion of residents lack the skills to ensure their fire safety themselves (Nilson et al. 2019). Also, there is a need for more elaborated modeling of the dynamic process of deaths and injuries in case of fire (corresponding to traffic crash violence), and how this process can be affected by different types of interventions. In particular, the time aspect is critical for the dimensioning of rescue functions for residents lacking the ability to evacuate on their own. The observability criterion is linked to the measurement of the variables one wants to modify (numbers of deaths and serious injuries), occurrences and characteristics of residential fires, as well as significant determinants of the problem, such as proportions of elderly people and single residents and disabled people. Finally, the controllability criterion is linked to the possibilities of influencing the problem. The Vision Zero in fire safety is still only adopted formally by the national fire safety agency itself, MSB, not by the parliament or government. MSB has no mandate over other sectors concerned, meaning that the conditions for proper governance of fire safety across sectors are still very limited.

The establishment and acceptance of a vision zero initiative addressing a cross-sectoral problem area must most probably be made at a top policy level to ensure adequate conditions for governance and controllability.

All in all, the Vision Zero initiative on fire safety appears still immature and based on fragmented evidence. Therefore, the ongoing strategy work should be largely focused on creating better conditions for effective governance. The strategy linked to the launch of Vision Zero on fire safety in 2010 reflected the status of knowledge and experience at that time. One crucial insight is the significant knowledge gaps on residential fires, in particular that related to deaths and injuries. An essential component of the strategy was, therefore, to initiate further research. Ten years later, there is now a richer knowledge base in several respects, both in terms of causes and countermeasures, but also on the need for a more comprehensive system approach and a strengthened societal governance approach. These new insights now constitute inputs to the ongoing strategy work described above, forming the next generation of strategy. An essential component of the new strategy, as in the previous version, will be to continue to identify remaining knowledge gaps that need to be addressed in upcoming research and innovation for future generations of strategies. In this way, a Vision Zero initiative can be described as an iterative process where knowledge acquisition and strategy development interact and strategies are continuously refined based on "best practice and knowledge" available at each time. From this view, the "reverse approach" rather appears as a reasonable and rational way of dealing with inspiring role models in parallel fields by formulating challenges for one's own area that accelerates a development that would otherwise have taken much longer.

In light of the above, the main lessons can be concluded as follows:

– Establishing Vision Zero initiatives in new areas where fundamental prerequisites for systematic control and governance are lacking may still appear valuable provided that the Vision Zero approach is used as a challenge to systematically establish the missing preconditions. The GMOC model is a valuable tool in this work.
– Knowledge gaps should never be accepted as an excuse for the lack of strategies. Strategies always need to be developed and updated based on the best knowledge and experience available. On the other hand, these gaps must be subjected to new research and innovation so that what today may seem utopian will tomorrow appear possible, realistic, and affordable. In this way, vision zero work can be

seen as a planned and controlled dynamic process in which strategy and action programming interact with research, development, and innovation.

– Governance takes place in a political context where the scientific rationale often has to be balanced against many other considerations. Vision Zero initiatives must, therefore, enjoy broad political support from a level that is respected among all sectors affected by the vision. The body appointed to lead the work needs strong top-level political support to ensure sustained participation from other actors.
– Governance and cooperation between different actors need to be orchestrated based on a shared understanding of the nature of the problem, its determinants, and the roles and responsibilities of all actors involved. A systems approach is the key to this.

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Vision Zero in Disease Eradication

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Abstract

The eradication of smallpox – the first and so far only human disease to be eradicated – generated a tremendous amount of excitement and attention to the idea of disease eradication and elimination. In the twentieth century alone, smallpox had claimed the lives of more than 300,000,000 people (Sneed A, Scientific American, https://www.scientificamerican.com/article/who-remember-smallpox/, 2014). The last natural case occurred in 1977, almost 200 years after the smallpox vaccine was discovered, and in 1979 the World Health Organization declared that the disease had been eradicated (WHO, Smallpox, World Health Organization. World Health Organization. https://www.who.int/csr/disease/smallpox/en/, 2019c). Most importantly, it demonstrated that eradication was possible; that through the use of science, we could change our future for the better in ways that we had not even dared to think about previously. This achievement also helped to focus attention on clear definitions of disease eradication and elimination. Since then, these definitions have been continuously evolving. In 1993, the International Task Force for Disease Eradication (ITFDE I) defined disease control, elimination, and eradication. With that, they evaluated over 90 potential infectious disease candidates and concluded that six were eradicable. Subsequently in 1997, the Dahlem Workshop focused on the science of eradication and defined a range of public health approaches to infectious diseases from control, to elimination of disease, elimination of infections, eradication, and extinction. Three years later, the second International Task Force for Disease Eradication (ITFDE II) convened in 2000 to review the progress over the past decade.

Inspired by these efforts, we reviewed our own experience and interviewed leaders of several disease eradication and elimination campaigns to identify lessons learned from a variety of disease elimination campaigns including smallpox, polio, Guinea worm, and onchocerciasis. Our aim was to identify lessons that might be applied to road traffic injuries. We identified 12 lessons from these infectious disease campaigns: (1) this is a cause and effect world; (2) know the truth; (3) coalitions are absolutely essential and absolutely hard; (4) avoid certainty (the Achilles heel of science); (5) measure frequently and build in continuous improvement; (6) respect the culture and work *with* the people you are trying to help; (7) the best decisions are based on the best science, but the best results, on the best management; (8) the best solutions move us closer to global health equity; (9) do not underestimate the time, resources, or tenacity it will take succeed; (10) eradication does not always require a vaccine or a cure; (11) start in the most difficult places first; and (12) you don't begin at the end. These concepts from infectious disease campaigns have broader public health applications, and we discuss some of the implications for reducing road traffic injuries.

Keywords

Disease elimination · Disease eradication · Campaigns · Surveillance · Coalitions · Health equity · Continuous improvement · Certainty · Tenacity · Cause and effect · Smallpox lessons

Introduction

The linkage of two visions has changed the world: the eradication of smallpox and the elimination of road traffic deaths, better known as “Vision Zero.” The strategy that ultimately led to the eradication of smallpox was proven effective in 1966, when Dr. William Foege was a medical missionary and faced a smallpox outbreak in Biafra, Nigeria, on the eve of civil war. The conventional response at the time was to vaccinate everyone, but this was impossible due to a vaccine shortage. He directed his team to map the spread of the disease and to vaccinate people only in villages where smallpox had already appeared and in the neighboring areas, forming a protective ring. This novel and efficient “surveillance and containment” strategy worked. Six months after the first case had appeared, no new cases were reported in eastern Nigeria. Working in relative isolation, Foege’s team developed the strategy that would eventually lead to global eradication.

In 1973, Dr. Foege, the then director of the Smallpox Eradication Program at the US Centers for Disease Control and Prevention, responded to a plea from the World Health Organization to assist them in India. For years, the Indian government, with the assistance of many outside organizations, tried to control smallpox through mass immunization. But the country’s size and enormous population, as well as the difficulty of reaching people in remote areas, had frustrated their efforts.

Working directly with government leaders, Dr. Foege helped develop a sense of urgency for addressing the disease and mobilized funding support from industries that had been affected by smallpox. He helped convince India leaders to shift from the unsuccessful mass vaccination approach to a containment strategy and then skillfully guided the surveillance and containment efforts. He knew success depended on motivating thousands of highly dispersed workers to map the incidence of the disease in more than 700,000 villages and to quickly contain the threat (Rosenberg et al. 2010). Putting his own life at risk, he carried millions of rupees in his briefcase to ensure that health workers received their salaries and stayed on the job and rode the trains across the country to keep morale among workers high until its clear eradication would be achieved.

Although the CDC encouraged Dr. Foege to stay until no new cases were reported, he purposely left India before the country was free of smallpox so the credit would not go to him. He felt that Indian officials and public health workers deserved the credit for the remarkable work they had done, and the recognition would motivate them to continue to work hard in the public interest. India went from 87,000 cases of smallpox in 1973 – more than any other country – to no cases at all in the spring of 1975 (Rosenberg et al. 2010).

This success led global health experts to believe they might achieve something that had never been achieved before: the actual eradication of a disease from every single country on the planet. In 1979, through the efforts of healthcare workers and experts across the world, the WHO did, in fact, declare smallpox eradicated (WHO 2019c). A disease that had killed millions of people had been driven from the face of the earth. This extraordinary success in smallpox eradication generated optimism and enthusiasm for eradication efforts for polio and Guinea worm. Both campaigns have made great strides, and these diseases are within reach of eradication today.

The success of smallpox eradication elicited inspiration beyond the infectious disease realm of public health. It inspired the Swedish Transport Administration to dare to declare that road traffic deaths could be completely eliminated. More than 30 years ago, the Swedish Transport Administration had to decide whether to aim for a 10% decrease in road traffic deaths or to do something bolder – something that would mobilize the energy, enthusiasm, and resources of the road safety sector, as well as public support and political will. The agency proposed the bold aim to eliminate all road traffic deaths in Sweden, to aim for Vision Zero (Ministry of Transport and Communications 1997). They saw that road traffic deaths are not a fact of life, nor are they the price we must pay for mobility in the modern world. Vision Zero's goal of no deaths on the road, combined with the dedicated leadership of Sweden, showed the world that this is not only a goal for which we should aim but also one that is possible through evidence-based interventions.

The Swedish Transport Administration helped to develop the Vision Zero policy, the goal of which was a road transport system free of death and serious injury resulting from road crashes. Designing safer roads was key to protecting road users from human error. One of their advances, for example, included substituting roundabouts for red lights at intersections, bringing the death rate down by 90% at these intersections (Robinson et al. 2000; WSDOT 2020). Vision Zero was subsequently presented in 1995 and adopted by the Swedish Parliament in 1997 (Ministry of Transport and Communications 1997; Larsson et al. 2010), sparking a movement of similar legislation in cities and countries around the world. In addition to the push behind the radical target of elimination rather than just a small risk reduction, Dr. Tingvall was essential in translating policy into practice, engaging stakeholders from private, public, and governmental sectors to work together.

Success in both safety and health can be represented by the idea of zero, whether that zero stands for zero deaths from disease or crashes or zero illnesses or injuries or collisions. We believe that there are important lessons to be learned from the history of infectious disease eradication and elimination efforts, lessons that might be applied to the field of road safety and beyond. With this in mind, we interviewed a number of disease eradication experts to hear what they thought were the most important lessons from the campaigns that they had worked on. We interviewed Drs. Walt Dowdle, Eric Ottesen, William Foege, and Don Hopkins. They shared with us lessons and stories of extraordinary work, extraordinary workers, and extraordinary numbers. We also added some of the most important lessons we had learned from our experience working with coalitions to address disease elimination and eradication campaigns. This chapter aims to share some of these lessons with the hope that these lessons can be applied, not only to future disease elimination campaigns but to the pursuit of reducing road traffic fatalities to zero, to making Vision Zero a reality.

Part I: Clarifying the Definitions of Disease Control, Elimination, and Eradication

The first and so far only human disease to be eradicated is smallpox (WHO 2019c). When this occurred in 1979, not a lot of attention had been given to strict definitions of disease eradication and elimination. Since then these definitions have been continuously evolving.

The International Task Force for Disease Eradication (ITFDE I) came together in 1993 to define these three previously ambiguous words: eradication, elimination, and control (Cochi and Dowdle 2011). They evaluated over ninety potential infectious diseases and six were concluded to be *eradicable*: dracunculiasis Guinea worm), poliomyelitis, lymphatic filariasis, mumps, rubella, and taeniasis/cysticercosis. Further seven conditions – including one noninfectious disease – were considered *eliminable*: hepatitis B, iodine deficiency disorders, neonatal tetanus, onchocerciasis, rabies, trachoma, and yaws (Centers for Disease Control 1993).

After much reflection and discussion, they defined eradication to be the worldwide achievement of obviating the need for further control measures. In contrast, elimination involves control of the manifestations of a disease such that the disease is no longer considered "a public health problem" within a specific region. Yet, this is a fairly vague term that may not be useful to those working on the problem.

In 1997, the Dahlem Workshop on the Eradication of Infectious Disease convened to further consider the biological and epidemiological factors of infectious diseases that are susceptible to eradication (Cochi and Dowdle 2011). The principal change to the previous set of definitions was the clearer distinction between the types of elimination and the addition of extinction. The definitions are (Cochi and Dowdle 2011):

Control – the reduction of disease incidence, prevalence, morbidity, and mortality to acceptable levels

Elimination of disease – the reduction to zero incidences of disease in a defined geographic area

Elimination of infection – the reduction to zero incidences of infection caused by a specific agent in a defined geographic area

Eradication – the permanent reduction to zero worldwide incidences of infection caused by a specific agent

Extinction – achieved once the specific agent no longer exists in nature or the laboratory

Over time, attitudes toward the feasibility and relevance of extinction of pathogens changed. Reasons for the shift in attitudes include the thought that in post-eradication, certain pathogens would inadvertently become potential bioterror agents if routine immunization and surveillance were discontinued. This is supported by the inability to account for all stocks and specimens containing pathogens, as well as the sophistication of modern genomics and molecular biology techniques which now allow for in vitro synthesis of infective agents (e.g., poliovirus) (Cochi and Dowdle 2011).

A second International Task Force for Disease Eradication (ITFDE II) was constituted in November 2000 to assess the progress over the past decade and to review the potential eradicability of the previously selected infectious diseases (Cochi and Dowdle 2011). While the definitions remained unchanged, measles was added to the list of possible diseases for eradication. The most recent meeting evaluating the definition and disease considered to be eradicable or eliminable took place in Frankfurt in August 2010 (Cochi and Dowdle 2011).

Aside from the official set of eradication and elimination definitions, some find other renditions to be clearer. Walt Dowdle, for example, finds:

> the terms national, regional, and global eradication [to be] much more powerful and meaningful than 'elimination'. Moving from national to regional to global eradication is a logical and defensible progression. Moving from "elimination" to "eradication" means crossing a huge, but artificial, barrier. (Dowdle, W. Interview by Mark Rosenberg, 2014)

Similarly, Dr. Foege suggested the use of global eradication, national eradication, and personal eradication (Foege, W. Interview by Mark Rosenberg, 2014). Clarity is necessary, yet it remains important not to become fixated to the point of inaction.

Part II: Twelve Lessons from Infectious Disease Campaigns

These 12 lessons were gleaned from our own experience and from conversations with leaders involved in past and current eradication and elimination campaigns. The lessons are not meant to be prescriptive. In fact, many – if not most – of the lessons learned became more apparent in retrospect than they were at the time the campaigns were initiated. As Walt Dowdle pointed out, "you never know until you get there" (Dowdle, W. Interview by Mark Rosenberg, 2014).

Lesson 1: This Is a Cause and Effect World

If We Understand the Causes, We Have a Chance to Change the Effects

We can use science to understand the causes, and if we understand the causes, we can intervene to improve the outcomes. Using the scientific method means that we look at the evidence and that we assess the evidence and use it to answer four basic questions:

1. What is the problem?
2. What are the causes?
3. What works to prevent this?
4. How do we do it or implement it?

Seeing that disease eradication is even possible helped us to set new targets that we had never before dared to declare. Knowing that this is a cause and effect world also helps us appreciate the idea of agency. Diseases do not disappear by chance. Disease eradication does not happen by chance. None of these things *just* happen – they happen because someone has set an objective saying we *want* it to happen. They happened because time, energy, and lifework are dedicated to achieving the goal.

A belief in cause and effect also brings about activism and optimism. Thus, if we understand the science, it is cause for optimism because it means we *can* change things in this world and change them for the better. For the first time, eradication meant that we can aim for and hope to achieve reductions in disease levels that we rarely thought possible before.

Science – both biological science and social science – can help us understand the conditions that are necessary for a disease to be eradicable. The conditions are different for elimination but those, too, can be defined. The ITFDE identified three groups of factors that determine the conditions and possible success of a disease eradication or elimination program (Hopkins 2013):

1. **Scientific feasibility** – The factors affecting scientific feasibility include epidemiological vulnerability of the disease; availability of effective and practical interventions; the lack of an animal reservoir for the disease; and demonstrating successful elimination of the disease in a particular area. Other factors include the cost-effectiveness of eradication versus elimination or control programs; benefits of eradication in terms of reducing morbidity and mortality compared to other health interventions; the ability to coordinate with other health programs; and the potential effects of control programs on the health system.

   For smallpox this meant that there was a proven effective vaccine with an easy means of administering it. Although vaccine standards were not initially in place when the final push toward eradication was begun, they were subsequently developed; infected individuals were easily detected because of their multiple blisters, fever, and malaise; people who were immune were visibly marked by multiple scars left by the disease or a single scar at the site of their vaccination. There were also no latent infections beyond a 2-week incubation period and no animal reservoir, and the virus could not survive in the environment.
2. **Political will/popular support** – Societal and political commitment is essential, as well as the capacity for financial, managerial, and technical support. Disease eradication programs should not bypass or compromise existing health systems and attempts should be made to expand benefits to health services beyond the limited impact of eradicating the target disease. The government must commit support with a willingness to sustain the effort until the campaign has been successful.
3. **Sufficient resources** – Eradication, elimination, and disease control campaigns require resources. As such, ensuring sufficient resources lined up or a plan to get the resources necessary for the job is key. Mobilization of adequate resources may require clarifying the perceived burden of the disease, not only including the number of deaths but also the number of persons affected and how they are

affected during the acute and subsequent phases; this includes but is not limited to the long-term disabilities, stigma, and mental health impact. It is rare that the true burden of a disease is accurately perceived. This total burden of disease suggests the benefits expected to accrue from eradication. The distribution of the costs and potential benefits among the population is relevant to both rich and poor countries.

It is also valuable to quantify the expected cost of eradication, especially in relation to the perceived burden of the disease. There may also be a synergy of eradication efforts with other interventions that should be noted. And finally, the accumulation of costs and benefits over a relevant time period should be taken into account. In the case of smallpox eradication, the smallpox vaccine was inexpensive and donated free of charge to the program by the Russians (Henderson 2009; Hotez 2017). It could be administered in a single dose that seemed to produce protection from the disease.

Lesson 2: Know the Truth

Knowing the truth first requires us to understand the problem. This is the lesson of the saying sometimes – but without proof – attributed to Albert Einstein: “If I had only one hour to save the world, I would spend fifty-five minutes defining the problem, and only five minutes finding the solution” (Einstein quote). For Foege, knowing the truth means knowing “the state of things—in the real world, honestly. You need to know your enemy. In the case of smallpox, you needed to know the disease and where the virus was. You needed to be able to pinpoint its positions at any one time”. Organizations have resources, cache, and networks that can be used to address many types of public health programs. For public health, this means surveillance. As Foege shared, “Surveillance is intelligence gathering and it should be complete, accurate, and honest” (Foege, W. Interview by Mark Rosenberg, 2014). Our experience with smallpox and polio eradication efforts furthered our understanding of surveillance – both as to how crucial it is and how it should be done. In turn, strengthening our surveillance systems allowed us to identify, understand, and define new strategies against diseases that not been adequately controlled in the past.

Continuous Reassessment Has Collateral Benefits

Surveillance systems, in addition to requiring continuous evaluation and improvement, also require indefinite replacement in order to detect the possibility of future disease recurrence. This requires ongoing data collection, analysis, and response. This has the additional benefit of creating a system that may have the additional ability to detect other infectious and noninfectious problems. For example, the surveillance system established by the polio program became the major source of surveillance for the Guinea worm eradication campaign (WHO 2014), and this same system was later used in efforts to control Ebola.

The Closer You Get to Elimination, the Closer You Have to Look; the Closer You Look, the More You See

The story of polio eradication also taught us that what we surveil, even for the same disease, constantly changes. For example, when the polio vaccine was first developed and deployed, public health personnel thought that since the disease produced by polio was an acute flaccid paralysis (AFP), it would be easy to count the cases of polio by looking for cases of AFP. The effectiveness of vaccination campaigns could then be monitored by looking for all cases of AFP and seeing if the number of these cases was going up or going down. While there were other causes of AFP – usually due to other types of viral infections – these were rare in comparison to the cases of AFP due to poliovirus. As such, the overall number of cases of AFP was indeed a good indicator for tracking the success of the polio vaccination programs. However, once a large number of children had been vaccinated in a particular area and the number of cases of AFP caused by the poliovirus was markedly decreased, the percentage of acute flaccid paralysis due to the other previously "rare" viruses became significant. At this point, AFP was no longer a useful indicator of infection by poliovirus. Here a new lesson became clear: *the closer you get to elimination, the closer you have to look*.

Scientists now had to look for evidence of poliovirus infection by testing each case of AFP for evidence of infection. As scientists looked more closely, they found significant numbers of persons infected with the poliovirus, but without AFP. The prevalence of asymptomatic carriers meant that surveillance now had to be looking for the virus itself. That, too, was not enough, as it also turned out that the virus is excreted in feces and could survive in sewage. Now environmental sampling of sewage was needed to know that the poliovirus was not lurking in a given area where individuals could be infected. Another lesson gave rise: *the closer you look, the more you see*.

It turned out that not only did the poliovirus live in sewage, or in contaminated fecal samples that might be stored in a laboratory, but some types of live viruses used in vaccines could actually mutate and revert to virulent viruses that could actually cause the disease – creating a new subset of now-monitored disease, vaccine-derived poliovirus cases. This ultimately led to changes in the formulation of the vaccines, with the hope that if only killed viruses were used in the vaccine, they would no longer be capable of mutating and causing disease. More experience keeps leading to new insights and improved strategies. The endgame of this eradication campaign gets more and more complicated and difficult as we get closer to eradication and learn more and more about the virus and vaccines.

Surveillance Is Useful for Tracking More Than Just the Number of Cases

In the case of vaccinating populations against smallpox or treating large populations with drugs to treat and prevent the neglected tropical diseases, it also became clear that surveillance was necessary at many different stages. Initially, surveillance was focused on searching for cases. But after that it was necessary to do surveillance to track the population that had been vaccinated or treated. Surveillance also provided the epidemiologic data to define risk groups, to assess the effectiveness of vaccine or preventive treatments, to monitor adverse events, and to assess the effectiveness of different treatments and interventions.

Be Open and Honest with Your Data Even When That Might Be Risky

It is important to know the truth even when there is a risk that it might endanger your campaign. Information collected has also been used to undermine a public health campaign. When Dr. Foege first arrived in India to help oversee the smallpox eradication efforts, he saw that mass vaccination, the traditional smallpox strategy, was not working. Despite the best efforts of the Indian government, they could not vaccinate everyone and could therefore not achieve complete coverage of the population. There would always be susceptibles and enough of them to keep the disease going. Foege switched the strategy to one that would (1) focus on places where there were active outbreaks of smallpox and (2) vaccinate everyone in those areas. They would contain the population of towns and villages where there was active smallpox and not let anyone leave until everyone had been vaccinated. If anyone had been exposed to smallpox and then left, they would go find them, bring them back, and vaccinate that person and all of their contacts. People would be "contained" in these areas for 30 days until either they became sick and recovered or died or until they had been vaccinated and became immune. This was called the "containment strategy" (Foege 2011). Applying this containment strategy also meant that active and thorough surveillance was needed to identify every town or village with an active case of smallpox. For it was in these places that the containment strategy would have to be applied. But after only several months of applying the containment strategy, the Minister of Health (MoH) for the Indian state of Bihar went to Dr. Foege and wanted to stop the containment approach (ibid.). This would have to be stopped, the minister declared. This alarmed Foege who then asked the minister "why?" The minister replied that when Dr. Foege had arrived, when the containment program began, there were 85,000 known cases. Now, he said, the improved surveillance showed there were 125,000 cases (ibid.). "Clearly," the MoH said, "your strategy is making the problem worse and you will have to stop it" (ibid.). Fortunately, they were allowed 30 more days to turn the problem around, and in that time the containment strategy was working, and the numbers started heading down.

Establish a Very Clear Goal and a Mechanism to Certify That You Have Reached It

Surveillance is also needed to confirm that an eradication or elimination goal has been achieved. This demands precise definitions and clarification of the program goals and a degree of rigor. An important mechanism for certifying that the elimination or eradication goal has been reached is the appointment of an independent commission that is able to collect credible and accurate information and can then certify that the goal has been achieved.

To date, 156 cases of wild poliovirus were reported in 2019, 128 of which were within Pakistan and the remaining 28 within Afghanistan. Nigeria, the third and only remaining polio-endemic country – in addition to Pakistan and Afghanistan – has the

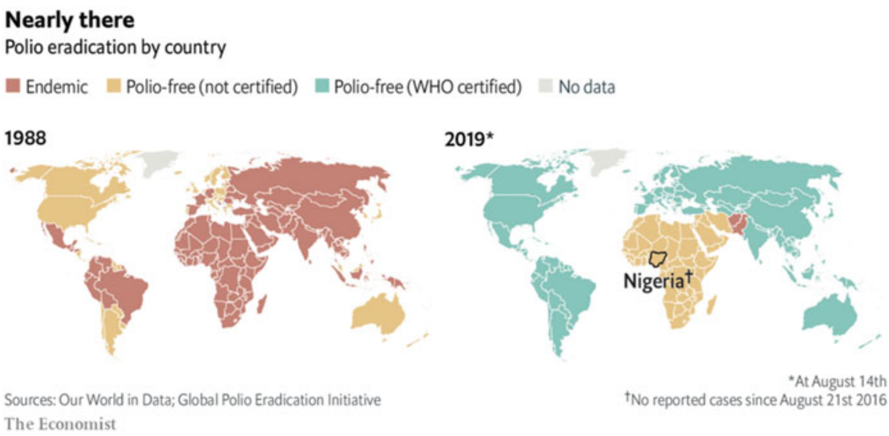

Fig. 1 Economist (updated August 21, 2019)

possibility of being certified polio-free in 2020. While circulating vaccine-derived poliovirus remains to be a challenge, with 249 cases reported in 2019, it is estimated that over 1.5 million lives have been saved and 16 million cases of paralysis averted since the onset of the polio eradication initiative in 1988 (Global Polio Eradication Initiative 2020) (Fig. 1).

Lesson 3: Coalitions Are Absolutely Essential and Absolutely Hard

The possibility of eradication rests on the ability to bring multiple stakeholders together; in effect, the ability to form a coalition. Indeed, solving any large-scale global health problem today requires effective coalitions. And effective coalitions require the following: (1) a clear, overriding common goal; (2) a strategy for achieving that goal; (3) a structure for the coalition; (4) defined membership; and (5) effective management of both meetings and programs. Without these, coalitions will fail. In fact, most coalitions do fail to achieve their goals. A coalition is like a marriage: it is very easy to get into it but very hard to make it work. Obstacles (and opportunities) occur at every level: global, multinational agencies, regions, countries, and communities. And these obstacles to effective collaboration abound. James Austin, Harvard Business School Professor Emeritus, characterized them as the seven C's and we have added the eighth C, conflict (Austin 2000):

Culture – All of the elimination and eradication campaigns had to deal with geographic, social, and ethnic differences in culture, including North-South differences and a multitude of different languages. In addition, in the culture of global health, there was an antibusiness bias and distrust of the private sector. Business and global health also operated on different time scales: public health traditionally used decades to measure progress, while business wanted it measured in terms of calendar quarters. The nonprofit culture of global health also doesn't like measurements because it is doing good (rather than well). There are diverse cultures at all levels.

Conflicting goals – Inadequate attention to clarifying the overriding, shared goal at the beginning of a coalition is the most common reason for the failure of a coalition.

Confusion – The confusion that arises when coalitions fail to take time to adequately diagnose and define the problem often leads to confusion about roles, responsibility, structure, and about what the problem really is.

Control – The members of most coalitions don't want to give up control. Member organizations want control, even if individual members of the coalition are willing to give it up. For these members, they reason that even if they are not going to get resources by joining the coalition, they can at least get control.

Capabilities – Coalition members want to be seen as good at everything, often reluctant to admit that others might do it better; if you don't know your own capabilities and don't want to know your weaknesses (much less admit them), then you struggle to be seen as omnipotent, and this becomes a barrier.

Competition – Competition can become a difficult obstacle when members continue to focus on "me" rather than "us." The goal for them then becomes who is the best, who has the most, and who is the biggest. There is competition for credit, power, and funding.

Costs – In many cases, we are not realistic about what things cost, limiting our thinking to what we can do with the scarce resources we have rather than define the resources we actually need; or we focus on the costs of collaboration but not the benefits.

Conflict – Shared goals are what can help to transcend politics and even bring warring sides of a conflict together. During elimination campaigns for vaccine-preventable diseases, in several countries which had ongoing civil wars, the opposing sides agreed to a truce on days that were designated as vaccination days to allow complete coverage of the entire population by vaccination teams. Partnerships are even more vital when working in areas of conflict. Insecurity remains a substantial obstacle to current efforts on polio eradication and the control of Ebola.

The critical elements of a successful coalition are simple and clear, and we can't overstate their importance.

Clear, Overriding, and Common Goal

Getting the members of a coalition to agree upon a shared goal is the most important determinant of whether a coalition will succeed. Elimination and eradication of a problem represents a clear goal that is easy to understand and measurable. These are also goals that can inspire organizations to join the effort and become active members of a coalition. When the WHO adopted elimination goals for many of the neglected tropical diseases, this stimulated new donors and new program delivery institutions to join these efforts as active participants in these campaigns.

Strategy for Reaching the Goal

Coalitions need to have a strategy for reaching their goals. It took almost 200 years after the development of smallpox vaccination, for the delivery strategy to change from mass vaccination to containment of outbreaks and vaccination only of persons exposed to active cases.

Structure

No one would suggest that an important organization could function without a structure or organizational chart. But people sometimes fall into the trap of thinking that a coalition can function without a structure. They don't realize that a coalition made up of several different organizations is *more* complex than its member organizations. It is the sum of complicated parts. The structure need not be formal and elaborate, but it needs to assign to individuals the roles that are critical to keep it functioning. And as opposed to many corporate or bureaucratic organizations where all decision-making may be concentrated in one chief executive officer, in coalitions the most effective leadership is often shared leadership, where different leadership functions – such as strategy implementation, financial accounting, advocacy, and dispute resolution – are delegated to different coalition members. The successful leader, and especially the successful public sector leader, is one who can persuade these various people able to lead these various functions to join in harmony to support a worthy goal. This requires that the players be empowered and be given credit for their contributions. This requires, in turn, that the leader or leaders involved be more orchestra leaders, intent on the results, than themselves trumpet players. Such leadership is facilitated when the goal to be attained is easily understood, when progress is easily measurable, and when the goal itself is narrow (Henderson 1999).

Defined Membership

It is important to get the right people working together. You need people who are problem-solvers looking for problems to solve. The coalition leader, too, must have the right set of leadership skills. This includes both visionary leadership and operational leadership from the person who can make things work (Foege 2011).

For several disease eradication campaigns, people and organizations came together across governmental, private, public, civil society sectors, between countries, and between international entities. Coalitions must also include the political leaders. Don Hopkins, who, for many years, led The Carter Center's efforts to eradicate Guinea worm, noted that this was a lesson learned from smallpox eradication; however, Jim Grant, a former director of UNICEF, pushed it further in his efforts to expand childhood immunizations through the Task Force for Child Survival. Hopkins shared "we pushed as far as we possibly could in Guinea Worm eradication. We have involved not just President Carter, but General Yakobu Gown and then General AT Toure, now president of Mali" (Hopkins, D. Interview by Mark Rosenberg, 2014). In India alone, smallpox eradication required mobilization of more than 250,000 workers and staff and contributions from many different countries (Foege 2011). Eradication on a global level required the participation of more than 150 different countries and highly skilled leadership at all levels, from the WHO down to regional, national, state, and local levels (Rosenberg et al. 2010).

Multi-sectoral collaboration can be particularly challenging. Each sector may think that this problem it is not their responsibility. For example, in trachoma elimination, clean water is needed but if the water sector thinks that this is a problem that belongs to the health sector, they may not prioritize the bringing of safe water to trachoma-affected communities. Or the education officials may not think it is important to teach children the importance of using latrines and wearing shoes to protect against soil-transmitted worms. The members of a coalition will all have their own "day jobs" and may be too busy dealing with their own set of crises to spend time working toward the coalition's goal.

Management of Meetings and Programs

Coalitions pose their own management challenges that go beyond the need for effective management of meetings and programs. Global or regional coalitions that are addressing large-scale public health problems often require that people come together, transcending politics. Most of the work on smallpox eradication took place during the cold war, and it was a global collaboration, with Russia making the offer to supply vaccine (Hotez 2017). Russia supplied the early vaccine – millions of dollars' worth – for the Global Eradication Program (Henderson 2009; Hotez 2017). Bilateral aid donations have also been very important in other disease elimination programs. The USAID has donated hundreds of millions of dollars for NTD elimination programs; the DFID and the UK have donated millions of pounds for trachoma elimination (Solomon et al. 2016). When working on an underfunded problem in an underfunded area, the problem may be that no coalition member is eager to control it or be responsible or accountable.

Lesson 4: Avoid Certainty (the Achilles Heel of Science)

A Great Many Things Are Subject to Change as We Learn More About Them

The CDC published a guideline for disease elimination and eradication campaigns that required that potential eradication campaigns be almost certain that eradication is possible before committing to the campaign. While it is important to highlight the feasibility and overall benefit of a campaign, Dr. Foege counters that "if we had waited until we knew that we could eradicate smallpox, we never would have been able to do it" (Foege, W. Interview by Mark Rosenberg, 2014). Even if we know what to do, there is so much uncertainty, so much we do not know. The physicist Richard Feynman said that certainty is the Achilles heel of science (Foege 2013). It is quite clear now that we did not know how to eradicate polio when the WHO first committed to doing it. Now we are not certain it can be done. But it is better to try and then learn that it cannot be done, than to prematurely think that something cannot be done and create the self-fulfilling prophecy that it will not be done. As Don Hopkins asserts, "there is no getting around it. The only proof that you *can* eradicate something is that you *have* eradicated it. . .CDC is right to want to reduce the risks that you can, but eradication is always risky business" (Hopkins, D. Interview by Mark Rosenberg, 2014).

Stay open to revisiting and revising your goal. Participation in a successful eradication campaign can also be effective in improving the morale and performance of workers in public health, although this potential benefit can also sometimes be derived from a control program. An eradication campaign requires complete surveillance, rigorous administration, and operational research to a degree that may not be necessary in a control program because the standard of success in an eradication program is unambiguous and uncompromising. Another requirement of an eradication campaign may be funding to support measures to eliminate a minor focus of disease from a country where the disease has limited impact and does not constitute a national priority. But don't be afraid to change your goal if you learn new information or it appears that for reasons you had not foreseen, eradication or elimination would not be possible.

The potential negative effects of an eradication campaign, especially an unsuccessful one, must also be weighed. It is important to take into account the economic burden and consequences as well as the potential negative impact on broader public health programs. The possible effects of competition for scarce resources and the political implications of a campaign that fails are among the factors that should also be considered (Henderson 1999). Campaigns that succeed may also have unexpected consequences. After the successful conclusion of the smallpox campaign, "support for any new eradication effort seemed especially unlikely since the smallpox eradication programme was then being critically maligned by traditional international health planners. To them, the smallpox campaign epitomized the worst of what they characterized as anachronistic, authoritarian, 'topdown' programmes which they saw as anathema to the new 'health for all' primary health care initiative" (Henderson 2009).

Lesson 5: Measure Frequently and Build in Continuous Improvement

Don Hopkins designed and oversaw the campaign to eradicate Guinea worm and believes that it is important to "pick a handful of indices for the most important outcomes and processes that people implementing the programs can use to track their own progress or lack thereof (Hopkins, D. Interview by Mark Rosenberg, 2014). This handful of indices can focus attention on the interventions that are most important, and they can foster friendly competition. Besides showing progress, these data are useful for motivating people and for advocacy" (ibid.).

During the course of the campaign, the overarching goal – eradication of Guinea worm disease – remained constant, but the strategy and tactics would change based on what they learned. When the campaign to eradicate Guinea worm began in 1986, an estimated 3.5 million human cases were occurring each year spanning across 21 countries (CDC 2011; The Carter Center 2019). By 2019, only 49 human cases were reported, 43 of which were within Chad, 4 in South Sudan, and the remaining

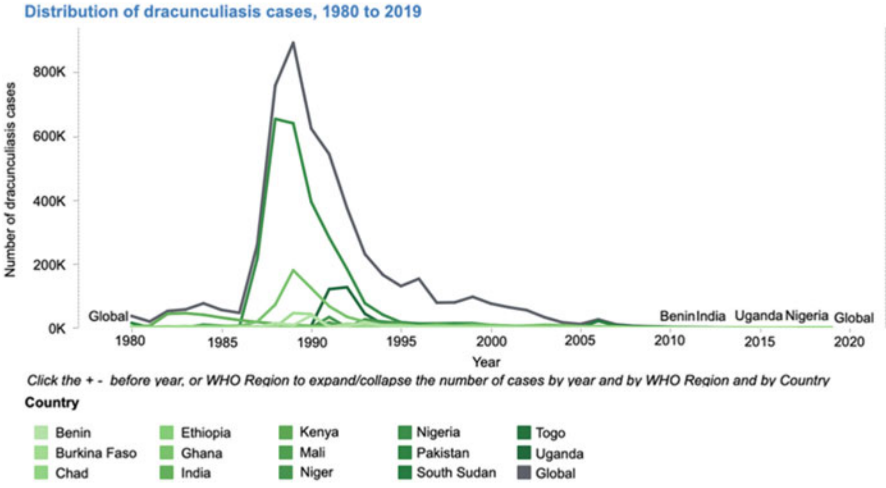

Fig. 2 (WHO 2019a)

1 in Angola (The Carter Center 2019). This was a remarkable 99.9% reduction in human cases since The Carter Center began their Guinea worm eradication campaign in 1986 (ibid.) (Fig. 2).

But after 30 years of campaigns to control Guinea worm, and just when it appeared that eradication was in sight, it was discovered that dogs could also be hosts for the Guinea worm. Dogs had previously been overlooked as reservoirs for the parasite, and it was clear that a major change in strategy and tactics would be required. The strategy for eradicating smallpox also changed as the program progressed.

Lymphatic filariasis (LF) is another one of the neglected tropical diseases, a group of deforming and debilitating diseases collectively known as the NTDs. These are diseases that for a long time were neglected because they infected “neglected people” living in poor tropical and subtropical countries. The NTDs include onchocerciasis, trachoma, intestinal parasites of children, schistosomiasis, and lymphatic filariasis. For LF, also known as elephantiasis, changes in the strategy for eliminating it also occurred as new treatments, and new diagnostic tests were developed. The main strategy for eliminating LF is treatment of those infected by mass drug administration with the goal of preventing further transmission. Using this approach, the Global Program to Eliminate LF has mobilized treatment numbers that have never been seen before [Ottesen]; since the start of the program in 2000, 7.7 billion treatments have been delivered throughout 68 countries with a target population of 910 million people (WHO 2019b). But an even broader and more effective strategy became feasible when new diagnostic tests and new treatments became available.

As we look at the history of efforts to control NTDs, we noticed a larger pattern, a meta-cycle, that we think is worth pointing out. These are very roughly stages in the evolution of the battle against these diseases. Different stages required different strategies that needed to be modified, extended, and continuously improved as more players and resources joined the battle. Our short and greatly oversimplified history of the battle against NTDs has 8 phases:

1. **Creation** – The modern history of global health institutions began in 1945 when the WHO was born, along with UNICEF and the World Bank. It was thought that the WHO would be *the* organization to deal with global health, the World Bank would deal with poverty, and UNICEF would take care of the health of children. It was thought that these organizations would each have a clear and well-defined role, but that was not to be. Overlapping mandates often resulted in fierce competition. Defining a role for each organization and getting them to collaborate effectively in the disease elimination programs was not automatic and not easy. As noted above (Lesson 3) coalitions would be needed to facilitate effective partnerships.
2. **Donation** – Another NTD, onchocerciasis, *or river blindness*, was endemic to 31 countries within Africa and several in Latin America. Then Merck developed and tested a human version of the drug, avermectin, and they were faced with an interesting dilemma. They had a drug so good it could inhibit the microfilaria of onchocerciasis for an entire year with a single dose. But the population in need included some of the poorest people in the world. This was not a promising commercial endeavor. In October 1987, Roy Vagelos, the Merck CEO, decided to donate the drug, all that was needed for as long as it was needed. Thirty-three years later, more than 1 billion avermectin treatments have been provided free by Merck. Millions have been spared the loss of sight and even more spared the burden of itching. A coalition of partners has now made huge advancements in the reduction of onchocerciasis worldwide through mass drug administration. The disease is diminishing to the point where it has been possible to contemplate a new strategy aimed not just at control, but at elimination, first in Latin America and eventually even in the most infected regions of Africa. The Mectizan Donation Program brought Merck a very high return on this investment in terms of disease and disability prevention, employee morale, and positive company name recognition. This, in turn, has inspired other pharmaceutical companies to follow suit. And now it is not just Merck but GSK donating albendazole for control of soil-transmitted helminths (STH) and LF; J&J donating mebendazole for STH; Merck Serono donating praziquantel for schistosomiasis; Eisai donating DEC; Pfizer donating Zithromax for trachoma; Novartis for malaria and leprosy; and more. And funds are being donated for implementation by the USAID and DFID and Geneva Global and more. And for operational research, by the Bill and Melinda Gates Foundation (BMGF) and more. These donations, are rewriting history.
3. **Multiplication** – Increased donations of money and drugs led to more participation by private sector, nongovernmental (NGOs), governmental, and multilateral organizations working to eliminate NTDs.
4. **Fragmentation** – As more organizations from civil society and the private sector entered the battle against NTDs, they created a changed landscape with no focal point. Competition – for countries to work in, for resources to work with, and for credit – rather than collaboration characterized this stage. Countries were faced

with a shortage of healthcare workers, generally lacking critical skills, especially in the areas of management and finance. While this may have been a more democratic approach to global health, it also led to a change in the authority and perception of the WHO. There was a dispersion of strategy and governance and a culture of diplomacy with little accountability. This lack of coordination imposed a huge burden on the minister of health who had to deal with many multilateral, philanthropic, bilateral, nonprofit, and corporate organizations. A multiplicity of donors acting on their own contributed to the burden.

5. **Aspiration** – To make the challenge even tougher, the donations and multiplication of interested players raised hope and led the WHO to set some aspirational goals: to eliminate some of the NTDs and control others.
6. **Collaboration/integration/convergence –** It became clear that things had gotten out of control. Bringing people together from different organizations and different cultures with different needs and expectations is challenging and takes strong, but sensitive, leadership. Collaboration takes time and attention, and these are scarce resources that are often not well-managed. Participants will not commit these resources unless they see that the collaboration is worth it. Because people believe collaboration should be easy and natural, they are naïve about what it takes to collaborate successfully, and they often don't put in the time and attention needed. In the beginning of the worldwide effort to control NTDs, many donors and implementers set up parallel programs for NTD control that were not centered in country governments. That was a mistake (Fig. 3).

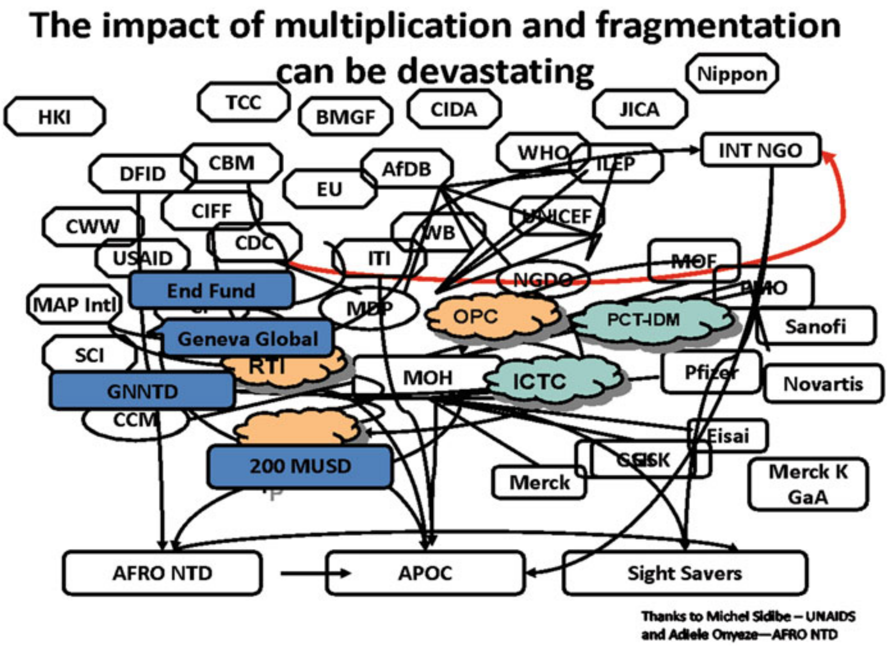

Fig. 3 Based on personal communication from Michel Sidebe and Adiele Onyeze

7. **Capacitation** – Later, each country developed their own NTD master plan, and it became clear that the capacity to control NTDs must reside within country health systems. NGO and donor implementers can work alongside – not in the place of – country programs. Countries coming together will strengthen the countries' voice and role.
8. **Elimination** – Having built the capacity to achieve elimination, states, countries, regions, and continents can certify that they reached their goal. But post-elimination plans need to be put in place. These plans should be open to continuously assessing your strategy and your progress because your world will keep on changing.

Lesson 6: Respect the Culture and Work with the People You Are Trying to Help

"If we are to succeed," Foege noted, "it will be because in everything we do, behind every decision we make, we see the faces" (Foege, W. Interview by Mark Rosenberg, 2014). Seeing the faces means we need to remember exactly who are the people we are trying to help. We need to understand both the individuals and communities that we work with. This means respecting diversity and including those who are different from ourselves. It also means we need to understand what the theologian Dietrich Bonhoeffer called "the view from below," the view of those who suffer from the problem and those who suffer most. Bonhoeffer said:

> There remains an experience of incomparable value. We have for once learned to see the great events of world history from below, from the perspective of the outcasts, the suspects, the maltreated — in short, from the perspective of those who suffer. Mere waiting and looking on is not Christian behavior. Christians are called to compassion and to action. (Bonhoeffer 2015, p. 16)

Global health, by definition, crosses boundaries and involves the participation of citizens of multiple countries, multiple cultures, multiple languages, and many diverse people. We, coming from one culture, need to work together with partners whose knowledge and cultures complement our own. We must be respectful and collaborative if we want to be successful. When global health began in the nineteenth century, it was very much a missionary-fueled movement, where people largely from the Global North traveled to the Global South to improve the health of the people there. The missionaries did things to improve their health, and they also tried to convert people to their own religion. They did things TO the people. In the next phase of global health, it was fueled by philanthropy, and people from the Global North did things FOR the people. Today it is clear that we need to do things WITH the people we want to help. And this means we need to understand and appreciate the local culture. It is also important to recognize lingering effects of colonialism.

That said, while "respecting the culture" is important, we must go beyond to empower: realizing that every elimination intervention is, in fact, a concomitant and essential opportunity to strengthen health systems, bring and create parity, and build cross-cultural exchanges with bidirectional (and equal) shared learning and receiving. Middle- and high-income countries stand to learn a tremendous amount from low-income countries because poverty often drives innovation and discovery (Hiatt et al. 2016).

Lesson 7: The Best Decisions Are Based on the Best Science, but the Best Results Are Based on the Best Management

The importance of good management is often undervalued, but it is absolutely essential to the success of any elimination or eradication program. The ability to actually reach your goal, to get to the "last mile," and to deliver the results you are aiming for depends on good management. The importance of strong management with meticulous supervision cannot be overemphasized. It is not enough to just train people and send them forth to do good. It is imperative to encourage them and to ensure that they get supplies, constructive mentoring, and constructive supervision in order to keep them on target. It is also important to supplement what they have learned with training and re-training sessions (Hopkins, D. Interview by Mark Rosenberg, 2014).

Good management also means that we understand how decisions will be made. Graham Allison, a professor of political science at Harvard's Kennedy School of Government, gave us a powerful way to understand the issues by saying we have to look at three models or levels of thinking to understand how decisions will be made (Allison 1969). The **rational model** views actions as the rational deliberation of a single solitary and strategic actor who chooses actions that are most likely to achieve a goal. This model leads us to ask what are the costs and benefits of an elimination or eradication campaign? What are the most cost-effective strategies for achieving our goal? The **organizational model** sees output as a function of "routine" rather than of "choice" and leads us to ask: How do the organizations operate that make the policy and lead the implementation? The WHO passed a resolution to eradicate polio in 1988, but essentially nothing happened for 10 years. To understand why nothing happened, a good manager has to understand the organizational dynamics. In 1988 when they passed the WHO polio resolution, the program was going so well in Latin America that they almost shamed the WHO into doing something about it. Haftan Mahler, the WHO Director General at the time, really pushed this. But the WHO staff fought it because they did not know where the money would come from, and without that it would not be possible. In addition, the WHO had signed onto the Declaration of Alma Ata, which had a goal of "healthcare for all," and many staff said "no more vertical programs." These staff felt that to provide primary care for all, the WHO would have to emphasize programs that addressed *all* of the most basic healthcare needs, i.e., horizontal programs. When polio came up, they had already agreed there would be no more programs that focused on a single disease like smallpox, no more vertical programs. All of these organizational factors contributed to the WHO missing their 2000 polio eradication target by more than 20 years. The

individual model sees policy as the outcome of individuals in positions who can pull strings depending on who they know. It leads us to ask: Who are the key players, how are they connected, and what strings can they pull and what levers can they push? At the WHO, the Director General, Dr. Mahler, had signed on to the Alma Ata agreement but he personally strongly supported the polio eradication campaign. And that made a very important difference.

Lesson 8: The Best Solutions Move Us Closer to Global Health Equity

Eradication is a step toward global health equity and social justice. Smallpox eradication did this. Before smallpox was eradicated, the rich countries were already rid of the disease, but the disease still percolated along among the world's poorest and most vulnerable citizens. Millions living in poverty remained vulnerable. For other global health problems as well, frequently those who continue to suffer from the diseases or public health issues that we can eradicate and eliminate are those with the fewest resources and those who are the least well-off. This is global health delivery in the pursuit of social justice, a noble calling.

The campaigns to eliminate the "neglected tropical diseases" are another good example. NTDs are widespread, disabling, and devastating diseases, and elimination means people like us will be able to see, learn, walk, and support our families. We are concerned with the suffering of others. But they are diseases of poverty, so the developed world does not see the people, bear witness to their lives, and understand their problems. Advocacy and resource mobilization for HIV/AIDS was extremely effective because the advocates were highly influential individuals affected with HIV/AIDS who lived in the USA. NTDs are diseases of neglected people who live out of our sight. As long as the high-income countries only track diseases that represent threats to their own health (like MDRTB, SARS, and influenza), they will not focus on the NTDs because they do not spread in rich countries with cooler climates and good sanitation. Therefore, we need to work even harder together to make our case, mobilize the resources we need to implement our master plans, and reach our ambitious elimination goals.

Finally, in designing and implementing disease elimination and eradication programs, it is important to achieve clarity about our values and what our goal really is. Is it to protect the most poor and vulnerable or is it to protect ourselves? The philosopher Martin Buber described two types of relationships, which can be the drivers for disease elimination and eradication campaigns. We can be concerned with others primarily as they affect us and our own security and well-being, seeing ourselves as "I" and others as "It" (Buber 1958). Or, we can view others as important in their own right and recognize that their well-being affects us because we are interconnected, and their suffering diminishes us. This latter view leads to what Buber called "I and Thou" relationships (ibid.). Our current global health security priorities are driven by "I-It" considerations: we need to protect ourselves here by controlling this disease over there. The WHO's International Health Regulations primarily require reporting of diseases that represent cross-border threats, for example, Ebola virus or multidrug-resistant tuberculosis. While “I-It” surveillance serves an important public health function, “I-Thou” campaigns are needed if we are to reduce health disparities, monitor progress toward global health equity, or address the complex social determinants of health in the twenty-first century. Indeed, if we value consequential compassion, I and Thou values must play a role in designing our elimination and eradication campaigns.

Lesson 9: Do Not Underestimate the Time, Resources, Tenacity, and Focus It Will Take to Succeed

Elimination and eradication campaigns always take longer than people initially thought. Looking at the extended time it has taken to eradicate Guinea worm, Don Hopkins emphasized that it is important to focus and stay focused. With respect to Guinea worm, Hopkins said he never imagined it would take this long, as he shared:

> To me it was such a logical thing with just obvious benefits and an obvious no-brainier, and I didn’t anticipate how much work it would take to mobilize the countries and the international agencies. That to me is the biggest surprise of all... It took wearing them down, working with those groups willing to work. There were a lot of people willing to work, but results came not from standing there and butting your head against the wall of those unwilling to move but going with those who were willing to move. I thought that the results would convince the others to come along. That also took longer than I would have liked. (Hopkins, D. Interview by Mark Rosenberg, 2014)

Costs as well have been much greater than anyone had dreamed in regard to the polio campaign. Simply because the personnel needs have been quite high in the countries that require assistance for adequate surveillance and immunization coverage, also the costs for supplies – including new types of vaccine and antiviral agents that came to be required – have been greater than anticipated.

There is always a decline in coverage and interest when any country has reached its initial elimination target. When coverage is reduced in countries that have become polio-free, they are at a great risk of becoming reinfected, and that contributes to the high cost. The lack of participation in the campaign of Nigeria for several years led to virtually all of the susceptibles becoming reinfected, in very large numbers. They had not had any polio in that area for 10 years, so they kept doing the same thing, surveillance, for years, and then slowly stopped paying attention. But there were groups that were difficult to reach, and they had gone un-immunized. In other neighboring countries, endemic transmission has been cleared only to find that the virus from Nigeria has entered the country (Dowdle, W. Interview by Mark Rosenberg, 2014).

The deliberate spread of disinformation about polio case workers has generated violence against them. This slowed the polio campaigns in Nigeria and has led to the murder of some case workers in Pakistan.

Measles is a prime example of how important the social will and public trust are and what happens when that trust is lost and resistance to the elimination campaigns gets crystallized and spread. Biomedical science only gets you so far; effective implementation in the face of human complexity can continue to be a tremendous challenge. Today, *measles* remains a leading cause of death for children worldwide. The WHO has made significant improvements to decrease that number by vaccinating over one billion children in high-risk countries since 2000, hoping to achieve measles elimination in at least five of the WHO regions by 2020. But in recent years, low vaccination rates in many areas of the USA and Europe have led to a resurgence of cases. Resistance to vaccination by groups opposed to vaccinations – given the name of "the anti-vaxxers" – has resulted in large outbreaks in several cities in North America (Benecke and DeYoung 2019).

Sometimes a variety of factors have contributed to the undermining of public trust. 1986 saw one of the biggest bovine spongiform encephalopathy (BSE) (i.e., mad cow disease) outbreaks in the UK (WHO 2010). The rise in cattle deaths led to the speculation of a circulating disease. It took time for scientists to identify the pathway of infection and etiological agent, which was later discovered to be a prion. In the meantime, lack of certainty led officials, the very people on whom the public depended, to deny any risk to human beings. In fact, in 1990, John Gummer, the presiding Minister of Agriculture, not only stated the threat BSE posed to humans was "so remote as for all practical purposes to be ignored," he also tried to publicly feed his daughter a hamburger to assuage public concerns (*The Guardian* 2000). Sir Donald Acheson, Chief Medical Officer at the time, followed, stating on TV that there was "no risk associated with eating British beef" (ibid.). It would be another 5 years until a ban was placed on "mechanically recovered meat" (ibid.). Between 1986 and 2004, it is thought that Creutzfeldt-Jakob disease, the human BSE variant, contributed to 152 deaths in the UK (WHO 2010).

Soon after, in 1998, Andrew Wakefield published a paper in the Lancet, claiming a link between vaccine and autism (Rao and Andrade 2011). The wavering credibility and authority of science and health officials from the preceding years of BSE in the UK created the perfect storm for Wakefield's claim to prevail even though his work was quickly discredited.

Today there are similar problems where the truth is not welcomed. Climate change, tobacco, and gun violence, all reinforce the importance of human factors in campaigns directed at disease elimination and eradication.

Lesson 10: Eradication Does Not Always Require a Vaccine or a Cure

If successful, Guinea worm (dracunculiasis) would be the first parasitic disease to be eradicated, and the first disease to be eradicated without a vaccine or even without a curative treatment. Guinea worm disease is spread when an individual drinks water that is contaminated by tiny water fleas that carry the Guinea worm larvae. By treating unsafe drinking water with a chemical that kills the water fleas and always filtering drinking water from possibly unsafe sources, the disease can be prevented. When an individual is infected with the larvae, they mature after about 1 year in the subcutaneous tissues of the legs or arms, reaching a length of 70–80 cm. After the worms emerge, if that person enters a lake, pond, or well, the emergent worm can liberate larvae into the water which can then contaminate additional water fleas.

Before the recent development of an effective Ebola vaccine, some Ebola outbreaks were also eliminated without a vaccine or cure. But the idea of eradication extends well beyond infectious diseases; it is applicable to general public health eradication or elimination campaigns, such as women who die in childbirth, or deaths due to smoking, or medical errors. In this case, environmental, educational, and engineering interventions are powerful tools. It is usually not the discovery of a single magic bullet that turns the tide, but successful elimination usually depends on incremental improvements over time, as new parts of the problem are understood and new solutions are discovered. This requires a sustained commitment to research and continuous improvement.

Lesson 11: Start in the Most Difficult Places First

Don Hopkins, the architect and long-time manager of the Guinea worm eradication program, told us that:

> The most difficult places will take the longest and will be the hardest, and that time cannot be bought back. It might seem better to go after the low hanging fruit first, but it's just the reverse: it's better to face the harder problems and solve them and then pick up the low hanging fruit later. Ideally, it would be done simultaneously—but that is usually not how the world works. (Hopkins, D. Interview by Mark Rosenberg, 2014)

Eliminating the problem in the most difficult places will often require the development, testing, and delivery of new and innovative approaches. These will take time, so better to get this work started earlier. In addition, there is often a limited amount of time during which the public will pay attention to an elimination or eradication campaign, but it may be possible to sustain that interest for a longer time if you can show that you are making progress even in the most difficult to reach places. If you start on only the low-hanging fruit initially, then it may be more difficult to sustain interest – of the public, of your funders, and of your staff – when you are trying to push through to the end.

Sometimes the most difficult place is not a particular geographic locale, but it is the most difficult part of the strategy, made difficult because of intense disagreement. Sometimes the decision is made to defer working out an agreement because two sides may seem just too far apart, and a discussion could threaten the survival of the coalition. But that is usually a mistake. We have found it is better to try to resolve these basic differences directly. The conversations needed to resolve these differences can be very difficult, but they are important. Frances Kissling has given very helpful advice:

> Have the courage to be vulnerable in front of those we passionately disagree with. Ask what is it in your own position that gives you trouble? What is it in the position of the other that you are attracted to?. . .When people who disagree with each other come together with a goal

> of gaining a better understanding of why the other believes what they do, good things come of that. . ..It is very hard for all of us in these situations to acknowledge, for example, that we just don't have the answers to this problem. (Kissling 2011)

Lesson 12: You Don't Begin at the End

Be wary, Walt Dowdle said, of prematurely closing our minds thinking that we know what eradication is when we have only seen it done once (Dowdle, W. Interview by Mark Rosenberg, 2014). Smallpox has been seen as an example of eradication, but the problem is that it has been seen as the *only* example.

Smallpox was not the first disease eradication program. The Rockefeller Foundation began campaigns to eradicate hookworm in 1907 and yellow fever in 1915. Both these campaigns against diseases of humans failed: the hookworm campaign because mass treatment of affected populations with anthelmintic therapy reduced the severity of individual infections but rarely eliminated them and thus did not prevent rapid reinfection (Nuwer 2016) and the campaign against yellow fever because of the previously unknown, inaccessible cycle of disease among nonhuman primates living in forests (Soper 1963). Acceptance of the concept of eradication declined during the late 1920s and early 1930s, after the futility of the eradication of hookworm and yellow fever was recognized.

Humility and an open mind are needed because when you begin, and at almost every stage before the last mile, you can't be sure what will work and when you will succeed. The CDC's guideline requires that potential eradication campaigns must be almost certain that eradication is possible before committing to the campaign. But as Don Hopkins noted earlier, "The only proof that you *can* eradicate something is that you *have* eradicated it" (Hopkins, D. Interview by Mark Rosenberg, 2014). And there is no way to know that at the beginning. You will not know it until the end.

The Lessons from Disease Eradication and Elimination Apply to Road Traffic Safety

We believe that all of these lessons are relevant to the elimination of road traffic injuries and can be useful in the development and the application of Vision Zero.

1. This is a cause and effect world
2. Know the truth
3. Coalitions are absolutely essential and absolutely hard
4. Avoid certainty, the Achilles heel of science
5. Measure frequently and build in continuous improvement
6. Respect the culture and work *with* the people you are trying to help
7. The best decisions are based on the best science, but the best results on the best management
8. The best solutions move us closer to global health equity

9. Do not underestimate the time, resources, or tenacity it will take to succeed
10. Eradication does not always require a vaccine or a cure
11. Start in the most difficult places first
12. You don't begin at the end

These lessons are not as much about the behavior of infectious agents as they are about how to understand problems, develop strategies, and successfully apply those strategies to solve those problems.

Claes Tingvall has been a pioneer in applying the idea of elimination to road traffic injuries and in spearheading the development of a standard for the management of road traffic safety systems; he has focused our attention on the importance of good management (ISO 2012). He has pointed out that there are interventions – such as traffic circles – that have been so effective that they have been called "vaccines for roads" (Rosenberg 2007). The biggest changes have been in road design, infrastructure designed to reduce the number of crashes by widening and straightening roads. Recent efforts to reduce road traffic injuries have aimed not just to decrease the number of crashes but to decrease the number of fatalities and serious injuries. The body has crash tolerance limits; they should not be exceeded. As soon as the driver loses control, the infrastructure should take over to mitigate the seriousness of the crash, for example, by clearing trees and boulders from the sides of roads and installing side barriers; it is kinetic energy control.

As Vision Zero is adopted by more and more governmental and non-governmental organizations, the value of applying elimination to road traffic injuries is proving its worth. Barriers and roundabouts and design for pedestrians have become increasingly important in improving road safety. The idea of a "shared space" between pedestrians and vehicles was trialed successfully in Gothenburg and other cities, as long as the environment is redesigned for slow traffic. Two-lane roads – the real killers – were also adapted into roads with two lanes in one direction and one lane in the opposite direction, the 2+1 system. But the real trick was to install a crash barrier between the lanes, saving approximately 50 to 60 fatalities per year.

Conclusion

The lessons above highlight the importance of partnership, leadership, strategic planning, as well as compassion, focus, determination, and, above all, perseverance. The thoughts shared from these disease eradication and elimination experts go beyond disease. Compassion moves us to seek to eliminate suffering as much as is humanly possible. We understand the perspective of those "down below," in the words of Dietrich Bonhoeffer, and we know that those who continue to suffer from the diseases or public health issues that we can eradicate and eliminate are those with the fewest resources and those who are the least well-off. This is global health delivery in the pursuit of social justice, a noble calling.

Every eradication or elimination campaign, however, will learn much more as it progresses. It is important to capitalize on this opportunity for continuous improvement by creating, from the beginning, a strong research component, including a research agenda, and strong links between the research community and the operational challenges facing the implementers.

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Zero-Waste: A New Sustainability Paradigm for Addressing the Global Waste Problem 40

Atiq Zaman

Contents

Abstract

There is a growing interest in addressing global waste problems by applying innovative ideas and philosophies such as zero-waste and circular economy. As a new sustainability paradigm, zero-waste challenges the common assumption of waste as a valueless and unavoidable by-product created at the end of the product's life phase. Instead, it acknowledges that waste is a "misallocated resource" or "resource in transition"; produced during the intermediate phases of production

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and consumption activities. Waste should be recirculated to production and consumption processes. Therefore, zero waste means no “waste” would be wasted under the circular economy system. This chapter presents various examples of zero-waste practices derived from family, community, business, and city levels. In addition, zero-waste implementation strategies and actions are also discussed in the chapter. Despite its potential, the visionary zero-waste goals cannot be achieved without responsible global stewardship and active citizens’ role.

Keywords

Zero-waste · Consumerism · Sustainable design · Waste diversion · Value hill · Circular economy

Introduction

With a growing interest and raising awareness of sustainability, waste has become one of the focal points of sustainable urban development. Yet, it is still one of the least priority areas for allocating budget and necessary infrastructure in many countries around the world. Millions of people’s livelihoods in various parts of the world depend on collecting and recycling waste. According to the World Bank’s report, around USD 205 billion was spent on waste management worldwide in 2010, and it is predicted that the cost will increase to USD 375 billion by 2025 (World Bank 2012).

Despite technological advancement and engineering solutions, one-third of the global waste is managed in environmentally unsafe manners such as littering, open dumping, open burning and unsanitary landfill, etc. (Kaza et al. 2018). Globally, around 85% of the collected waste is sent to landfills, including uncontrolled landfills and open dumping, and only 15% of the collected waste is recycled (Zaman 2016). To date, the landfill is the leading waste management option because of the low management cost (Hoornweg and Bhada-Tata 2012). Although the actual environmental cost of landfill is significantly higher, unfortunately, the traditional market-driven economic system often ignores the environmental costs of the pollution caused by landfills (Eriksson et al. 2005).

Plastic waste pollution is a major environmental concern since 79% of all plastics we generate are ended up in some form in the environment through land or water. These plastics will continue to pollute the environment for hundreds of years as plastics’ decomposition rate is generally prolonged. It was estimated that the emissions from plastics in 2015 were equivalent to nearly 1.8 billion metric tons of carbon dioxide (CO_2), and it will reach 17% of the global carbon budget by 2050 (Zheng and Suh 2019). The recent discovery of the Great Pacific Garbage Patch illustrates the level of long-term pollution and damage occurring in our marine environment.

Urbanization and overconsuming lifestyle trends are the key challenges related to sustainable waste management (Zaman and Ahsan 2019). Cities expand horizontally and vertically to accommodate many people every year (Ahsan and Zaman 2014). According to the UN report, the global urban population has increased by a factor of five, from 0.7 billion in 1950 to 3.9 billion in 2014, and it is expected to increase by another 60 percent by 2050 (UN-DESA 2014). At the same time, global consumption of natural resources could almost triple to 140 billion tons a year, as predicted by the United Nations (SMH 2011). A study indicates that, even with a more aggressive sustainability growth scenario and a drastic waste reduction in intensity by 30%, the global "waste peak" will occur after 2075 (Hoornweg et al. 2014). This indicates that even with our best intention and efforts, the waste generation will continue to increase until the end of this century.

Therefore, a paradigm shift is urgently needed to address the ever-growing global challenges. China was once seen as a global hub for receiving and treating a significant amount of waste from different parts of the world. Since the China Waste Ban (24 different categories) in 2018, countries worldwide are experiencing significant challenges to manage waste locally. Innovative ideas and solutions are urgently needed to overcome the current waste crisis. This book chapter presents a critical analysis of the emerging concept of "zero-waste" as a new sustainability paradigm for addressing the global waste management system's core problems.

The Anatomy of Zero-Waste

The term "waste" is commonly referred to as the valueless by-product that emerges at the end of life phase, and the substance needs to be disposed of or incinerated for proper management. The concept of zero-waste directly challenges the common assumption of waste as a valueless and unavoidable by-product created at the end of the product's life phase. Zero-waste acknowledges that waste is a "misallocated resource" or "resource in transition" which is produced during the intermediate phases of production and consumption activities, and thus, it should be recirculated to production and consumption processes through reuse, recycling, reassemble, resell, redesign, or reprocess (Zaman and Ahsan 2019). Zero-waste does not see "waste" as a substance that must be disposed of or incinerated but considers waste as a resource that should be used repeatedly (Glavic and Lukman 2007).

The Zero Waste International Alliance (2018) defines zero-waste as "the conservation of all resources through responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health." This implies that zero-waste as a concept is a target for transforming waste management systems towards a "circular economy," where extraction, production, and consumption become increasingly waste-free. Zero-waste doesn't mean that we would not create any "waste" in the transition of resource extraction, production, and consumption. Rather, it means no "waste" would be wasted under the circular economy system.

Zero-waste is a vision, a target, and an aspiration to progress towards sustainable management of waste. The underpinning principle of zero-waste is retaining the

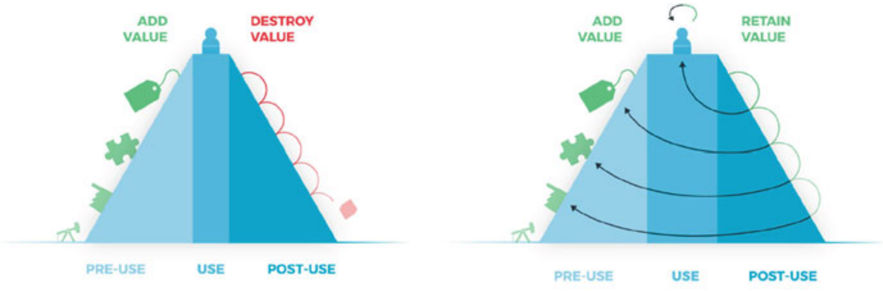

Fig. 1 The value hill as a business strategy tool. (Credit: Achterberg et al. 2016)

value of products instead of depleting the value of the resources. The value retaining strategy proposed by Achterberg et al. (2016) is presented in Fig. 1.

According to the value hill concept, value is added while the product moves "uphill," and circular strategies keep the product at its highest value (top of the hill) for as long as possible. The circular design is one of the fundamental principles to apply during the pre-use or the design, production, and distribution phase of a product. "Tophill" is about the optimal use of resources-circular design, and sustainable consumption would be a useful tool. "Downhill" is about value recovery, which involves the post-use phase of a product. Instead of disposal of end-of-life products to landfill, the resource would be recovered during the post-use phase at the optimum level possible (uphill to downhill).

The Development of Zero-Waste Concepts

The term "zero-waste" was coined by Palmer (2004) in 1973. Since the late 1990s, the concept has attracted much public attention. Many cities around the world, such as Adelaide (Australia), Dubai (UAE), Milan (Italy), San Francisco (USA), Tokyo (Japan), Vancouver (Canada), Wales (UK), and so on, are working towards zero-waste cities. Besides, several organizations such as Adidas, Ethique, Procter & Gamble, Subaru, Unilever, etc. have adopted the concept of zero-waste by setting zero-waste disposal targets. The Australian Capital Territory (ACT) Government released the "No Waste By 2010 – Waste Management Strategy for Canberra" in 1995, which was the first initiative that a government anywhere in the world had set such a challenging goal for waste management (Connett 2013, p. 303; Snow and Dickinson 2003, p. 5). Unfortunately, the "No Waste Bill" and the zero-waste targets were unsuccessful as the proposed implementation time (5 years) seemed to be unrealistic.

The zero-waste movement in New Zealand was started by establishing the Zero Waste New Zealand Trust in 1997 (Zaman and Ahsan 2019). The Trust voiced a goal of creating "a closed-loop materials economy; where products are made to be reused, repaired and recycled, an economy that minimises and ultimately eliminates waste"

(Tennant-Wood 2003). In 2000, Del Norte County, California, took on the first comprehensive zero-waste plan in the USA. In 2001, the California Integrated Waste Management Board adopted zero-waste goals as strategic waste management plans (Connett 2013, p. 307). Table 1 summarizes the key milestones and events about zero-waste development.

The Enigma of Consumerism, Environmental Degradation, and Zero-Waste

Apparently, continuous technological innovation, easy access to goods and credit, low prices, online shopping, and ongoing cycles of advertising and marketing cycles all reinforce the way of life called "consumerism" (Aspin 2012, pp. 8–10). This is usually defined as a "way of life and state of mind" where activities associated with consumption become a means for establishing social position and expressing individual identity (Smart 2010, pp. 7–10). The core of our modern world's economic system is founded on the principle of consumerism of the mass population. Let us explore what we mean by consumerism and why it is essential and related to zero-waste.

In the pre-modern consumerism era, the consumption of luxurious goods and services was only available to affluent people. However, consumerism is not limited to wealthy people anymore; it is for everybody. Initial signs of consumerism include high demand for sugar in the late Middle Ages (one of the early mass consumer goods); household furnishings (beds, cloths instead of straw mattress) in the early sixteenth century; and tea and fashionable clothing at the end of the seventeenth century (Stearns 2006). According to Stearns (2006), although there was an explosion of shops and new marketing methods in the eighteenth century, which played a significant role in consumerism, it was a shopkeeper and his methods that anchored the first iteration of a consumer society (p. 16).

Shopping become an important cultural activity among the "elite" people in the eighteenth century, and the industrial revolution brought more variety in the clothes and household items and not only for the affluent elite but also for the ordinary people in the Americas and Europe (Crocker 2017; White 2009). After the post-world wars era, consumerism was mainly driven by "economic consumerism" to stimulate economic growth and ensure a good living standard (Crocker 2017, p. 10). The global economic growth model is founded on a linear material flow, i.e., "take-make-disposal" approach, whether the "planned obsolescence" is the primary principle for repetitive shopping of "waste ready" products. Planned obsolescence, i.e., designing a product for a limited useful life, is one of the biggest drivers to make products more affordable for mass people and somewhat influence economic development. Along the way, various marketing strategies and approaches such as "big is better" or "buy now pay later" were inherent in our modern consumer culture. In the 1950s, plastics appeared to be the "magical" material to produce "waste ready" single-used products. It would be challenging to find a product nowadays that doesn't use plastics in the product's supply chain (Zaman and Ahsan 2019).

Table 1 The key milestones and events on zero-waste development (Zaman and Ahsan 2019)

Year	Country	Milestones/events
1970s	USA	The term "zero-waste" was coined by Paul Palmer
1986	USA	The National Coalition against Mass Burn Incineration was formed
1988	USA	Seattle introduced the pay-as-you-throw (PAYT) system
1989	USA	The California Integrated Waste Management Act was passed to achieve 25% waste diversion from landfills by 1995 and 50% by 2000
1990	Sweden	Thomas Lindquist introduced the "extended producer responsibility"
1995	Australia	Canberra passed the ""No Waste by 2010" bill
1997	New Zealand, USA	The Zero Waste New Zealand Trust was established The California Resource Recovery Association (CRRA) organized a conference on zero-waste
1998	USA	Zero-waste was included as guiding principles in North Carolina, Seattle, Washington, and Washington, DC
1999	USA	The CRAA organized zero-waste conferences in San Francisco
2000	USA	The Global Alliance for Incinerator Alternatives was formed
2001	USA	GrassRoots Recycling Network published "A Citizen's Agenda for Zero Waste"
2001	Australia	Towards Zero Waste Action Plans, WA vision for Waste 2020
2002	New Zealand, USA	The book *Cradle-to-Cradle* was published Zero Waste International Alliance was established The first zero-waste summit was held in New Zealand
2004	Australia, USA	ZWIA gives a working definition of zero-waste GRRN adopts zero-waste business principles Zero Waste SA was established in South Australia
2008	USA	The Sierra Club adopted a zero-waste producer responsibility policy
2012	USA	The documentary film Trashed premiered at the Cannes Film Festival The Zero Waste Business Council was established in the USA
2017	USA	Zero Waste Development and Expansion Act of 2017
2018	China	From 1 January 2018, China banned importing 24 categories of solid waste. China stopped importing plastic for recycling by setting the acceptable contamination level at 0.05 per cent – compared to the up to 10 percent it previously accepted
2018	Global (C40, UK)	Twenty-three global cities and regions advance towards zero-waste. This commitment will avoid the disposal of at least 87 million tons of waste by 2030
2018	Australia	The Australian governments set 100% packaging targets, i.e., Australian all packaging be recyclable, compostable, or reusable by 2025
2019	Australia	The Australian governments has banned waste export to overseas countries
2019	Singapore	Singapore has designated 2019 as the year towards zero-waste
2020	N/A	Apple's all established final assembly sites are Zero Waste certified
2021	Italy	ABB Smart Power's manufacturing in Frosinone, Italy has achieved the zero waste to landfill goal — 14 years ahead of the European Union's Circular Economy Package target

People are obsessed with changing or upgrading their "almost new" gadgets because there is a newer and a little more "fancier" version available. However, both would perform similar or identical functionality. People find "pleasure" in consumption and try to establish a social identity in a diminished social value system. On the contrary, economic growth doesn't always ensure a similar level of human subjective well-being as promised to deliver. The current overconsumption trends are mainly driven by technological innovation, fashion, deferral pricing, corporations, branding, and marketing strategies (Crocker 2013; Princen et al. 2002; Slade 2006). Over time, these influential factors contribute to product obsolescence and repetitive consumption practices, which are the core cause of generating excessive waste and depleting natural resources.

Clothing is an excellent example of how consumer culture significantly impacts the environment. Like America and Europe, Australia's obsession with new clothes and "fast fashion" textiles is hurting the environment significantly like America and Europe. Australia's obsession with new clothes and "fast fashion" textiles seriously hurts the environment (Pepper 2017). A T-shirt retails in America often travels over 10,000 miles, and most of the distance (88%) travels during the production (mainly in Asia) and distribution phases (Xing et al. 2016). As consumers, very few of us truly realize how our consumption choice, even for a single T-shirt, impacts people's livelihood and the environment in the distant parts of the world.

On average, Australians dispose 6000 kilograms of fashion and textile waste every 10 minutes. Only 15% of it is sold again locally in opportunity shops, and the rest 85% ends up in landfills (Wynne 2017). The moment we throw our clothes and consumer goods into the waste bins, it becomes somebody else's problem. The realization of the impacts from waste through greenhouse gas and leachate contamination in landfills is not easy and fun to do.

Given various contexts, how does zero-waste tackle these challenges? The zero-waste concept recognizes that the current linear economic model which is based on consumer culture is not sustainable. Thus, an alternative economic model such as a circular economy model is necessary, which will ensure "custodian citizen" to promote sustainable consumption, material circularity, and conserve the natural environment. Since zero-waste identifies waste as materials in transition, it favors the repetitive use of resources instead of burning and burying forever. The following sections present the zero-waste practices worldwide from an individual level to a city level.

Zero-Waste Practices Around the World

Zero-Waste Family

We have seen several occasions where people or a family live without producing a notable amount of "waste." Although most cases are published through social media and blog, they can be regarded as aspirations that people are trying to achieve after realizing how our way of life is depleting the environment. Some families in California (Johnson 2013), Phoenix (Mlynek 2018) in the USA, and Tasmania in Australia and many other places in the world are trying to live without creating any waste. In all these families, one thing is common: they have embraced the zero-waste challenge and are working towards the aspirational zero-waste goals. Bea Johnson and her family, living in Mill Valley, California, USA, is one of the most renowned zero-waste practitioners in social media who has adopted the zero-waste lifestyle since 2008. After living a decade on the zero-waste lifestyle, the outcome is extraordinary concerning well-being, and she states, “We not only feel happier, but we also lead more meaningful lives based on experiences instead of stuff” (Zero Waste Home 2018).

Zero-waste practices in families worldwide give a mixed message (needs to be vegan, sacrificing lifestyle, etc.) because the practitioners maintain different enthusiasm levels considering the practicality under the current system. Zero-waste requires transforming our existing system concerning product design and shopping system, which is not entirely equipped to achieve zero-waste goals. Thus, under the current situation, zero-waste practices could mean differently to families. Moving towards zero-waste lifestyles requires individual or family commitments and the necessary supporting infrastructure, for example, packaging-free bulk grocery shops. In recent years, packaging-free zero-waste shops are growing in numbers in many cities.

The most common practices that the zero-waste families are conducting are:

- Focusing on needs instead of desire when it comes to consumption and shopping
- Avoid shopping single-used goods (bottled water, bags, utensils, etc.)
- Avoid shopping goods with unnecessary packaging and buy bulk with reusable/refillable bottles/jars and from local growers
- Reuse non-compostable items such as jars, bottles, cloths, etc. as much as possible
- Mindful about what to buy and how it would contribute to waste generation and seek alternatives
- Recycle whatever cannot be reused
- Composting all organic materials in the household

Considering only municipal solid waste, achieving zero waste goals would be tough and challenging to achieve zero-waste goals, even though several families have shown how they live by creating only a jarful of waste in a year instead of three different bins full of waste every week. However, it is also essential to acknowledge that they achieved that because of their extreme dedication and desire to change their lifestyle, which may not be valid for mass people. It is also expected that almost all notable zero-waste families live in stand-alone houses with gardening and composting facilities. It may not be possible to maintain the same outcome if one lives in an apartment block without any composting facility. This affirms that systemic changes in personal, social, and infrastructural are needed to achieve the zero-waste goals.

Kamikatsu, Japan: A Zero-Waste Community

Kamikatsu Community

Kamikatsu is a small town in Japan located in Katsuura District. Kamikatsu is hilly and dominated by a range of mountains higher than 1000 meters above sea level. A total of 1556 people (in 2018) live in 788 households with a higher ratio of female than male (1:1.1) (Kamikatsu 2018). Over half (50.3) of the population is over 65 years old, and one-quarter of the population is over 85 years old (Suzuki, 2018). There is no formal door-to-door waste collection system from the local authority; thus, the local community is responsible for collecting and managing their waste.

Although waste was predominantly managed through open burning, the restriction of open burning and the mandate for recycling in the early 1990s forced the local community to sort recyclable from non-recyclable. Even the waste-to-energy plant was shut down due to a high level of dioxin pollution and to meet Japan's pollution reduction target, encouraging the community to look for an alternative solution to manage waste more sustainably. In 2003, Kamikatsu considered zero-waste as part of its waste management policy, aiming to be a 100% zero-waste town by 2020 (Sakano 2017).

Kamikatsu Zero-Waste Declaration

Kamikatsu was one of the first towns in Japan to declare the zero-waste goal in 2003. The aspects of Kamikatsu Zero Waste Declaration are (ZWA 2018):

- Kamikatsu will strive to foster ecologically conscience individuals.
- Kamikatsu shall promote waste recycling and reusable resources to the best of its ability for eliminating waste incineration and landfill by 2020.
- Residents of Kamikatsu shall join hands with people around the world for ensuring a sustainable global environment (Table 2).

Zero-Waste Practices at the Kamikatsu Community

Zero Waste Academy (ZWA) is a local organization working towards achieving zero-waste goals by changing people's mindsets, actions, and social systems to make zero-waste Kamikatsu (Sakano 2017). Under the zero-waste strategies, 100% of all organic waste is composted at home either with the traditional home composting method or an electric composting machine. The local government subsidizes the composting devices' cost as this will help reduce organic waste volume. Each household and store are responsible for washing, sorting, and delivering their trash to the recycling center (Hibigaya Waste Station) (Fig. 2).

Household waste sorting is one of the biggest challenges to recovering materials from waste. In many countries and cities in Europe and North Americas, waste is

Table 2 The key waste management milestones at Kamikatsu. (Adapted from ZWA (2018) with permission)

Year	Options	Brief descriptions
Before 1990s	Informal disposal/open burning	The absence of formal waste collection leads to open burning and informal disposal of household waste
1991–1995	Open incineration with alternative options	Subsidies for the household composter, formation of the Kamikatsu Recycle Town Plan, along with open incineration
1997	9 segregation categories	Commenced separate collection of wastes under the National Recycling Act (clear, brown, and other colored glass bottles, aluminum cans, steel cans, spray cans, milk cartons, incineration waste, bulk waste)
1998–2000	22 segregation categories	Concern about dioxin pollution from the incineration and increasing the sorting categories from 9 to 22
2001–2015	34 waste categories	Shut down small incinerators and increase sorting categories from 22 to 34 to improve recycling efficiency. Volunteer group "Recycle Kamikatsu" helped transport waste from households to the collection center
2016–2017	45 segregation categories	Renewed the Resource Segregation Guidebook for residents Established the Zero Waste Accreditation system

Fig. 2 Sorting options for various resource types at the waste station. (Courtesy: Akira Sakano, Zero Waste Academy, Japan)

sorted into several categories: paper, plastics, metals, glass, electronic waste, organic waste, etc., depending on the local management infrastructure's availability. Local people at Kamikatsu sorted waste into 45 different categories (Sturmer 2018). There are 13 main categories, and under each category, there are several subcategories to sort waste based on their characteristics. For example, cans are subcategorized as aluminum, steel, and spraying cans; glass bottles are subcategorized as clear, brown, other, and returnable glass bottles. These subcategories require a higher level of knowledge and understating of waste sorting and recycling issues to recycle correctly. Table 3 shows the waste categories at Kamikatsu.

Table 3 Waste sorting categories at Kamikatsu

Number	Main waste sorting categories	Waste sorting subcategories	Potential use
1	Reusable	Reusable items	Second-hand shop
2	Organic	Organic waste	Home composting
3	Metals	Aluminum cans Steel cans Spray cans Metal cans Scrap metals	Aluminum products Steel products Metal products Metal products Metal products
4	Papers	Newspaper flyers Cardboards Magazine scrap paper Paper cups Paper carton with aluminum Hard paper core Shredded papers Other papers	Newspaper Cardboards Recycled paper Recycled paper Recycled paper Cardboards Recycled paper Refuse paper and plastic fuel (RPF)
5	Cloths	Biodegradable cloths Other cloths	Second-hand shops RPF
6	Firewood/fuel	Chopsticks wood Master oil	RPF Compost fodder
7	Plastics	Clean plastic packaging Dirt plastic packaging (squeezy pack) Styrofoam trays (white) Styrofoam PET bottles PET bottle caps	Plastic products, RPF RPF Styrofoam trays RPF Cloths Plastic products/RPF
8	Glass	Clear glass bottle Brown glass bottles Other colored bottles Reusable glass bottles	Clear glass bottles Brown glass bottles Glass bottles Reuse
9	Mixed product	Other glass, potteries Mirrors, thermometer Light bulb, fluorescent tubes Dry batteries Discarded batteries Lighters	Based course material Mercury & glass wool Mercury & glass wool Metal products Lead Metal products
10	Bulk products	Large metal products Bulk wooden product Beddings, mattress, etc. Large/bulk PVC/rubber products	Metals RPF RPF Incineration
11	Mixed items	PVC, leather products, etc. Diapers and sanitary napkins	Incineration Incineration
12	Shells	Shells	Landfill
13	Home appliances	Discarded tires Specific home appliances	RPF Recycled by each producer/brand

All individuals in the community are responsible for taking their waste to the recycling center. A significant proportion of the community is very elderly people, and an intermitted waste collection system is offered once every two months. The local community needs to sort their non-organic waste into 45 different categories. Still, they also need to meet the recycling requirement, such as properly sorting, cleaned, and dried, which is also true for the residents outside of Kamikatsu. If waste is not properly cleaned and separated, it is not picked up (Sturmer 2018). After 15 years of implementation of the zero-waste practices in Kamikatsu, the town currently recycles around 80% of its waste, and the remaining 20% that can't now be processed – things like nappies and certain types of plastics – gets sent off to be incinerated (Garfield 2018; Sturmer 2018).

At the beginning of the zero-waste program, the community found the zero-waste practices were challenging and time-consuming. A survey in 2008 showed that around 40% of residents were still unhappy about at least one aspect of the zero-waste policy, which is washing each recyclable item before sending it to the recycling center (McCurry 2008), which has become a norm after a decade-long practice. According to Akira Sakano, Chair, the Board of Directors of the Zero Waste Academy, the sheer inconvenience of the process can act as a deterrent to excess consumption in the first place. The detailed categorization can make people start thinking about what they should buy, how much, and when, i.e., beginning of the problem (Garfield 2018).

Zero-Waste Business

Adidas: Zero-Waste Sporting Project

As part of its sustainability initiative, Adidas has partnered with "Parley for the Oceans" – an organization working for the ocean's ecosystem. Adidas launched a zero-waste sporting project called "Sport Infinity" in 2015 with a plan for a new breed of sporting goods that will never be thrown away. The Sports Infinity project has the potential to be recycled endlessly and combined into new products through a closed-loop supply chain of sports products (Adidas-Group 2015).

Adidas-Parley's AIR approach is to avoid (A) through reducing and replacing materials with sustainable ones, intercept (I) through retrieving and recycling problematic materials such as plastic waste from the ocean, and redesign (R) through creating a new industry standard (Parley 2018). In 2016, around 740 tons of plastic pollution were collected by the partnership organization "Parley for the Oceans" from the Maldives, Indian Ocean, to turn plastic waste into yarn (Parley 2018) (Fig. 3).

The recycled plastic yarn is used to produce shoes and t-shirts, and the target was to produce one million shoes using ocean plastic (McCarthy 2018). Each pair of sneakers takes 11 plastic bottles to make, which could mean that Adidas will recycle 55 million plastic bottles in 2018 if they hit their projected sales. Adidas wants to make all products from recycled plastic by 2024 (WMC 2018). Adidas has started to produce shoes made from reclaimed and recycled ocean trash (Borchardt 2017).

Fig. 3 Converting ocean plastic into yarn. (Parley (2018), with permission)

The Zero-Waste Stores to Phase -Out Unnecessary Packaging

In recent years, zero-waste stores have been opened up aiming to minimize the environmental impact by phasing out unnecessary packaging (Moss 2019). Plastics waste seems to be one of the biggest environmental changes for humanity due to its adverse pollution to the environment. However, unnecessary packaging is a common practice that can be easily avoided through zero-waste thinking. Over 36% of all plastics are used for packaging (Geyer et al. 2017); therefore, reducing and phasing out unnecessary plastics packaging through zero-waste make more sense than the traditional business model. Understandably, people who would like to implement zero-waste practice in everyday life need the necessary support infrastructure, such as zero-waste stores within their close proximity. The zero-waste shops offer consumers reusable containers and refill the required products ranging from oil and shampoo to cereals. A significant proportion of packing waste can be avoided through these alternative shopping practices. Another benefit of buying unpackaged items from the zero-waste store is that one can buy the amount the person or the family needs, which may not always be the case for prepacked supermarket stores. As a result, a significant proportion of foods and groceries are wasted in households due to over-shopping. Figure 4 shows an example of unnecessary packaging (left) and a zero-waste shop.

Zero-Waste City: The Case Study of San Francisco, USA

Waste Management in San Francisco

San Francisco is one of the world's leading cities that has considered zero-waste as its core waste management manifesto. In the UN-HABITAT (2010) study of solid waste management in the world's cities, San Francisco has been identified as one of

Fig. 4 The examples of unnecessary packaging (left) and zero-waste shop (right). (Sources: Flickr Creative Commons)

the most resourceful cities in waste management services. However, San Francisco has a long history in waste collection systems, from informal waste recycling in the early twentieth century to today's modern collection systems. Homeless and jobless poor people mostly drove informal recycling in the early 1930s as a means of survival. This was also seen in the last global economic crisis in 2008–2012. San Francisco has successfully transformed its waste management system by integrating informal waste recycling activities with formal waste management systems.

The composition of MSW waste in San Francisco includes organic (34%), paper (24%), plastic (11%), glass (3%), metal (4%), and miscellaneous (24%). Household hazardous waste is included in municipal waste, and, therefore, hazardous waste is also managed by the local waste management authority. A total of 508,323 tons of MSW (609 kg per person per year) was generated in 2008, making San Francisco one of the world's highest waste-generating cities. MSW is primarily managed by recycling (52%) and composting (20%), and the remainder of the waste (28%) is managed by landfills. The landfill waste in San Francisco has consisted of 31% organics, 23% paper, 23% C&D, and 23% other inert (SF Environment 2019), which indicates that with a proper system, the recycling rate can be improved further.

Over time, San Francisco has adopted various policies and strategies around waste management and zero-waste. In regard to waste services, San Francisco predominantly depends on a single service provider. Recology collects waste from households and public waste bins and transports it to the central material recovery facility (MRF). Figure 5 shows the schematic waste management systems in San Francisco.

Regulatory Policies and Zero-Waste Strategies

San Francisco has an effective and successful implementation of waste management policies and strategies. The notable policy can be outlined back to the Scavengers

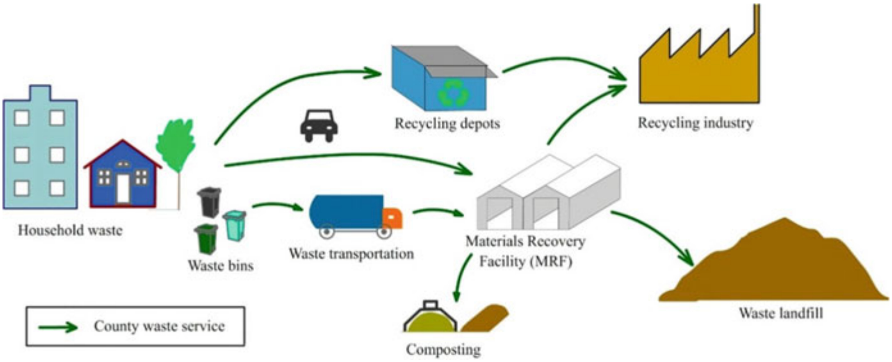

Fig. 5 The material flow of waste management systems in San Francisco

Protective Union's formation in 1879 (Perry 1978, p. 19). Since the nineteenth century, San Francisco has been visionary and supportive of environmentally friendly solutions. Thus, in 1987 the community opposed incinerator as a solution, instead enforcing community recycling and curbside collection systems. In 1988, San Francisco set a 32% reduction in the city's waste stream by 1992 and 43% by 2002 (US-EPA 1993).

The sustainable waste management strategy in San Francisco started in 2005 when the city initiated the UN Urban Environmental Accords, which include zero-waste, manufacturer responsibility, and consumer responsibility under the Waste Reduction Accord (City of Berkley 2005). San Francisco has adopted a range of regulatory policies to ensure maximum resource recovery from waste by integrating many stakeholders' involvement, including local businesses, local governments, and communities.

The first zero-waste strategy was adopted in 2005 under the Urban Environmental Accords to achieve a waste-free city by 2020. As a result, San Francisco achieved an 80% diversion rate (residential and commercial) and 61% diversion rate (equivalent to Germany's 62%) of municipal solid waste in 2012 (MacBride 2013). Undoubtedly, achieving zero-waste in the future is an ambitious target. It involves product manufacturers and consumers to ensure that all discarded materials are diverted from landfill. Realizing the challenges of zero-waste, San Francisco updated the zero-waste goal at the Global Climate Action Summit, in September 2018, to these two pledges:

- Reduce municipal solid waste generation by 15% by 2030 (reducing recycling, composting, and trash)
- Reduce disposal to landfill and incineration by 50% by 2030 (reducing what goes in the black trash bins)

Table 4 shows the critical milestones of municipal waste management policies and strategies in San Francisco

Table 4 Key milestones of municipal waste management systems in San Francisco

Year	Milestones in WMS	Goal and focus
1879	Scavengers Protective Union	The union protects the scavengers' right and promotes recycling
1932	Refuse Collection and Disposal Initiative Ordinance	Waste collected only by license holder: waste service provider (Recology)
1970	Community recycling center	Community recycling centers promote recycling activities within the city and involve local people
1981	Curbside waste collection	Collect recyclables from the community by the systematic curbside collection system
1987	Suspension of Incineration Plant	Incinerator for waste management deferred due to environmental pollution
1988	Waste Diversion Targets	Visionary diversion targets for higher recycling and less landfill
2003	Extended Producer Responsibility Resolution	Ensure producers' responsibility on the end-of-life product
2004	Fantastic Three Program	Promote higher sorting efficiency and recycling rate
2004	Green Building Ordinance	Requires city construction to manage waste and provide adequate recycling storage space in buildings
2005	Urban Environmental Accords	Visionary zero-waste strategy, producer, and consumer responsibility
2006	C&D Debris Recovery Ordinance	Requires C&D projects to use city-registered transporters and processing facilities to increase debris recovery
2006	Food Waste Reduction Ordinance (extended in 2016)	Requires restaurants and food vendors to not use Styrofoam food service ware and instead use foodware that is recyclable or compostable
2007	Plastic Bag Reduction Ordinance	Requires the use of compostable plastic, recyclable paper, and/or reusable checkout bags by supermarkets and drugstores
2010	Mandatory Recycling and Composting Ordinance	Everyone is required to separate and put their recycling, composting, and trash in the right place
2010	The Alameda County Landfill Ban	Alameda does not receive any contaminated recyclables to promote recycling and zero-waste
2012	Extended Bag Reduction Ordinance	Reduction of single-use plastic bags and promotion of reusable shopping bags
2014	Bottled water legislation	Restricted sale or distribution of drinking water in plastic bottles of 21 ounces or less on city property
2018, 2019	Plastics, Toxics, and Litter Reduction Ordinance	The Single-Use Foodware Plastics, Toxics, and Litter Reduction Ordinance aims to: Reduce plastic pollution by prohibiting the distribution of plastic straws, among other foodware accessories, and providing allowed accessories only upon request Eliminate toxic fluorinated chemicals from foodware products
2019	Zero-waste events	The event producers in San Francisco must do at least one of the following:

(continued)

Table 4 (continued)

Year	Milestones in WMS	Goal and focus
		Provide, lend, or sell reusable beverage cups to event attendees Promote or incentivize attendees to bring their own reusable beverage cup
2020	Compostable foodware requirements	Starting 1 January 2020, straws made of natural fiber or paper and all other compostable foodware sold in San Francisco must be certified by the Biodegradable Products Institute (BPI). Examples of compostable foodware include: Grease-resistant paper Paper plates To-go containers and straws made of paper or other natural fiber

One of the critical zero-waste drivers for San Francisco is the city's strong commitment to the precautionary principle and visionary strategies. Various regulatory policies and strategies have shaped the current waste management performance, such as Refuse Collection and Disposal Initiative Ordinance, curbside collection, Fantastic Three Program, landfill ban, food and plastic waste reduction, and so on. The zero-waste challenge in San Francisco is reflected in the solid waste systems support for reducing consumption, maximizing diversion, and encouraging reuse, repair, and green purchasing. Banning troublesome goods such as plastic bags and superfluous packaging and promoting alternatives such as recyclable or compostable takeout food packaging and reusable transport packaging are the most prominent initiatives for achieving zero-waste goals in San Francisco (UN-HABITAT 2010).

Implementation of the Zero-Waste Strategies

Based on the discussion presented above of various waste management challenges and by analyzing the current zero-waste practices in family, business, and urban scale, this chapter proposes several zero-waste strategies and exemplary action plans which could be useful to implement zero-waste principles. The listed strategic elements presented in the below table were identified in the author's previous study (Zaman 2017) through a perception survey of the waste experts. Table 5 summarizes the guiding principles as the zero-waste framework elements (in no particular order). Four selected groups of stakeholders (national and state governments, local government, community and family, and industry) are analyzed based on their relevance and importance (low, medium, and high) of the action plans in Table 5.

Table 5 presents overarching zero-waste strategies in the context of the relevance for various stakeholders. It is apparent from Table 5 that the local governments seem to be the most relevant, followed by industry and local community and individuals. It is important to acknowledge that the proposed strategic elements and action plans are

Table 5 The strategic elements for the zero-waste and the relevance for stakeholders

Phases	Strategic elements	Action plan	Example	National/ state	LGA	Community/ individual	Industry
Waste prevention and reduction	Effective public awareness and education on plastic waste	Inclusion of waste education program at the school curriculum	Primary school	H	M	M	NA
		Organize promotional awareness program on plastic waste avoidance and reduction	Plastics hackathon	H	H	H	H
	Zero plastic waste program	Hands-on training and knowledge-sharing program	Crafts and design	L	M	M	M
		Sustainable packaging and consumption practices	Avoid unnecessary packaging	H	M	H	H
	Sustainable and responsible living	Citizen initiatives through responsible shopping and consumption behavior	Buy loose items	NA	NA	H	M
		Promote local farmers market	Popup shops	L	M	H	M
	Shared-ownership of product & service	Collaborative consumption	Borrow/resell	L	L	M	L
		Owning services than products	Renting instead of owning	H	H	H	H
	Zero plastic waste products	The designing for reuse	Cradle-to-cradle product	M	NA	NA	H
		Alternative use of plastic waste	Storage container	NA	L	M	NA
	Extended producer responsibility	Mandatory take-back scheme for producers	Swap	M	L	L	H
		Container deposit scheme	Return	H	H	H	H
	Extend the life of post-consumer items	Resell and repair	Gumtree/eBay	NA	NA	M	L
		Men’s shed or community resource center	Men’s shed	NA	H	M	NA

		Promote completive recycling market	Green procurement	H	H	M	H
Waste management and treatment	Appropriate waste infrastructure (centralized and decentralized)	Mandatory 3 bin	FOGO	NA	H	NA	NA
		Plastic sorting infrastructure	Optical/density sensor	M	M	NA	M
		Take-back points	Reverse vending	NA	H	M	H
		Community, precinct-based drop-off points	Drop-off point	NA	H	M	NA
	Empower social technologies	Social business for plastics recycling	SMEs	L	L	L	M
		Reuse, repair, and recycle through community participation	Community business	NA	L	M	NA
	Regulatory policies	Improved policy	100% packaging	H	NA	NA	H
		Polluters pay principles	PAYT scheme	L	H	M	NA
		Incentives for green initiatives	Green procurement	H	H	L	M
	Restrictions on WTE technology	Interim use of WTE	Temporary use	H	M	NA	NA
	Landfill ban for plastic waste	A 100% plastic waste diversion from landfill	100% diversion	H	H	H	H
	Economic incentive	Refund, landfill levy, etc.	10c/levy	H	H	H	H
Monitoring and assessment	Standardized data collection systems	A mandatory online data collection system	Online platform	H	H	M	H
	Research on zero plastic waste	Zero plastic waste research collaboration	National/ international collaboration	H	M	L	H

Fig. 6 Steps in the zero-waste action plan (Zaman 2017)

contextual and may not be applicable to all countries, especially in both developed and developing countries. Thus, the development and application of zero-waste strategies need an explicit consideration of the locality's local needs and priority areas. The strategic elements should be implemented by following both short-term (i.e., 5–10 years) and long-term (i.e., over 10 years) action plans. Cities that consider zero-waste practices worldwide indicate that achieving a 60–80% waste diversion from landfills is achievable within a short period of time. San Francisco (USA), for example, diverted 80% of the waste from landfills in 7 years (2005–2012), and Novara (Italy) achieved a 70% diversion rate within 18 months when the zero-waste program was initiated (Connett 2010). However, diverting the remaining 30%–20% of waste from landfills is the biggest challenge because of inappropriate design and poor recycling practices. Therefore, appropriate product design and responsible consumption and recycling behavior are crucial for achieving a 100% waste diversion rate.

Three steps (clockwise) of implementing action plans are presented in Fig. 6, which are (i) pre-assessment or evaluation of waste management system for benchmarking, (ii) implementing zero-waste programs, and (iii) post-evaluation of the waste management performance against benchmarking study.

Conclusion

The vision for zero-waste and zero-waste cities is not only a new sustainability paradigm for addressing the global waste problem, but at the same time, it is also very challenging to achieve. Zero-waste requires a long-term commitment and active participation from all relevant stakeholders including producers, consumers, and regulatory bodies. Similar to climate change issues, the skeptic would have different views on the zero-waste agenda. However, implementing zero-waste practices seems beneficial not only for the environmental aspects and for creating new business and economic momentum. Already global 23 cities (C40 Cities 2020) pledge to advance towards zero-waste cities by:

- Reducing the municipal solid waste generation per capita by at least 15% by 2030 compared to 2015
- Reducing the amount of municipal solid waste disposed to landfill and incineration by at least 50% by 2030 compared to 2015 and increasing the diversion rate away from landfill and incineration to at least 70% by 2030

The change is inevitable as the pollution from waste is significantly damaging to the environment. Education and awareness are the first aspects of working towards zero-waste. The second crucial aspect is the industrial transformation of product design and manufacturing. In recent years an influx of global initiatives has been observed mainly to tackle plastic packaging waste. Andrew Forrest (mining giant in Australia and the founder of Minderoo Foundation) has committed to USD 300 million and several big companies to end worldwide plastic waste (Minderoo Foundation 2019). Similar initiatives and commitments are needed from the world-leading manufacturers and retail brands. Finally, global citizens' role is also an essential aspect because zero-waste is not about managing the waste, but mainly about not creating it in the first place during the consumption process. Therefore, without responsible global stewardship, the visionary zero-waste goals can never be achieved.

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