Chapter 11
Possible Futures of Vehicle Safety

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> *Human Kind is condemned to progress. Till eternity*
> Alfred Sauvy (French economist)

11.1 Introduction

In more and more countries in the world, we can observe a proliferation of road safety planning strategies which present very clear ways and measures to struggle against road crashes in the countries where these plans are initiated. They are basically a response to a very detailed diagnosis of traffic safety issues, generally broken down into three categories: risk factors (e.g., speed, alcohol, vigilance, distraction, etc.); vulnerable users or group at (over)-risk (e.g., young drivers, motorized two-wheelers, etc.) and accident types (e.g., loss of control, intersection crashes, night crashes, etc.). Recommended deterrence actions are obviously responses to the safety issues but, above this, they belong to a paradigm, e.g., the 'Safe System', whose basic principles are the following:

- A human being has limited biomechanical capabilities to withstand impacts. Reduction or avoidance of impacts is therefore inevitable, noticeably by a management of impact energies and the limitation of people exposed to forces likely to provoke injuries.
- A human being is fallible, and therefore makes errors. The whole system of traffic and land transport must be designed and maintained taking these errors into consideration.
- A comprehensive diagnosis of safety issues must be conducted in order to determine safety measures that have high safety benefit potentials and a high efficiency/cost ratio.

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Fig. 11.1 General principles of the ‘Safe System’

- Measures must be consistent with choices for society (economic, human and environmental), with positive economic impact on providers of products and services useful for safety on land transport.
- The responsibility of safety actions must be shared among all public and private players and not by only one player (e.g., the public authorities).
- Safety is first generated by the reduction of crashes that are easily avoidable, and then by sustaining a transport system (not only roads) compatible with the safety of future generations.

These general principles are often presented in these programs, according to 4 (prosaic) chapters which put forward systemic, holistic and integrated aspects or road safety policies (Fig. 11.1). These four chapters are:

- Safe speeds
- Safe vehicles
- Safe roads, streets and roadsides
- Safer road usages

And, of course rescue services and medical treatment.

11.2 Safe Vehicles

The focus of this paper is safe motorization particularly passenger cars which count for approximately 83% of all motorized vehicles in France. They are also involved in 78% of injury crashes and in 75% of fatal crashes. These figures may vary a lot between regions, especially in emerging countries where two or three motorized two-wheelers are predominant as well as trucks, buses and coaches. Technologies that apply to passenger cars can in most cases also apply to other motorized vehicles except some that are very specific (e.g., car structure, restraint systems, dynamic control, etc.).

The question is: What is a safe vehicle? The answer to that question claims will help us understand the extent to which the automobile design contributes to road safety.

Safety consists of a series of measures which ensure that a task or a whole set of tasks are conducted without any property damage or injury or any kind of other harm (moral harm, economic loss, social harm or esthetic harm), to the one who conducts the tasks and to others as well (Page and Coz 2003).

Safety can be envisaged from to several angles:

- Primary safety aims to prevent a harm. The difference between prevention and avoidance is a bit vague. Say, for the sake of simplicity, that any measure that targets attitudes and behaviors of road users as well as other players of road safety (in charge of design, maintenance and control of vehicles, road, road equipment and traffic management) are preventive actions, whereas measures that correct a driving situation which is critical or is about to be critical are avoidance measures. We do not elaborate here on the term 'precaution', which consists in taking measures against a new risk, unknown and not well-documented, which generally leads to very restrictive measures.
- Secondary safety aims to reduce the consequences of a harm (severity).
- Tertiary safety aims to bring the best and fastest care to victims.
- Quaternary safety aims to reduce the physical and psychological sequelae after a harm.

Therefore, vehicle safety consists of a series of measures which ensure, via a vehicle (or, nowadays, the so-called extended vehicle taking also into consideration the connectivity between vehicles or between vehicles and environment), automobile trips with minimum harm and external effects.

Road risk prevention is currently being coordinated by public authorities which encourage associations and the private sector to develop, each in its own field of expertise, actions that can help in preventing or avoiding crashes or, at least, mitigating injury severity in the case of a crash. However, since decades, for the sake of innovation in safety or under regulatory or consumerism pressure, vehicle manufacturers and automotive suppliers have developed systems to protect vehicle occupants (e.g., safety belt was patented in 1903 and the concept of bag filled in with air is dated 1941) or external users (e.g., pedestrian-friendly bonnets) to improve safety inside or outside the vehicle in reducing the consequences of an impact. Active safety (accident avoidance) has been improved via steering, dynamic control and braking performances.

A vehicle manufacturer contributes to efforts in road crash and injury prevention by undertaking and applying many safety measures via technology and by conducting safety actions and social responsibility (driver training, education, communication, research and corporate sponsoring). OEM's contribute to national and international road safety actions by acting specifically in vehicle safety, i.e., in designing and fitting vehicles with primary safety systems (assisting drivers in his/her navigation/guidance/control tasks), secondary safety systems (i.e., able to optimize occupants protection as well as external users protection in case of a crash), tertiary safety systems (e.g., automatic crash notification; rescue code, which is a QR code pasted on the front and back windshields allowing the rescue services to quickly get a vehicle identification card of the vehicle, which helps in cutting it at the right places in case of necessary extrication).

These systems have various origins: either the availability of technologies, or a brilliant engineering idea or inspiration, or the existence of such a system by a competitor, or a specific strategy of a vehicle manufacturer which makes safety a brand identity, or an economic interest, or a regulation, or a norm, or a specific consumer test (such as New Car Assessment Programs), or, a particular accident analysis that reveals that such and such a safety issue could be a priori tackled by these systems.

11.3 Secondary Safety of 'Safety of Protection'

Sequentially, an automobile impact induces an impact between an occupant (or an external user) and a part of the vehicle (or another element of the environment if the occupant is ejected) and then impacts between different internal organs of the victim's body (Page 2012).

First impact is, for an occupant, the consequence of one of these three injury mechanisms:

- Intrusion in the passenger compartment.
- Projection (or deceleration) of an occupant against a rigid part of the compartment, or interaction between an occupant and the restraint system (belt or airbag).
- Ejection of the body (or part(s) of the body outside the compartment).

There are other ways to be injured or die on the roads, such as carbonization or intoxication by smoke.

Injury severity depends on, for each of these mechanisms, on the violence of impact, on impact configuration (frontal, side, rear, rollover, etc.), on stiffness of the obstacle and on biomechanical tolerances of the human body. These three mechanisms should be targeted by secondary safety and it is usually done by using two options:

- Vehicle structure.
- Restraint systems.

Vehicle structure must dissipate energies released during the impact while maintaining the integrity of the compartment, i.e., avoiding/reducing intrusion in also limiting the pulses and efforts sustained by the occupant. Prosaically, a soft structure would properly dissipate the energy when the vehicle is deformed but would induce intrusion. A rigid structure would reduce intrusion but would put much more pressure on the occupant's body.

Vehicles being very different from one to another, one must also ensure a good compatibility between them (mass compatibility, stiffness compatibility and geometric compatibility) for some vehicles must not be too aggressive to the others. This is the reason why, for example, trucks are in most countries fitted with anti-underrun devices or heavier passenger cars must not be too stiff otherwise too aggressive against smaller and less stiff cars (even though they still have to be stiff enough to appropriately protect their occupants in case of a crash against an stiff obstacle).

Restraint systems (e.g., seat belt with pretensioners and load limiters tuned for persons biomechanically fragile; frontal airbags; side airbags for thorax and head; seat bossage; etc.) are essential complements to a stiff vehicle structure, which is the current choice. Occupants must absorb their own kinetic energy residuals: the pretensioner (seatbelt tension) couples the occupant to his/her seat. In a frontal impact, for instance, load limiter unrolls a few centimeters of the belt for it does not provoke lesions to the thorax organs, and then the airbag 'welcomes' the occupant head and thorax and diffuses more efforts while, additionally, preventing head and thorax to smash into rigid parts of the wheel or the dashboard. Obviously, these features work at reasonable impact violence. Above a certain threshold (like, for example, a frontal impact against a deformable obstacle above 70/75 km/h), the laws of physics make full protection hardly achievable at a reasonable automotive cost. In that case, the vehicle sustains a heavy deformation and intrusion can no longer be prevented and the restraint system can no longer be functional.

Lots of improvements in protection safety (usually known as passive safety) was done at the end of the 1990s, with voluntarist policies of a few OEM's which can be considered as pioneers in the field, and with the development of regulations concerning frontal impact (Directive 96/79/CEE et ECE.R94) and side impact (Directive 96/27/CEE et ECE.R95), as well as development in consumer testing such as EuroNCAP (and other kinds of NCAP's around the world) which assign points and stars (1 up to 5) to new cars. The first car which was ever awarded with Euro NCAP 5 stars is a French vehicle, in 2001. Ever since, a lot of passenger cars have been awarded 5 stars, even though with the continuous improvements, hardening and broadening of tests since 2009 and planned up to 2020 (see Road Map EuroNCAP released in 2014, which specifically hardens tests in passive safety and adds tests for the presence of preventive/active safety devices). We must here underline that EuroNCAP does not only target car occupant protection. Tests also target pedestrian safety and soon pedal cyclist safety in crashes against passenger cars. Other kinds of NCAP's, under the supervision of global NCAP, also have roadmaps for enlarging their testing.

11.4 Primary Safety

The analysis of a road traffic system reveals that it is composed of motorized and non-motorized road users, who drive or walk on roads/streets. They move in a general environment that they do not generally control or monitor (e.g., traffic conditions, temporary signals, road works, etc.). These trips are governed by traffic laws. Each and every road user is therefore supposed to monitor and adapt his trip/driving according to rules/laws that he/she is also supposed to know since he/she has got a driving license (not all pedestrians I admit), according to the situation he/she faces (road, trip motivation, type of driven vehicle, etc.) and the presence of other users at the same time and place.

The diversity of components of a traffic system obviously shows that the user is not responsible for everything. He/she does not conceive/maintain roads, he/she does not select the weather, he/she does not select traffic density, road works occurrence, missing signals, etc. On the other hand, he/she has to take the right decisions against what he/she encounters on the road. In other words, he/she is the last regulator of his/her trip. Vehicles that are sold, roads that he/she drives on, road and traffic maintenance, must increase his/her safety and must optimize his/her decisions/actions (even though, in such an automated task like driving, decisions are often implicit).

Therefore, if we set apart design, the conception and effectiveness of conditions in which transport of persons and goods are performed (e.g., failures in urban management, inefficient transport and land planning, missing alternative transport, etc.), if we set apart problems in designing and maintaining roads and infrastructure (i.e., visibility, clarity, adequacy to characteristics of vehicle dynamics, potential for forgiveness, etc.) as well as vehicles, traffic safety issues develop around drivers who violate basic safety rules (excessive drinking and driving, excessive speed, drug use, aggressive driving, risky driving, etc.), or make mistakes and errors (perception, cognition, vehicle control, bad or insufficient skills) often due to altered states (alcohol, inattention, distraction, stress, fatigue, lack of sleep), or due to inexperience of driving, or due to specific trip conditions.

Consequently, OEM's find another way in traffic safety via driving assistance systems. These systems have two interests: they make it easier to perform some driving tasks and help drivers not to enter into dangerous or critical situations… or to get out of these situations. There are a lot of these systems on the market (mainly in highly industrialized countries), with a lot of variants, but they often demand environment sensors that are often costly and not yet sufficiently robust.

There are currently a few taxonomies of driving assistance systems. We propose 4 of them, according to the assistance type, according to the level of influence of the assistance and according to the active or passive participation of the driver.

According to the assistance type:

- The assistance can be of a strategic type. It then targets the itinerary planning and the navigation. Navigation systems are typical examples of this type.

- The assistance can be of a tactical type. It targets the selection and the performance of the manoeuver adapted to the encountered situation. Blind spot helps detection is a typical example of a tactical aid.
- The assistance can be of an operational type. It consists of controlling the vehicle trajectory. Emergency braking or electronic stability control is typical examples.

According to the assistance influence:

- In a first step, the assistance brings an information to the driver (e.g., an information about density of traffic or tire pressure).
- In a second step, the vehicle activates an alarm (e.g., a tone if the seat belt is not buckled up).
- The vehicle can also activate an enhanced information (e.g., a long and high tone if the belt is still not buckled up after a few seconds).
- The vehicle can perform a corrective action on the manoeuver (e.g., electronic stability control).
- The vehicle can, at last, take control, the driver being fully out the loop (automatic braking for instance).

According to the driver participation:

- Without driver intervention (e.g., automatic emergency braking)
- An assistance which takes part of the driving task (e.g., autonomous cruise control)
- A driving assistance under control, which accompanies an action by the driver (e.g., electronic stability control).

Apart from automotive parts (e.g., steering column, hydraulic brakes and tire rubber) that are reliable and safe (compliance to rules and laws as well as general safety of products), and apart from the considerable progress over time on steering, braking and dynamic control, and specific primary safety systems are not that much fitted in most vehicles nowadays and are often available in premium passenger cars or as an option in mid-class cars. Speed limiters or cruise controls are largely disseminated (in any case by French OEM's) but not the adaptive intelligent cruise control (maintaining a speed compatible with the vehicle pace ahead). Systems such as ABS, ESC, emergency braking systems, navigation systems, automatic head lights, automatic commuting low beam–high beams, tire pressure monitoring systems, automatic wipers, blind spot help detection, lane departure warnings, lane keeping assist, driver alert systems, night vision systems and variants of intelligent speed adaptation are on their way, in the pre-market introduction, at a reasonable pace. On the other hand, systems such as anti-collision at junction radars or anti-head-on collisions radars, alert of incidents/accidents ahead of the trip, or systems informing the drivers about risky sites or black spots are still at the research or advanced engineering phases.

The field for driving aids is henceforth extremely huge. Sensors detecting the environment (ultrasonics, cameras, radars, lidars, navigation maps, GPS, etc.) are more and more mature and algorithms more and more powerful: they detect obstacles around the vehicle, lanes on the roads, junctions, insertion access, line markings, road and traffic signals and therefore assist the driver in his/her driving tasks (navigation/guidance/longitudinal and lateral control).

The question is: to what extent OEM's and suppliers are able to propose protection systems and driving assistance systems that are economically accessible to mass production and mass commercialization. Recent history shows that it is definitely possible when we, for example, look at the large dissemination of ABS and ESC. Of course, often, sophisticated systems are released first on high-end vehicles before being tried on entry level vehicles. The fast renewal of the automobile fleet is one of the most promising safety measures though. To that end, the affordability of such systems is crucial.

11.5 Tertiary Safety

Development of portable devices (smartphones, tablets, etc.) including the e-call (most well known as automatic crash notification in the USA) will inevitably reduce delays in the intervention by rescue services. Although the European Commission considers that generalization of e-call could save up to 5–15% of fatalities in Europe, the latest studies show lower estimates, around 2–3% in France for instance.

In addition to the alert, cooperation between OEM's and rescue services has recently come up with a Standard of Extrication Card which allows fire brigades to cut vehicles more efficiently (if necessary, of course), in order to extricate occupants trapped after an impact. It is very likely that, in future, intelligent e-calls (able to provide information about the crash like impact speed, occupant's presence and belt age status, etc.), and e-health may also contribute to help rescuers and hospitals in their injury and injury severity diagnosis and therefore help in triaging the victims to the appropriate hospitals and trauma centers.

11.6 Technology and Safety Benefits

Past and current studies show high potential safety benefits of existing systems (protection systems as well as driving assistance systems already largely disseminated onto the market) (Sferco et al. 2001; Forêt-Bruno et al. 2001; Page et al. 2005, 2006a, 2009b; Page and Cuny 2006; Kassaagi et al. 2006; Couturier et al. 2007; Zangmeister et al. 2007; Page and Labrousse 2007; Cuny et al. 2008; Zangmeister et al. 2009; Page 2011, b; Fildes et al. 2015). Passive safety systems coupled with collision prevention system and/or injury mitigation systems such as ESC or EBA already show an unprecedented effectiveness value ever since seat belt effectiveness, first speed limit settings or automatic speed camera settings (in France at least) came into being: a front seat occupant of a vehicle which got 5 stars at the EuroNCAP (old rating) and which also has the ESC and the EBA has reduced the risk of severe fatal injury by 70% compared to an occupant in a vehicle without ESC nor EBA.

A recent study showed that, if we consider the declining trend of fatalities between 2000 and 2010 in France (−48%), 6 points are due to the vehicle safety improvements over this period (Page 2010). This seems very small but if we also consider that the rate of deployment of these technologies in the vehicle fleet is very low and slow (vehicle fleet is renewed every 15 years or more), and these systems have started being deployed in early 2002–2003 for passive safety and even later for active/preventive safety, and mainly in high-end vehicles first, then we are forced to conclude that the promise in safety benefits is actually high.

Perspectives for systems that are not largely disseminated, or still under development, are also positive (Page et al. 2006b, 2009a; Page and Hermitte 2007, 2009; Driscoll et al. 2007; Chauvel et al. 2013; Hynd et al. 2015). Each system has an expected effectiveness (in terms of savable lives or avoidable severe injured people) relatively low (often between 2 and 5%, a bit more for some of them, if the whole fleet is fitted) according to available studies. Therefore, a combination of systems that address various safety issues (loss of control, loss of guidance, blind spot, late braking, night vision, etc.) is to be preferred. Expected safety gains are potentially high and effectiveness studies research (today embedded as ‘stand-alone’ systems and tomorrow connected with one another) must be encouraged to identify this promise in greater detail (Page et al. 2015).

It is indeed difficult to establish a ‘Top 10’ rating of the most promising systems which for a few reasons (Page and Hermitte 2009): Effectiveness studies are of three kinds: the ones which simulate the expected effectiveness of systems not yet or poorly on the market, the ones which observe the actual effectiveness of systems in the market according to their penetration rate in the fleet, and the ones which extrapolate the safety gains that would be observed if existing systems would be disseminated 100% in the fleet. We thus have a problem of consistency among different estimates.

Whatever their types, available studies vary in the effectiveness indicators they use. It can be reduction in injury crashes, reduction in all kinds of crashes, reduction in fatalities, in severe injuries, in crash risk, in injury risk, taking into consideration (or not) the penetration rate, etc. (Possibly depending on accident or impact types such as loss of control, frontal impact and pedestrian collisions). As a consequence, they are not exactly comparable.

Similarly, methods and techniques of evaluation as well as simulation assumptions (noticeably concerning the use of driving aids by drivers) vary a lot too. Furthermore, some sensitivity studies establish effectiveness estimates depending on different values of a set of parameters entering into consideration to make the function work. Subsequently, effectiveness estimates might be quite different between variants of the same system.

Actually, numerous systems present numerous variants. Variants may concern the function itself: for example, a lane departure warning can have different triggering thresholds, possibly selected by the driver, when the car is about to leave the lane, when it crosses the lane line, or long before crossing the line; or an AEB can detect only moving obstacles in the same direction, or can detect any kind of moving or stopped obstacles.

OEM's and suppliers continuously improve the systems, from time to time and new systems are continuously released. Therefore, the long list of functions and variants is always evolving. A Top 10 would shed the light on a few fashioned systems at a given time and possibly hide promising functions not properly analyzed yet. Moreover, some functions improve better than others overtime by, for example, extending their coverage (AEB against moving vehicle, than against stopped or fixed obstacles, than against pedestrians, at low speed and speeds) or by strengthening the technology.

Primary, secondary or tertiary safety systems must not be considered in competition with one another but rather like different opportunities to solve similar problems. For example, an intelligent speed adaptation system can reduce the driving speed, an automatic braking system can reduce the impact speed, a reinforced car structure combined with restraint system can be even better at lowering impact speed and an automatic crash notification can reduce intervention delays by rescue services. Rating them all in a Top 10 would mean ignoring their additive impacts.

If systems are sometimes complementary or additive, they are seldom fitted individually in a vehicle, which would demand the establishment of a Top 10 of the 'packages of systems' rather than a Top 10 of isolated functions. Given their high number, classifying hundreds of combinations or packages is impracticable.

To our knowledge, there is no unique Top 10, accepted by the scientific community as absolutely irrevocable.

Some systems might have a restrictive target population (e.g., blind spot detection address between 4 and 6% of the injury crashes) but a high effectiveness potential (e.g., 50% out of the 4–6%) and a low cost. It would be unfair to disqualify these systems by underlying the low effectiveness if it can be reached at a lesser cost. The 'Top 10' should therefore be established on the basis of the effectiveness as well as on the basis of the effectiveness/cost ratio, which would, in the end, make it fully undecipherable.

Some systems, highly effective ex-ante in theory, can be fully rejected by drivers/users because of whatever reasons. They might feel like they (the systems) are inefficient, useless, intrusive, and non-adapted to driving. This is, for instance, the case of lane departure warning in the USA, which is often disconnected because it is considered too intrusive in daily driving. This drives us back to real usage of the systems and their parametrization, of which knowledge is still poor even though it is highly important in the estimation of their effectiveness.

As a consequence, we do not mean to establish a kind of 'Top 10' so far, but recommend to multiply effectiveness studies in a private/public partnership to consolidate effectiveness estimates available by now, and disqualify ambiguities.

11.7 Current Trends and Possible Future

A lot is said, written, discussed, wrongly or badly, about connected vehicles and automated driving (Pajon et al. 2012). In both cases, connectivity and automation make people dream about better days for road safety (an automated or autonomous vehicle is supposed to eradicate human driving errors and connected driving assistance systems are supposed to be better than current stand-alone driving aids) but they also frighten people (is technology relevant, reliable, robust? What about human beings in a highly or fully automated world, what about transmission of personal data? etc.)

It is therefore useful to recall the basics of connectivity and automation to avoid any confusion or misunderstanding. In the current real-world, what is all this about precisely?

11.7.1 Connected Vehicle

Professionals and the public now seem to be aware of what we call 'the connected vehicle,' meaning vehicles connected to other vehicles or to infrastructure or to … whatever. This is actually a technical definition that hides two different functional definitions of connectivity (Road Safety & Connected Mobility (Collectif) 2014):

- A driver or a passenger can be connected with the external world via a nomadic device (e.g., a smartphone or a tablet) which has nothing to do with the vehicle. He (or she) just uses the device while driving (or as a passenger) as he or she would use these devices outside the car. This is just the general continuation in the car of the 'connected user.'
- A driver or a passenger can be connected via an integrated device which is embedded in the vehicle and can offer different types of services. In this case, the vehicle offers some services, which could by the way be redundant to the services available with a nomadic device. Let us call it the 'connected vehicle.' Of course, the connected vehicle mediates between the driver (and the passengers) and the external world. The connected vehicle can also give information to the rest of the world in case it is itself a sensor (e.g., if it detects slippery road and sends the information to the surrounding traffic).

In both cases, the services provided by connectivity (whatever the technologies behind and whatever the medium, nomadic or integrated) can be classified according to the following taxonomy:

- Safety systems: the service has a primary objective to prevent crashes and injuries. For example, car-to-car communications can help in preventing crashes at intersections where visibility is reduced by buildings, trees, bus stops, whatever kind of fixed or mobile masks to visibility.

- Driving assistance: the service has a primary objective to help the drivers in performing a driving task (navigation, guidance or control). For example, a navigation system helps the driver in choosing his (her) route and to follow directions that are proposed by the system.

These two categories can easily be grouped together since driving assistance systems often have a safety aspect too.

- Traffic information: the service has a primary objective to help the driver knowing more about the traffic ahead, e.g., whenever a route is congested, road works are present ahead of the trip or whether a route is closed for whatever reasons—services related to transport, usually called intelligent transport systems.
- Services not related to transport, often called infotainment (Internet in the car, watching or downloading videos and many other applications currently available on smartphones and tablets…).

The connection is ensured by whatever kinds of technologies (3G, 4G, 5G, DSRC, etc.), which are beyond the scope of this paper but which present high performances as well as limits. Therefore, especially for connected safety systems and driving assistance systems, the functions work under particular circumstances called 'use cases' and not in any circumstances. For example, as connected technologies usually use GPS to localize a vehicle or a person somewhere on earth, this information is known to be not very accurate (a few meters accuracy) which prevents one from using it for impact avoidance for example (at least for the moment).

Moreover, international standards of principles allow some consensual rules for human–machine interaction (HMI) in order to properly design interfaces that are not distracting drivers. These apply for any kind of manipulation the driver is in charge of (radio tuning, navigation system use, etc.).

These systems are in full expansion, though in pre-deployment phase by now. They deserve a lot of attention, especially to hinder possible distractive effects, to select, amongst all systems, those which have the largest expected safety benefits, and of course to prevent cyber-crime.

Preliminary effectiveness studies about connected driving assistance systems or connected safety systems (and for functions such as alert of incidents, blind sport detection and information about status of traffic lights) show that expected benefits are positive but minor. These effects are even lower if they are considered to be 'in addition' to stand-alone driving assistance systems.

11.7.2 Automated Driving

Autonomous vehicle, automated driving, self-driving cars, driverless vehicles, unmanned driving, automated car, etc., are expressions often used to name a vehicle (and not necessarily a car) which takes over all or part of the driving task which is today under the driver control during a trip or a fraction of the trip. The delegation from the driver to the system consists of longitudinal control and/or lateral control and/or environment monitoring, and especially obstacle detection.

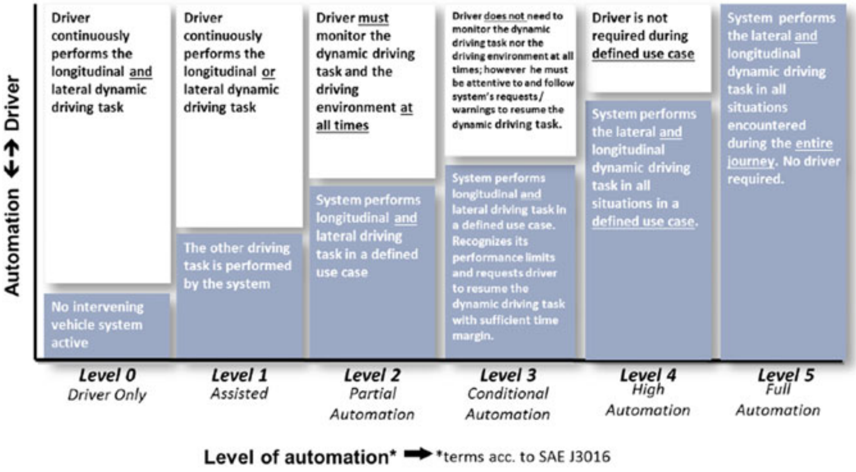
Therefore, an automated car is not systematically automated continuously and automation is not systematically complete. Automation can be conditional, partial, high or full, depending on automation level and driving situations (so-called use cases). A use case depicts a function of delegation, in certain conditions (traffic, road and environment and delegation mode). For example, the ‘Traffic Jam Assist’ function often addresses the following use case: dense traffic, up to 40–50 km/h, the vehicle drives on its lane, without any possibility of automated lane change, with road markings (left and right), all weather conditions but fog (or lack of visibility), when the driver can have his/her hands off the driving wheel.

Various bodies (NHTSA, SAE, OICA, VDA5, etc..) defined automated driving levels (in general, from 0 to 5), starting from manual driving or driving assisted with some low level of assistance, i.e., information aids (level 0) to full automation in all circumstances (level 5). These levels are established according to the distribution of tasks and driving authority between the driver and the vehicle, especially in situations when an impact is predictable (Table 11.1).

Motivations for such vehicles are ecological (optimization of traffic flows and reductions of pollution), demographical (assistance to anxious drivers, increase of comfort, assistance to elderly drivers in some difficult/uncomfortable manoeuvers), safety (reduction in crashes and mainly injury crashes), economical (optimization of vehicle lifetime and use, optimization of land use) or related to quality of life (additional time to do something else in the vehicle) (Page 2014).

The big challenges are technological (performance, reliability and robustness of sensors and artificial intelligence), ethical and legal (are we ready to drive on

Table 11.1 Automation levels



Automation ↔ Driver	Level 0 Driver Only	Level 1 Assisted	Level 2 Partial Automation	Level 3 Conditional Automation	Level 4 High Automation	Level 5 Full Automation
Driver	Driver continuously performs the longitudinal and lateral dynamic driving task	Driver continuously performs the longitudinal or lateral dynamic driving task	Driver must monitor the dynamic driving task and the driving environment at all times	Driver does not need to monitor the dynamic driving task nor the driving environment at all times; however he must be attentive to and follow system's requests / warnings to resume the dynamic driving task.	Driver is not required during defined use case	
System	No intervening vehicle system active	The other driving task is performed by the system	System performs longitudinal and lateral driving task in a defined use case	System performs longitudinal and lateral driving task in a defined use case. Recognizes its performance limits and requests driver to resume the dynamic driving task with sufficient time margin.	System performs the lateral and longitudinal dynamic driving task in all situations in a defined use case.	System performs the lateral and longitudinal dynamic driving task in all situations encountered during the entire journey. No driver required.

Level of automation* ➡ *terms acc. to SAE J3016

Source OICA, vehicle standards map 2014, Ministry of Transport, New Zealand automated road and what is the appropriate legal framework that goes with it?) and ergonomics (how to design driver automaton relationships that manage driving situations, critical situations and crash risk situations better than today?).

Some driving tasks are already partially or fully automated, for example, longitudinal control in certain traffic conditions (e.g., adaptive cruise control), but automation will come progressively, starting with simple use cases and then with more complex ones (i.e., congested traffic on dual carriage ways with longitudinal control exclusively, and then on highways at higher speeds, and then in both cases with lateral control and possible lane change, and then in more complex environments such as urban areas, etc.). Of course, fully automated vehicles are also experimentally possible now in complex traffic, at very low speed, at a high cost, on very well-known routes that the system learns: shuttle on reserved lanes without any traffic will be possible sooner than usually expected.

Conditions for deploying such vehicles also concern technical certification (homologation requires reference to technical regulations or assumption of absence of danger related to the technology if no technical regulation exists yet) and their compatibility with usage regulations: indeed, if a vehicle is certified but cannot be used because of traffic laws, for example, deployment is impossible.

There are a lot of automated systems which work in certain traffic conditions, in certain modes (eyes-on, hands-on, eyes-off, etc.), for passenger cars, public transports, other types of vehicles and on dedicated roads or public roads. There are, by now, in the research phase or in the experiment phase, current vehicles on the market being fitted with driving assistance systems underneath level 3 (out of 5) of automation. In other words, these are assistance systems. The driver can always act as a supervisor (except for autonomous braking systems, but these kinds of ‘last resort’ systems are not classified in the SAE taxonomy).

Assessment of the expected safety benefits of automated driving system is starting and the few available studies are not really convincing since they usually assert that 90% of crashes are due to human errors (meaning implicitly the driver) and that removal of drivers would remove crashes… which is to a large extent questionable…. Driver error is most often the consequence of a combination of factors, human, technical and situational that prevent the driver from correcting a critical situation with which he/she is confronted (Page 2013). Error is a symptom of a malfunction (that sometimes leads to the crash), but not a primary cause of the malfunction: accident causes are found before the error and their influence is direct or indirect, depending on when we go back in the accident analysis. For example, the combination of fatigue, speed and grip problem is a group of factors that impact the situation at the end of the accident process that ends up with a guidance error and finally a loss of control. But, upstream this process, one can identify other intermediary causes such as road configuration which favors speeding before entering a difficult bend, lighting that does not allow a good bend visibility, etc.; as well as causes even more ‘indirect’ but also predominant in terms of accident prevention such as education, information, social culture toward speed, driving, risk and safety.

An additional way of presenting things consists of considering driver errors as limits of adaptation of drivers with critical situations to which the current traffic system confronts him/her. We have also to consider that ‘human factors’ are what actually make the driving system work, more or less efficiently, despite its shortcomings, thanks to the adaptation capabilities that are inherent in humans.

If the driver is removed from driving, driver adaptation is also removed…a loss that has to be compensated by automated systems.

11.7.3 Frugal Engineering and Frugal Safety

In high-end countries, short-term future and mid-term future are definitely related to automate driving and connected vehicles that allow different types of services, especially safety services. Highly or fully automated driving, even in some specific simple use cases such as traffic jam pilot or traffic jam chauffeur on motorways, will definitely not come very soon since there is still room for technical improvements to get safe and secure vehicles that will drive with non-automated vehicles on the same roads. The more eyes-off, the more difficult. If occupants are supposed to do something other than driving, they will of course be willing to sit in a vehicle comfortably and not behind at the wheel seat, and not necessarily belted. Therefore, we collectively have to think about new restraint systems compatible with an ‘eye-off’ traffic, i.e., ‘out-of-regular-position’-occupants!

Beside this, the most predominant barriers to the deployment of safety systems are definitely their costs, and if most of them are considered to be effective in preventing injuries and extending years of life, they deserve to be encouraged.

One way of doing this is frugal engineering. Frugal engineering is the process of reducing the complexity and cost of a good and its production. Usually, this refers to removing nonessential features from a durable good, in order to sell it in developing countries. It also refers to make cost reductions during the process of innovation, engineering, production and commercialization. There are many ways of doing this, the biggest challenge is to avoid producing bad products/services at low cost in bad conditions, which could have long-term negative effects on the brand, the whole economy and the safety/security of products.

Current examples of low-cost safety systems can be found in smartphones, with a lot of free or cheap applications such as lane departure warning, drowsiness warning or forward collision warning, based on simple algorithm and the smartphone camera as sensor, for example (or blood pressure sensor as another example). They do not prove efficient and cannot be considered as frugal engineering as they are often nomadic devices produced outside the OEM’s world. A step forward would be to integrate frugal engineering as a basic paradigm for safety, so that it is for low-end cars which present nevertheless quite good levels of quality so far.

Automated vehicles, connected vehicles and frugal safety engineering are the three likely pillars for the future of vehicle safety based on technology.

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