

Routes' Safety Evaluation Application Development

Ksenia Shubenkova^{1*}, *Vadim Mavrin*¹, *Gulnaz Sadygova*¹ and *Polina Buyvol*¹

¹Kazan Federal University, 10A Syuyumbike prosp., Naberezhnye Chelny, 423812, Russia

Abstract. Pedestrians and cyclists are the most vulnerable road users. One of the ways to increase their safety is the safest route selection. Nowadays, there are a lot of navigation systems and route planners. However, these routes are not assessed from the viewpoint of their safety. The article describes one of the possible system alternatives to assess the safety of route for different types of road users. The developed system is based on the multifactorial analysis of information. Correction factors allow considering special features of each type of road users. The developed algorithm is implemented as an application.

1 Introduction

The scale and significance of the problems accompanying positive changes of the world transport in the 21st century are considered as strategic challenges of national and even continental level. First of all, this applies to urban lands, where negative consequences associated with development and operation of the transport systems reduce quality of life of population. This is also relevant because of the prediction that in 2030 most of the world's population will be concentrated in cities. Assuming that this trend will continue, by 2050 more than 80% of the world's population will live in an urban environment. Therefore, it is necessary to take into account all possibilities that transport system provides for population's mobility support and, at the same time, to make progress towards the increase of its safety [9].

The global trend of urbanization and population growth, together, create a negative pressure on environment and necessitates the development of an environmentally friendly and energy-efficient way of living in cities. Sustainable development of society is ensured through environmental sustainable solutions combined with a full use of all possibilities of society's digitization. This means an enablement of information technologies to gather data, to transfer collected information to people or to other information systems, and to obtain the necessary data from any sources that can be used to adapt the most sustainable and smart development of society [6].

Cities are places for innovation, drivers of our economy and places where wealth and jobs are created. At the same time, urban lands are characterized by the density of people, realization of their activities, interaction of economic, social and cultural functions. Thus, cities are the places of accumulation of both, opportunities and threats to sustainable

* Corresponding author: ksenia.shubenkova@gmail.com

development. In this context, the three pillars of sustainability (economy, society and environment) become equally important.

The image of the transport system of the future implies interaction between all road users (vehicles, buses, pedestrians, cyclists, rail and other modes of transport), as well as between them and transport infrastructure, V2X (vehicle-to-everything) connection.

It will save time and resources; reduce emissions, congestion and traffic jams; increase efficiency of the land use, and provide safety for all road users.

2 Review: Current State of Transport System and Traffic Safety Problems in Cities

Transport safety is an essential component of sustainable urban mobility and have to be firmly integrated into the planning of the city's transport infrastructure. In order to stop the road death epidemic, the United Nations has set the target of halving traffic fatalities by 2020. Every year, 1.25 million people die 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 [3]. Their economic value is 2-5% of GDP in many countries. According to the European Commission, only about 7% of traffic accidents occur on highways, 38% of all traffic deaths occur in urban areas (Fig. 1). Most deaths (55%) occur in rural areas, but the percentage of vulnerable road users, including pedestrians, cyclists and motorcyclists, who make up almost half of the road traffic victims, is higher in urban areas. It is possible to increase the worldwide road safet only if all road safety programs and actions will take into account, first of all, the needs of the least protected road users.

Traffic planning and safe routes development should be carried out considering characteristics of all road users. It is necessary to take into account the fact that each of these categories can be considered as a separate subsystem 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 [10]. In such systems, managerial (decision-making) capabilities based on real-time information should be available not only to transport operators, but also to all road users. The main target of such a system is an integration of all road users' interaction (people – transport infrastructure – vehicles) with the maximum use of the latest information and management technologies.

Since transport safety is one of the most important components of sustainable mobility, any changes in urban mobility patterns and efforts to improve road safety can be concerned as a critical challenge affecting the social and economic costs of accidents. Thus, road safety problems have to be solved at all levels of mobility planning. Real and subjectively perceived safety can have a profound impact on the modal split, especially in terms of the most sustainable modes of transportation – walking and cycling, access to public transport.

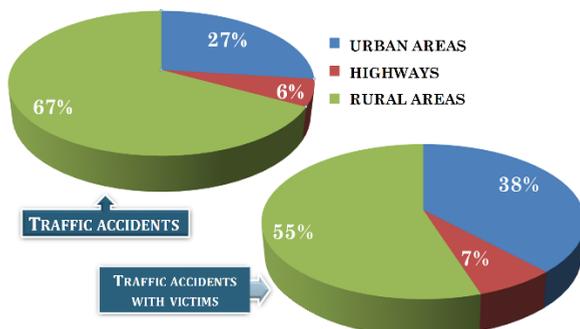


Fig. 1. Traffic accidents by road types.

In recent years, more and more cities are included in the Smart City program. The concept of Smart City can be defined as a city development model, in which resources are effectively spent through the use of information and communication technologies (ICT), applying a systemic approach, as well as eco-friendly integrated solutions. This raises the need to increase mobility and interaction through the pooling of efforts and knowledge among all spheres of society [15]. One of the directions in the Smart City creation should be implementation of smart transport systems that corresponds to Millennium Development Goals, to the concept of sustainable development and to transition to a green economy [4]. Since transport is one of the main sources of air pollution, greenhouse gas emissions, consumption of non-renewable resources, household inconveniences caused by the proximity to a highway and noise [3], there is an increase in the number of supporters of the transition to “green” transport, initiating development of the concepts and policy documents on the sustainable development of urban transport systems [6,7].

3 Materials and Methods: Organizational Actions for Safe Route’s Planning

3.1 Electronic Route Planners and Their Disadvantages

Quality of the transport system’s operation is largely determined by the quality of management. Operational management in modern conditions is carried out through the creation of intelligent transport systems (ITS), which provide modules for collecting operational information on the status and parameters of the vehicle’s operation, analyzing imbalances and finding the causes of their occurrence, and developing recommendations for optimizing processes. ITS is one of the ways to solve current and future transport problems. Rational management allows not only to increase the economic performance of the system, but also to solve social problems, such as improvement of transport services for population, as well as improvement of the transport system’s safety [9].

Rational management is based on the implementation of the “feedback” principle, according to which management should be adjusted in accordance with the system’s errors and deficiencies identified in previous period. The purpose of the safety management is to reduce accidents and injuries, therefore, the problems of monitoring dangerous situations on the roads, identifying their causes, developing actions to eliminate causes and reduce severity of the accidents’ consequences are solved.

One of the main feature of large cities is the need to overcome significant distances, both with regular and single trips. In addition, safety and complexity can be the determining factors when certain categories of population select the given route.

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 depending on the mode of transport: personal vehicle, public transport or walking. The quality of the route depends on the degree of elaboration of maps and, unfortunately, it is not always possible to obtain adequate information. There are planners designed for a concrete country that allows using more accurate and elaborate selection algorithms. However, in addition to routes, such planners can contain advertising information that makes it difficult to use them. For Russia it is 2GIS, in Poland – jakdojade.pl. Such planners provide more opportunities to consider individual characteristics of a person while selecting a route. For example, you can select the route for the disabled people. Some planners can consider a bike as a mode of transport.

Despite the large number of applications for route planning, they have one significant disadvantage: they don't allow to evaluate a route in terms of its safety.

3.2 Pedestrian Crossings as the Places of Increased Danger

Pedestrian crossings are safe places for crossing a road by pedestrians, where they have a priority. In different countries, the types of crosswalks are determined by local legislation. Thus, in the United Kingdom such types of pedestrian crossings as Zebra, Pelican, Puffin, Toucan, Pegasus (also known as Equestrian crossing) [13] have their own design features. These types of pedestrian crossings are created within the framework of the "pedestrian priority" concept and are aimed at ensuring its maximum safety.

Authors of the research [12] note that almost 30% of pedestrian injuries were obtained at non-signalized crosswalks. To study the influence of various factors on the risk of pedestrian death, a binary model of mutual influence was developed. The statistical information provided by the police was used for this study.

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. The main advantage of signalized pedestrian crossings is the provision of a clear understanding of the situation at intersection to both drivers and pedestrians. Instead of solving complex logical-physical problems, they allow us to react primitively to a light signal with the aid of a conditional reflex. In Europe, where priority is given to pedestrians, there are numerous signalized crosswalks and practically no non-signalized ones across high loaded four and more lane roads [8].

The main factors influencing the violation of pedestrian crossing rules are: waiting time and parameters of traffic and pedestrian flows, as well as the type of traffic lights [2]. The effect of the traffic light's constructive solution on the pedestrian crossing safety is analyzed in the research [11]. Another risk factor is the conflict between vehicular and pedestrian flows at left-hand corners [1,14].

To assess risks and to develop measures to improve pedestrians' safety, various solutions are offered. Thus, the author of the research [5] proposes a model for estimating the influence of the waiting time on the number of pedestrian crossing rules violations. At the same time, the author notes that a multi-factor risk analysis is needed and allocates a promising direction for future researches: a multivariate approach to estimate solutions based on the proposed model.

4 Theory: Proposed Software Solution for the Route's Selection

Since the main purpose of actions to improve transport systems' safety is to prevent deaths and injuries, both technical and organizational measures should lead to reduction of the accidents' likelihood and the severity of their consequences. Accidents' statistics of different countries show that a significant part of incidents in the transport system is determined by the "human factor". This concept includes incidents of completely different nature (inadequate behavior of drivers and pedestrians, objective reasons in the form of complex road conditions, poor health, etc.). That is why proponents of the transport systems' intellectualization believe that excluding a human from the control loop can increase safety. However, in our opinion, decrease in the number of road accidents depends to a large extent on the quality of the transport system's management. This means, first of all, a reduction in the number of conflict points between different categories of road users. Currently, many solutions are offered to improve the situation on roads. These decisions are aimed at reduction of the likelihood of potentially dangerous situations. For example,

infrastructure solutions: creation of roundabouts, lanes separation, allocation of bike paths, creation of pedestrian underpasses and crosswalks.

Such decisions have positive consequences, however, in our opinion, when planning routes for urban movements, it is necessary to choose the safest route possible, taking into account characteristics of the road user.

We suggest a software solution for the best route selection. Evaluation of the route should be carried out in terms of its safety, convenience and comfort. To compare the routes, a multi-criteria evaluation is used, taking into account the characteristics of the road users and their preferences.

The route can be categorized by evaluating factors that complicate traffic conditions. Depending on the type of transportation routes can be walking, cycling, motorized and combined. The combined route, as a rule, consists of transportation by public transport and walking or cycling between the initial (final) point and the bus stop. These parts of the route are assessed using different groups of criteria, because priorities may differ for different population categories. So, for instance, the route selected by the criterion “the fastest route” may be not suitable for disabled people, and, in some cases, such a route may be unsafe. Therefore, we propose a methodology for multi-criteria evaluation of the route’s safety.

At the first stage, factors that determine the category of the route’s complexity were identified for pedestrians and cyclists (Table 1). Since the importance of the factor for different categories of road users is determined by their characteristics, to determine the weight of each factor the categories of pedestrians and cyclists were identified by age and physical conditions (Table 2).

Factors determining the safety of the route can be either objective (terrain, presence of non-signalized crosswalks, etc.), and subjective, depending on characteristics and physical capabilities of the road user (age, state of health, etc.). Route’s assessment can be adequate only if factors were identified correctly and their interaction is considered. To evaluate the route, the initial data should be specified and a matrix of standardized factors influencing the route’s safety should be built. Then, a complex indicator of each route is calculated:

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

where K_i – the value of the i -th factor, α_i – weight of the i -th factor.

Table 1. Factors influencing the route’s safety.

Factors	The significance 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	Without health problems	Without health problems	Doesn't require special conditions for movement
Students	With problems	With problems	With problems	Needing special conditions

The weight of the i -th factor depends on the characteristics of the road user. To standardize factors, the total length of the route is used (Fig. 2). Since combined routes that comprise parts of the route where public transport is used, as well as walking and cycling ones, when evaluating the route the number of transfers should also be considered as a determination factor. The initial information to build routes (maps, characteristics of the street-road network's segments, data on terrain, type of road surface, presence of ramps, signalized and non-signalized crosswalks, etc.) is stored in the database.

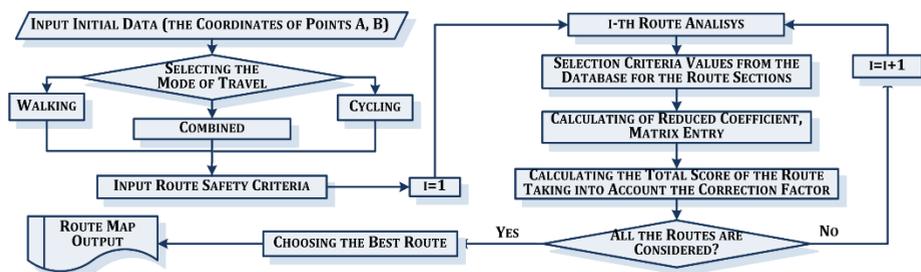


Fig. 2. Scheme of the algorithm to evaluate the route's safety

5 Results and Discussions: Practical Implementation of the Proposed Software Solution

To implement the proposed idea, an application for smartphones integrated with the GIS-system was developed (Fig. 3). To verify the route, the user enters or points to the map his location and destination. At the command “find a route” user gets a list of routes sorted by the time of reaching the goal.

Then, the user can proceed to checking the route's safety. After the route's evaluation is complete, the user can view the route. When the map is approaching, as well as when selecting a certain part of the route on the map, there are areas highlighted with different colours: dangerous areas are marked red and yellow (for example, non-signalized crosswalks, the part of the route without bicycle lane). Safe areas are marked green. Thus, the color of the route depends on the total safety score, from green (the safest) to red (the most dangerous).

The application provides the ability to evaluate the route by the user. He can leave a review and also indicate problems on the route, attaching photos or text description. The city government and road services, having received information on the state of infrastructure, can react quickly and take necessary actions to solve the problems identified by citizens.

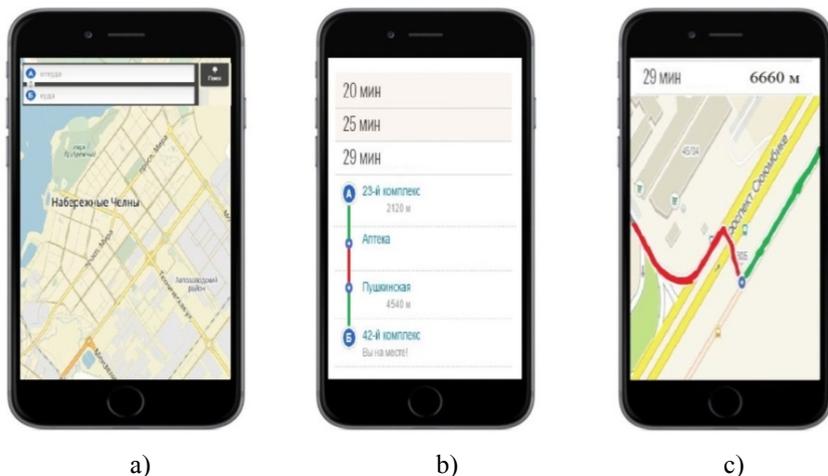


Fig. 3. a) Selecting the destination point on the map; b) Routes' alternatives; c) Viewing the route

The application was tested on the site of the Naberezhnye Chelny city's road network. For the correct operation of the application, it is necessary to update initial information stored in the database. Usage of a mobile application to find the safest routes will allow not only to plan trips, but also to reduce the likelihood of emergency situations. In addition, such an application will be useful in the development of walking and cycling infrastructure, as it will be possible to identify what routes need to be improved when building new points of attraction. Moreover, the analysis of information on accidents with cyclists and pedestrians will help to identify problem spots and inform the public when planning trips about the need for increased attention in unsafe areas.

The use of intelligent active assistance systems for cyclists and pedestrians, the design and construction of safe pedestrian and bicycle paths, their timely maintenance and repair will help to reduce the accident rate of the city's transport system as well as to prevent injury and death of people as a result of an accident.

6 Conclusions

The safety of pedestrians and city residents using non-motorized transport is a great problem, the relevance of which increases due to the growth of motorization and its negative consequences. To reduce the risks of road accidents, a tool allowing to react quickly to changes in the transport system and evaluating effectiveness of undertaken actions is needed. The proposed system for routes' safety evaluation will allow government and road services to make reasonable managerial decisions.

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