The use of intelligent systems when regulating road traffic

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Abstract. Statistics show that approximately half of all fatal accidents occur at unregulated and inadequately lit pedestrian crossings. To minimize the severity of the consequences, it is necessary to develop a set of organizational and technical measures to inform traffic participants about a safe pedestrian crossing. One of the ways to solve this problem may be to introduce the development of leading design organizations aimed at the use of intelligent technical systems to ensure the process of safe crossing of highways by pedestrians, i.e. smart pedestrian crossing. The article discusses the possibility of introducing an intelligent system into the traffic control process in sections of the road network with heavy traffic of cars and pedestrians. The operating principle of this system is based on the recognition of moving vehicles and timely warning pedestrians, as well as determining the location of pedestrians at the crossing and warning drivers about people on the road.

1. Introduction
The rapid pace of life in the modern city places certain demands on the organization of the transport process. First, municipal authorities pay attention to the possibility of the road network to provide the required traffic capacity without reducing the speed of the traffic flow in general. To solve this problem, various models of the organization of traffic in existing sections of the road network (RN) are developed and analyzed, new transport interchanges are designed and built (often at different levels), and measures are taken to improve the transport infrastructure as a whole. The implementation of the whole complex of the above measures ultimately leads to the desired result and traffic on the city streets becomes more comfortable and safe for car drivers, but there is a pedestrian on the road as well. As practice shows, the interests of the latter are not always taken into account when developing organizational and technical measures to improve the transport process, which leads to an increase in road traffic accidents with pedestrians in RN sections which seem perfectly designed [1, 2].

2. Target setting
The problem of road safety at the present stage of social development is gaining priority. The United Nations declared the period of 2011–2020 as the “Decade of Action for Road Safety” [3]. In the White Paper of 2011, the European Commission proposed a new approach to a “zero vision” of road safety, in order to exclude cases of death and serious injuries occurring on roads. The Government of the Russian Federation approved the Road Safety Strategy in the Russian Federation for 2018–2024 by Decree No. 1-r dated January 8, 2018, which states that in order to increase the safety of pedestrians in...
road traffic accidents and their consequences it is necessary to equip pedestrian crossings with a set of technical traffic management tools using innovative methods and technologies [4].

According to the data presented on the official website of the State Inspectorate for Road Traffic Safety of the Russian Federation for 2016–2018, about 511 thousand accidents occurred on roads of the Russian Federation. This is 3-4 times more than in Europe. For three years, 57,610 people died and 651,367 people were injured as a result of road traffic accidents [5]. According to the NHTSA’s National Center for Statistics and Analysis in the United States for the same period, these figures included 18,340 dead and more than 220 thousand people were injured. It is obvious that the figures of road traffic injuries among pedestrians in the USA as well as in Europe are much lower than in Russia. Road traffic accidents involving pedestrians make up a significant part of the total number of accidents – approximately 30 % for 2016–2018 (Table 1) [5].

| Year | Total number of road traffic accidents | Number of pedestrian accidents | % of the total | caused by drivers | caused by pedestrians | in the dark |
|------|----------------------------------------|-------------------------------|---------------|------------------|----------------------|------------|
| 2018 | 168,099                                | 48,814                        | 29.04         | 32,966           | 18,987               | 19,791     |
| 2017 | 169,432                                | 51,839                        | 30.59         | 31,234           | 20,861               | 22,401     |
| 2016 | 173,694                                | 52,001                        | 29.93         | 29,933           | 21,747               | 21,665     |

An analysis of the statistical data presented in Table 1 makes it possible to conclude that in the majority of cases accidents with pedestrians are caused by drivers (approximately 1.5 times more often than pedestrians), and a high percentage of pedestrian accidents happen in the dark (40 % of the total number of accidents involving pedestrians in 2018). Statistics show that every third victim crossed the road at a pedestrian crossing.

The great number of car collisions with pedestrians in the zone of pedestrian crossing is due to the following reasons:

- insufficient visibility of the crossing in the dark and during rainfall (heavy rain, snow, fog) due to poor lighting;
- poorly visible road marking (high degree of wear of the zebra marking, especially after the autumn-winter period);
- low discipline of road users (both drivers and pedestrians).

3. Discussion

Leading scientific and design organizations conduct research aimed at introducing intelligent systems into the process of pedestrians’ safe crossing highways, i.e. developing a safe pedestrian crossing [6].

In many cities around the world, pedestrian crossings are equipped with traffic light systems and pedestrians have to press a button to cross the roadway. Such a traffic light is always green for vehicles when there is no pedestrian who wants to cross the road. To indicate the intention of crossing, pedestrians inform the system of their presence by pressing a button. With such a traffic light control scheme, various problems arise. For example, older pedestrians prefer to wait until the car passes, rather than press a button. In addition, teens play with buttons and press them before and after crossing, which leads to traffic delays and affects the behavior of vehicle drivers. This approach is also a problem for pedestrians with disabilities, such as blind people and people who have difficulty to touch a button [7].

Employees of the Transport Institute of Tyumen State Oil and Gas University under the direction of I.A. Anisimov [8] developed an intelligent pedestrian crossing system, including a motion sensor. The principle of operation is as follows. A pedestrian approaches the carriageways and enters the range of the motion sensor. Moreover, to increase the reliability of the device, a button is provided that one can press and cross the road. The motion sensor includes yellow warning lights located above the roadway, and any driver approaching the pedestrian crossing will be warned of the imminent
appearance of a pedestrian on the zebra. In the dark, the pedestrian crossing area is additionally illuminated by bright LED light. The sensor determines the response zone exclusively for movement across the roadway. The disadvantage of this system is the operation of a motion sensor per person taller than 100–110 cm, which will not allow to recognize a child or an animal.

Scientists from the Republic of Bulgaria [9] have proposed an improved system for ensuring traffic safety at pedestrian crossings by the use of a range of organizational and technical means. The technical solution is based on recognition of pedestrians in the waiting area. The recognition method is based on a background pattern that is identified by the camera. When pedestrians enter the waiting area, the picture changes, as they are located between the camera and the background, which is a signal to inform the traffic control system. The study also presents the algorithm of the system modeling and controlling the traffic light system. According to the authors, the use of this method of traffic regulation will make it possible to reduce traffic delays caused by automatic traffic light control, as well as eliminate risks for traffic users when using buttons. The proposed approach will improve traffic safety in areas with pedestrian crossings and will be useful for people with disabilities who are not always able to press the button. The negative aspects when using this system include the lack of visibility of the background pattern during heavy rainfall, which can lead to false triggering of automatic control, and the possibility of unauthorized painting the background picture or drawing a silhouette (shadow) of a person on it by outsiders should also be taken into account.

In order to improve road safety, Dorokhin S.V. [10] proposed to equip the pedestrian crossing by highlighting a safe area in front of the stop line and the zebra marking, and monitoring the actions of traffic participants. The length of the safe zone was also determined. The mechanism of the sequence of movement of cars and pedestrians within the crosswalk was described. Suggestions for changing some sections of the RF Traffic Rules and state industry standards regarding the actions of pedestrians and the arrangement of pedestrian crossings were presented. The concepts of a dashed stop line and a special regulation sign were introduced, indicating the zone of the pedestrian crossing. A method for monitoring the actions of road users was proposed, which did not exclude administrative punishment for violation of the requirements of transport legislation. Creating a safe area between the car and the pedestrian will reduce the risk of traffic accidents and will increase road safety. The arrangement of the safe zone requires significant capital investments, the expansion of the carriageway and the introduction of amendments to certain sections of the RF Traffic Rules and state industry standards.

4. Materials and methods
In this work, it is proposed to consider the possibility of introducing an intelligent system based on the effect of early recognition of moving vehicles and timely warning pedestrians, as well as determining the presence of pedestrians at the crossing and warning drivers about the possibility of finding people in the way (Figure 1) [11].

A distinctive feature of the intelligent transport system under consideration from existing projects is the ability to visualize the presence of a person at a pedestrian crossing for the driver by automatic turning on additional lights located directly above the "zebra" that vertically illuminate the markings and traffic signs. In view of this, the system is equipped with video cameras that record the presence of a person in the waiting area and allow monitoring the start and end of the transition process.

The algorithm for informing pedestrians about approaching a car at high speed is as follows:

- a radar detector mounted on an illumination pole detects the speed of vehicles approaching the pedestrian crossing;
- when capturing the excess of the allowed speed, the information board installed in the pedestrian's visual contact zone is triggered;
- a warning message is displayed on the board indicating that the vehicle is approaching at high speed. The board is equipped with an additional sound signal for visually impaired pedestrians.
- Consider the principle of the system for informing drivers about the presence of pedestrians on the roadway:
- a motion sensor located in the waiting area detects a person at a pedestrian crossing;
• when determining a pedestrian, an electrical impulse from the motion sensor is transmitted to an information board mounted on a special support 50–70 meters before the crossing and designed to inform drivers about the presence of people on the roadway. The board can work continuously, and to enhance the visual effect for the driver, additionally blink or change color from yellow to red when people are on the way.

Figure 1. The principle of the intelligent pedestrian crossing

Consider the option of installing a warning system that excludes the algorithm for determining the presence of a person in the waiting area of a pedestrian crossing. In this case, the principle of operation of the intelligent system is based solely on radar data on the speed of the approaching vehicle. If a violation of the speed limit is recorded on the information board, a warning message about the presence of a pedestrian on the roadway is displayed for drivers. At the same time, the radar sends a pulsed signal to the receiver of the information board for pedestrians, on which accordingly a warning message appears about the car approaching and its actual speed. Speed information will allow pedestrians to estimate the time interval for a safe crossing correctly.

The possibility of using modern innovative developments in the intelligent transport system under consideration expands the scope of its application. Special supports with an installed lighting console and projections will provide a high level of visualization of the pedestrian crossing by all road users, which will positively affect the safety of pedestrians crossing the roadway, including in the dark [12].

The possibility of warning drivers about pedestrians by navigation applications, and later on transmitting a signal about the need to reduce speed and stop before the pedestrian crossing is considered for the future.

Currently, authorities in a number of regions are implementing similar projects of the intellectual pedestrian crossing. In particular, in the city of Ryazan, such a transition has been established and is successfully functioning (Figure 2).

The practice of regions where similar safety systems are already used when crossing the carriageways shows a significant decrease in mortality and the number of accidents.
5. Conclusion

The practice of implementing intelligent systems in the organization of traffic shows the high efficiency of their application. The range of artificial intelligence in the road sector is very wide. The work to optimize the traffic in the RN sections using intelligent pedestrian crossings should be carried out in a complex and take into account the needs of all participants in this process. Only in this case it will be possible to achieve greater discipline for both drivers and pedestrians, which will ultimately lead to a decrease in the number of accidents and reduce the severity of their consequences.

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