

Safe Routes as One of the Ways to Reduce the Number of Road Accidents Victims

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Abstract. The article deals with actual problems pedestrians and cyclists safety in the cities. It is shown that, despite the positive experience of interventions implementation, road traffic deaths and injuries are still high. One of the possible ways to ensure road safety for the most vulnerable road users is to develop the method to support the safest route selection. The proposed method will increase the quality of management and effectiveness of the adopted solutions to improve traffic safety.

Keywords: Road safety management · Route selection · Pedestrian safety · Bicycle transport

1 Introduction

The scale and significance of problems associated with positive changes in image of the world transport in the 21st century, are assessed as strategic challenges to national and even continental scale. First of all, it concerns the urbanized territories where the negative impacts associated with the development and functioning of the transport complex reduce the quality of people's life. This is true also for the reason that by 2030 the majority of the world's population will be concentrated in cities. Assuming this trend continues, by 2050 more than 80% of the world's population will live in an urban environment. Therefore, using the benefits of the transport system in the area of mobility, it is necessary to make progress in the direction of increasing its safety.

Transport safety is an essential component of sustainable urban mobility and should be firmly integrated into the mobility planning processes by cities. To stem the road death epidemic, the United Nations have set the target of halving traffic fatalities by 2020. Every year, 1.25 million people are killed in road crashes and up to 50 million are seriously injured. Road crashes kill more people than malaria or tuberculosis and are among the ten leading causes of death globally, and the main cause of death among those aged 15–29 years [1]. Their economic cost is estimated at 2–5% of GDP in many countries. Cyclists represent 8% of all road deaths in the European Union but big disparities exist between countries. Cyclists and pedestrians are generally unprotected and are vulnerable in traffic. As active travel is being encouraged for health, environmental, congestion and other reasons, the safety of walking and cycling in particular must be addressed urgently. Real and perceived safety can have a profound effect on

modal choice especially in terms of the most sustainable modes of travel – walking and cycling and ability to access public transport. In the ideal case, scenario of urban mobility should be inclusive, safe, resilient and sustainable. Inclusive cities enable citizens to have the freedom to access any opportunity in the city regardless of their social characteristics or economic means. Resilience is the ability for cities to adapt and respond to changes and stresses on social, economic, and environmental systems. Traffic lights that prioritize pedestrian, cyclist, and emergency vehicle traffic puts safety for the most vulnerable on the street first.

Working Group composed by international road safety experts prepared Research Report titled “Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System” which was presented in Paris on 3 October 2016 at a dedicated Road Safety Seminar of The International Transport Forum [2]. This report describes a paradigm shift in road safety policy, according to the principles of a Safe System. A Safe System is based on the premise that road crashes are both predictable and preventable, and that it is possible to move towards zero road deaths and serious injuries. This, however, requires a fundamental rethink of the governance and implementation of road safety policy.

Insufficient attention has been paid to the needs of pedestrians, cyclists and motorcyclists, who together make up 49% of all global road traffic deaths. Making the world’s roads safer will not be possible unless the needs of these road users are considered in all approaches to road safety. Traffic planning and safe routes development should be carried out considering characteristics of all categories of road users. It is necessary to take into account the fact that each of these categories can be considered as a separate sub-system of the city transportation system. Its safety and sustainability is ensured by minimizing the number of conflict points that might arise in the interaction of road users. In such systems, possibilities of management (decision-making) based on the information received in real time, have to be available not only to the operators controlling transport, but also to all road users. The objective of such a system is integration of all road users’ interaction: people - transport infrastructure - vehicles, with the maximum use of the latest information and control technologies.

2 Safety Issues of the Most Vulnerable Road Users

The number of road traffic deaths has plateaued since 2007 [1]. The plateau in road traffic deaths, set against a 4% increase in global population and 16% increase in motorization, suggests that road safety efforts over the past years have saved lives. However, low-income countries have fatality rates more than double those in high-income countries. Almost half of all deaths on the world’s roads are among those with the least protection – motorcyclists (23%), pedestrians (22%) and cyclists (4%). As motorization increases worldwide, walking and cycling have become less common and more dangerous. The traffic mix in many countries means pedestrians and cyclists share the road with high-speed vehicles, forcing them to negotiate dangerous situations and fast moving traffic.

2.1 Technical Measures to Increase Proportion Walking and Cycling in Modal Split

Written by Shannon Bouton, global manager of the McKinsey Center for Business and Environment, and three other senior McKinsey analysts, the report “Urban Mobility at a Tipping Point” finds that “Automobile sales are expected to increase from about 70 million a year in 2010 to 125 million by 2025, with more than half forecasted to be bought in cities” [3]. Authors mention the opinion of automotive analysts who predict that today’s 1.2 billion strong global car fleet could double by 2030. “The existing urban infrastructure cannot support such an increase in vehicles on the road”, McKinsey warns. Four major technological trends are converging, McKinsey reports. They are “in-vehicle connectivity, electrification, car sharing, and autonomous driving”. Walking and cycling are becoming increasingly popular in cities, notes the report, which finds that cities around the world are opening car-free zones to pedestrians and bikers.

Sustainable urban mobility plans and transport strategies aim to reduce mobility demand, shifting to environmentally friendly modes of transport such as walking, cycling and car sharing, increasing the share of public transport and clean vehicles, and the use of state of the art technology for the remaining individual motorized transport. Reducing travel distances and travel demand is therefore an important cornerstone for sustainable urban transport. This imply that the city’s inhabitants should not be forced to travel far to fulfill basic needs. Distances should ideally be kept so short that walking or cycling is the attractive/likely mode of transport.

Short distances also improve the possibilities for an enhanced modal shift. This is important to achieve a fair transport system that gives all groups in society equal or high accessibility to important services, independent of car ownership. Reduction of the transportation needs is achieved through the application of sustainable spatial planning polices that support and encourage mixed-use developments. These developments meet the housing, shopping, commercial and employment needs of residents within walking and cycling distance or are accessible by public transport.

Cities around the world are opening car-free zones to pedestrians and bikers. There are many examples of city centers, such as Venice and the medieval city of Mdina, in Malta, that have never allowed motorized vehicles. Mdina is even known as the “Silent City” because of the absence of motor-traffic noise inside the city walls. Pedestrian zones in Japan are called *hokōsha tengoku*, which translates as “pedestrian heaven”. Parts of the Calle Florida in Buenos Aires have been restricted to pedestrians since 1913 and the whole street since 1971. More recently, many cities have moved to pedestrianize parts of their city centers. Examples include London, New York, Paris, and Singapore. These efforts often include not only restricting access to cars but also making the streets themselves more attractive to pedestrians by installing better lighting, street signage, and paving materials and adding more greenery.

In addition, many cities are trying to make bicycling safer, easier, and more popular. A study conducted by the Urban Land Institute [4] allows us to understand main regularities in the development of cycling transport. Even in such country, that is oriented to automobile industry, like USA, where almost 70% of population live in private homes, remote 15–30 miles from major transport centers of attraction (jobs, shops, etc.), more than 50% of the residents consider, that cycling and walking

accessibility is a top priority when choosing a place of residence, and cycling has become the fastest growing form of passenger transport.

Some cities are experimenting with restricting the entry to the certain streets on weekends; for example, a portion of Central Jakarta is closed on Sunday morning to allow residents to exercise. These efforts can have positive implications for urban mobility. Forty years ago, traffic was terrible in Copenhagen. In 1981 the city developed its first cycling plan and it has been evolving its cycling and mixed-modal goals since 2002. Now transport authorities created a network of bicycle lanes as well as dedicated bicycle highways that reduce traveling time and improve safety. City has a target indicator: 50% of all commutes should be by bike.

It is perfectly feasible for a majority in a metropolis to ride a bike and not travel by car. Not everybody can ride a bike every day, however, which is why the bike should not be seen as a competitor, but rather as complementary to public transport. Especially on the way to and from work there is a lot of potential: in London around 2.5% of all commutes to work are by bike, in Berlin 13%, in Munich 15% and in Copenhagen and Amsterdam a whopping 36 and 37% respectively. Such a high percentage of number of trips to work or education by bicycles in Copenhagen is provided by the fact that the priority strategy of politicians is development of bicycles infrastructure as a way to create more friendly city living condition [5].

Bike sharing has hit the mainstream. In 2015, there were more than a million bikes in bike-sharing programs globally and more than 850 cities had such programs, up from 68 in 2007. One of the most popular counter-argument about cycling are adverse climatic and natural conditions. However, it is a matter of attitude and priority for cycle paths when clearing snow. This is confirmed by the example of Oulu, where a substantial proportion of people commute by bicycle, even when the temperature is below zero in deepest winter. This is ensured by 845 km of routes (4.3 m per inhabitant), 98% of which are maintained throughout winter because main route maintenance prioritised over driveways. Routes parallel to driveways are separated with a green lane, which also serves as snow build-up space. There are underpasses in most busy crossings and you can reach every place by bike using cycling routes [6].

London is building 12 “cycle superhighways” – extra-wide lanes dedicated to bicycles. New York expects to have 1,800 miles of bike lanes by 2030. Paris has a bike-sharing network that includes the suburbs and is integrated into the public-transit payment system; São Paolo is doing the same. Delhi is considering proposals to set up separate bike lanes and is providing bike parking near transit stops. Moscow is expanding bike sharing and adding dedicated bike lanes. San Francisco is expanding its network of bicycle lanes; the city’s goal is to increase the percentage of all trips taken by bike from 3.4 to 10% by 2018.

Companies in Silicon Valley are piloting electric bikes as means of commuting. At one major technology firm, more than 10% of employees bike or walk to work, and a half of them live within ten miles of the office. A ten-mile commute by car takes about 30 min door to door. By bicycle that would take about 60 min; by e-bike, though, it would be only 35 min, which makes it an attractive option. Getting employees to bike to work is worth real money; each parking space that can be saved on corporate campuses is worth \$10,000 to \$20,000.

Reduction of conflict points, where the flows of pedestrians, motorized and non-motorized vehicles cross, is the most effective method of increasing safety in transport system. Effective segregation of road traffic is the central requirement of the most campaigners' demands for greater safety, and SkyCycle is one of the most extreme methods of separating bicycles from cars on the agenda. By building a new network of cycle paths high above existing roads and railways, the scheme would create a series of cycle superhighways across London, with specific entry and exit points throughout the city [7]. Dominican architect Richard Morita Castillo offers for solution of transport problem in large cities to build dedicated lanes for cyclists. Innovation lies in placing these lanes over city highway. Such overpasses for cyclists Castillo calls ecobans (like autobahn) or Cycling underground [8]. A similar solution is proposed for Moscow and Kazan [9, 10]. And for Russia it is not only the division of space and diminution the number of conflict points, but also necessary protection for cyclists in difficult weather conditions.

2.2 Organizational Measures of Safe Route's Planning

The quality of the transport system's functioning is largely determined by the quality of management. Operational management in modern conditions is carried out through the intelligent transport systems (ITS) creation. These systems consist of modules for collecting operational information on the status and parameters of the vehicle's operation, analyzing imbalances and searching the causes of their occurrence, as well as developing recommendations for the processes optimization. ITS is increasingly seen as one of the components of solution of the current and future problems in the field of transport. Rational management allows not only increasing the economical performing indicators of the system, but also solving social tasks of the population's transport service improvement, as well as increasing safety of the transport system.

Rational management is based on the "feedback" principle implementation. According to this principle managerial decisions should be corrected in accordance with the identified errors and the system performance deficiencies in the previous period. The purpose of the safety management is reduction of accidents and injuries. This means that the problems of monitoring and conflict situations' detecting, determination of the causes of emergency situations, as well as development of measures to address the causes and reduce the severity of the accidents' consequences are solved.

The main feature of large cities and metropolises is the need to travel long distances both in regular and in one-time trips. Besides, safety and complexity of the route are the determining factors for certain categories of population.

Thus, it is necessary to pay attention to these issues while planning routes. Modern electronic resources (route planners and navigators) allow building a route between two points on the map. The most common of these systems allow selecting the route on the city map specifying one of three types of travel: personal vehicle, public transport and pedestrian route. The quality of the route depends on the degree of elaboration of maps and it is not always possible to obtain adequate information. There are planners

designed for individual countries: 2GIS for Russia, jakdojade.pl for Poland, etc. Such planners provide more opportunities to consider individual characteristics while selecting a route. For example, you can select the route for disabled or for cyclists. Despite the large number of applications for path finding, they have one significant drawback: the route is not evaluated from the point of view of its safety.

2.3 Crossroads as a Source of Increased Danger

Pedestrian crossings are safe places for pedestrians to cross the road and where they are given priority. There are various different types of pedestrian crossings, these are: Zebra, Pelican, Puffin, Toucan, Pegasus (also known as Equestrian crossings) [11]. As it is revealed in research [12], almost 30% of pedestrian injuries occur at non-signalized crosswalks. Factors of fatality risks were used to model a binary logistic regression which treated the statistical information provided by the police. Many countries apply signalized pedestrian crossings granting pedestrians the minimal waiting time and allowing the vehicular traffic to continue uninterrupted if there are no pedestrians in view. The main advantage of signalized pedestrian crossings consists in providing both motorists and pedestrians with a clear perception of the situation at intersection. Instead of solving of a complex logical-physical task, they are offered to primitively react to a light signal with a conditioned reflex. In Europe, where priority is given to pedestrians, there are numerous signalized crosswalks and practically no non-signalized ones across busy four-, and more, lane roads [13].

It is reported [14] that the major reasons for pedestrian noncompliance with traffic signals are the low quality traffic management, traffic volume and long waiting time. In the research [15] it is shown that designing of a signal should take into account the use of neighboring land and the results of traffic survey. Another factor of risk is the conflict between the vehicular and pedestrian flows at left-hand corners [16, 17].

Different models have been proposed for risk assessing and working out of measures to improve the pedestrian safety. Thus, the model proposed in research [18] allows measuring the impact of potential risk factors on pedestrians' intended waiting times during the red-man phase of the traffic lights. In a later research, the author proposes a multivariant method of risk analysis consisting of two hierarchically generalized linear models, characterizing two different facets of unsafe crossing behavior, and uses a Bayesian approach with the data augmentation method to draw statistical inference for the parameters associated with risk exposure. Dependence severity of accidents by vehicle speed is explored in research [19]. The authors took into account age group of pedestrians and vehicle type (sedans and light passenger cars). The authors determined that elderly age group (60 years old and over) faces higher risks of serious injury and fatality than both the child age group (12 years old and under) and the mid-age group (13–59 years old). The authors suppose that the findings should be included in designing specifications of pedestrian detection system in the near future.

3 Results and Discussion

3.1 Using the Haddon Matrix to Improve Traffic Safety

The Haddon Matrix, developed by William Haddon in 1970, looks at factors related to personal attributes, vector or agent attributes and environmental attributes; before, during and after an injury or death. By utilizing this framework, one can then think about evaluating the relative importance of different factors and design interventions. In fact, it is a set of preventive measures to improve road safety. In this context, primary prevention refers to interventions before the event, to prevent it completely; secondary prevention involves lessening the extent of injury given that an event occurs (e.g., wearing a seatbelt will not prevent the collision but may lessen its effects). Tertiary prevention limits the subsequent difficulties a person encounters given his injuries (rehabilitation, etc.). You could also add primordial prevention, which would refer to underlying social change that would alter the circumstances in which the accident occurred. For example, encouraging public transportation would reduce roads' overloads and likely prevent some accidents.

The adoption of measures to improve road safety, as a rule, is based on the analysis of statistical data on offenses and traffic accidents. This analysis allows you to adjust the traffic patterns, make changes to infrastructure and make recommendations to manage traffic [20]. Official statistics of the State Traffic Safety Inspectorate (STSI) of Naberezhnye Chelny city as well as the data from the official website of the STSI of Russian Federation is used as initial information. Preventive measures to improve the road safety include identification of violations that can be divided into two categories: violations that increase the possibility of an accident (drink-driving, leaving the oncoming traffic) and violations that increase the severity of accident consequences (disuse of child restraints and seat-belts). You could also add primordial prevention which would refer to underlying social change that would alter the circumstances in which the accident occurred. Such events may be, for example, planning safe routes, which eliminate or minimize risks, and include measures that will reduce the severity of the consequences in the occurrence of risk situations.

3.2 Proposed Algorithm of the Safest Route's Selection

In constructing the routes of urban mobility it is necessary to choose the safest possible routes, taking into account characteristics of the participant movements. The categorization of the route can be performed in the presence of different factors, complicating traffic conditions. Depending on the type of move routes in the city can be road, pedestrian, cycling and combined. The combined route usually includes areas where the movement takes place by public transport, and the movement between the start (end) point and public transport, on foot or by bike. These areas are evaluated by different criteria groups because for different categories of the population priorities may be different. For example, the selection by the criterion "fastest route" may just not realize for people with disabilities, and in some cases this route may be unsafe. Therefore, we propose a methodology a multi-criteria evaluation of the safety of the route. The integrated circuit evaluation algorithm is shown in Fig. 1.

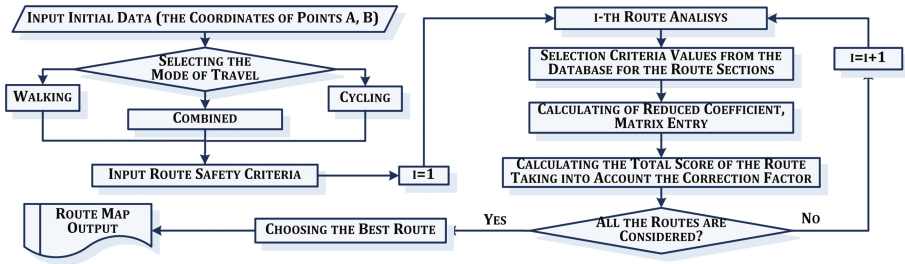


Fig. 1. The integrated algorithm of the route safety assessment

In the first stage there were the factors, which determine the category of the route complexity (Table 1) for pedestrians and cyclists. Since the significance of the factor for different categories of traffic participants is determined by their features to determine the weight factors have been used for the category pedestrians and cyclists by age and state of health (Table 2). The evaluation of the route can be done with the help of a complex indicator, which is calculated as the weighted average:

$$K = \sum_{i=1}^n K_i \cdot \alpha_i \tag{1}$$

where:

K_i - the value of the i -th parameter,

α_i - weight of the index.

In order to summarize dissimilar indices in the formula their reduced values are calculated.

Table 1. Factors influencing the route’s safety.

Factors	Significant factor for	
	Pedestrians	Cyclists
The length of the route	+	+
The length of sections with elevation changes	+	+
The number of pedestrian crossings	+	+
The number of unregulated intersections	+	+
The number of lanes of the highway at the place of pedestrian crossings	+	+
The number of ramps	+	+
The number of underground/raised pedestrian crossings	+	+
The length of bikeways on the route	-	+
The presence of places of concentration of road accidents on the route	+	-

Table 2. Types of pedestrians and cyclists.

Children	Youth, Middle-aged people, Retired	Disabled
Preschoolers	Without health problems	Doesn't require special conditions for movement
Students	With problems	Needing special conditions

Factors that determine the safety of the route can be both objective (e.g., terrain, presence of unregulated intersections, etc.), and subjective due to the features and physical condition of the road user (age, health condition, etc.). Adequacy of the assessment will depend on the correctness of the selected factors and their combined inclusion. For example, the same route can be safer in the daylight than in the dark, in the summer than in the winter, etc. Possible routes are evaluated on the base of this information. To do this a matrix of the given route options is constructed and then the overall routes' performance indicators are calculated. The value of the route safety indicator is calculated with provision for correction factors that depend on the physical condition and characteristics of the user. A significant part of all urban movements is a mixed routes that include parts of the route where people go on foot, by bicycle or by public transport. That is why when assessing the route along with the safety of walking and cycling areas the number of transfers on the route, because the safety of such interchange nodes can be a determining factor.

3.3 An Example of Route Planning: Case Study of Naberezhnye Chelny

The route between gymnasium "A golden hill" and Organ Hall can be considered as an example. This relatively small length route (from 1.2 to 1.4 km) has its own peculiarities. Part of the route passes through the yards, the most long part passes along Moskovskiy pr. and the small part passes along perpendicular streets: Yashlek prospect and Kamal boulevard. There are three lanes in each driving direction of Moskovskiy prospect, that is one of the main longitudinal streets of the city. There are only two traffic lights at the beginning and at the end of the considered area and there are two pedestrian underpasses near the bus stops. Besides that, there is a non-signalized crosswalk (Zebra) that due to the specifics of the traffic organization in this area is unsafe. As the Fig. 2 shows, Yandex Maps (YM) and Google Maps (GM) lay almost the same routes that differ from each other by the way of passing through the yards. However, both of them propose to use unsafe non-signalized Zebra crosswalk though there are two pedestrian underpasses in the considered area.

The second feature of this route is that it is too long for elderly people (seniors), physically disabled people and pedestrians with small children. It is possible to solve this problem by using public transport, i.e. combined route. YM system proposes to use a tram that follows from the point "Rembyttekhnik". This route is comfortable because you can cross the road using the signalized crosswalk. However, there is another alternative route that is not considered by YM system: if you use the pedestrian underpass that is located just before the tram stop, you can travel one stop less and,

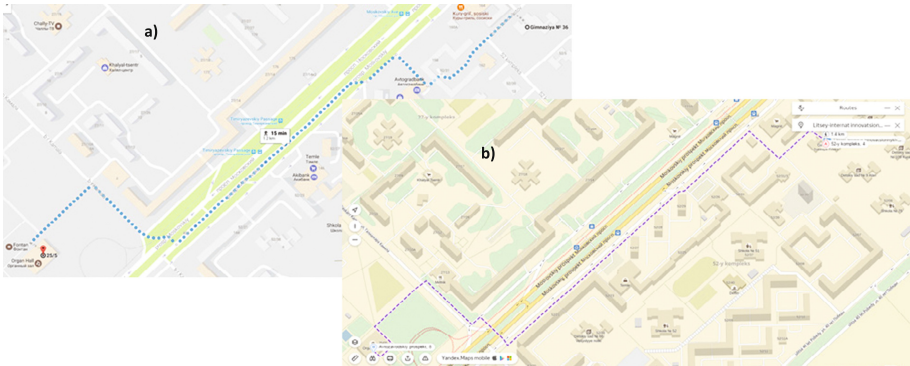


Fig. 2. The route laid by Google (a) and Yandex (b) Maps

what is more, you can use tram of any route. After selecting the “Less walking” option GM system proposes two variants. The first is to take the bus following through a turn in the direction, opposite to the destination and then to cross the road and to use public transport in the necessary direction (Fig. 3a). The second is to travel to the right direction directly after crossing the road (Fig. 3b).

At the same time specification of these maps is insufficient to construct an optimal route. Moreover, many residents of the city would have used a completely different route, which is not indicated neither in YM system, nor in GM system. A more adequate route is provided by the 2GIS search system (Fig. 4).

The given example shows that development of tools for comparison and evaluation of possible routes from the point of view of safety and acceptability for different population groups, is a good addition to existing route planners.

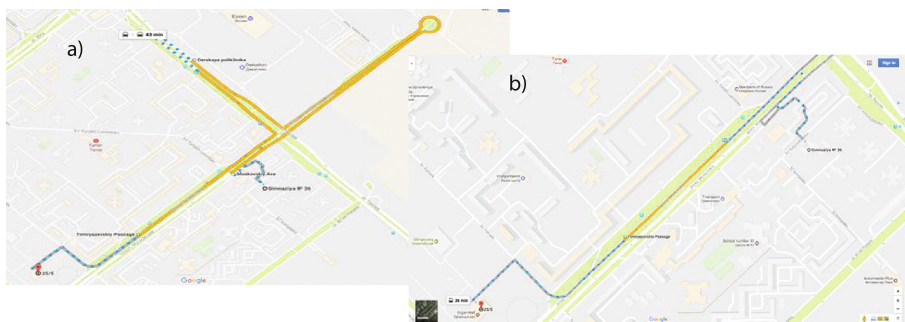


Fig. 3. The route laid with “Less walking” option



Fig. 4. The route laid by 2GIS

4 Conclusions

Safety of pedestrians and cyclists is an actual problem. Its relevance increases due to the growth of motorization and its negative effects. To improve the effectiveness of measures aimed at reducing the risks of road accidents the special tool is needed. It should allow responding quickly to changes in the transport system and to assess the effectiveness of the measures taken. Proposed system for the route's safety assessment and evaluation of the effectiveness of measures aimed at reducing the risks of dangerous situations will allow making justified managerial decisions.

References

1. World Health Organization. http://www.who.int/violence_injury_prevention/road_safety_status/2015/GSRR2015_Summary_EN_final.pdf
2. International Transport Forum. <http://www.itf-oecd.org/road-safety-seminar-safe-system>
3. McKinsey. <http://transact.org/mckinsey-report-urban-mobility-tipping-point/>
4. Urban Land Institute: Active Transportation and Real Estate: The Next Frontier. Urban Land Institute, Washington (2016)
5. Bredal, F.: The case of Copenhagen. In: Roethig, M., Efimenko, D. (eds.) Changing Urban Traffic and the Role of Bicycles. Russian and International Experiences, pp. 24–28. Friedrich-Ebert-Stiftung, Moscow (2014)
6. Tahkola, P.: The case of Oulu. In: Roethig, M., Efimenko, D. (eds.) Changing Urban Traffic and the Role of Bicycles. Russian and International Experiences, pp. 29–43. Friedrich-Ebert-Stiftung, Moscow (2014)
7. Construction Chat. <http://www.constructionchat.co.uk/articles/skycycle-london-bike-network/>
8. 5dimensions. <http://05dimensions.wordpress.com/2012/10/22/bici-metro-an-alternative-project-to-sky-cycles-is-available-for-global-implementation>
9. Smart News. <http://smartnews.ru/regions/kazan/14990.html>
10. Velomesto. <https://velomesto.ru/magazine/in-russia/na-vdnh-mozhet-poyavitsya-velopoliten/>
11. World Driving. <http://www.driving-school-beckenham.co.uk/pedestriancross.sigs.html>
12. Olszewski, P., Szagała, P., Wolański, M., Zielińska, A.: Pedestrian fatality risk in accidents at unsignalized zebra crosswalks in Poland. *Accid. Anal. Prev.* **84**, 83–91 (2015)

13. The National Archives. <http://www.legislation.gov.uk/uksi/1997/2400/made>
14. Brosseau, M., Zangenehpour, S., Saunier, N., Miranda-Moreno, L.: The impact of waiting time and other factors on dangerous pedestrian crossings and violations at signalized intersections: a case study in montreal. *Transp. Res. Part F* **21**, 159–172 (2013)
15. Di Stasi, L.L., Megias, A., Cándido, A., Maldonado, A., Catena, A.: The influence of traffic signal solutions on self-reported road-crossing behavior. *Span. J. Psychol.* **17**, 1–7 (2014)
16. Alhajyaseen, W.K.M., Asano, M., Nakamura, H.: Estimation of left-turning vehicle maneuvers for the assessment of pedestrian safety at intersections. *IATSS Res.* **36**, 66–74 (2012)
17. Quistberg, D.A., Howard, E.J., Ebel, B.E., Moudon, A.V., Saelens, B.E., Hurvitz, P.M., Curtin, J.E., Rivara, F.P.: Multilevel models for evaluating the risk of pedestrian-motor vehicle collisions at intersections and mid-blocks. *Accid. Anal. Prev.* **84**, 99–111 (2015)
18. Li, B.: A model of pedestrians intended waiting times for street crossings at signalized intersections. *Transp. Res. Part B* **51**, 17–28 (2013)
19. Oikawa, S., Matsui, Y., Doi, T., Sakurai, T.: Relation between vehicle travel velocity and pedestrian injury risk in different age groups for the design of a pedestrian detection system. *Saf. Sci.* **82**, 361–367 (2016)
20. Makarova, I., Khabibullin, R., Belyaev, A., Mavrin, V.: Urban transport system management in the context of region sustainable development strategy. *Trans. Probl.* **8**(2), 107–111 (2013)