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THE STATISTICAL ASSESSMENT OF THE TRAFFIC SITUATION BASED ON SAMPLE DATA OF TRAFFIC ACCIDENTS IN THE URBAN AGGLOMERATION

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The article analyzes the accident rate on the roads at the entrance sections of the Belgorod agglomeration road network with the help of a documentary study of traffic accident records for the statistical assessment of the road traffic situation. It has been established that collisions and hitting a pedestrian are particular types of traffic accidents. The results of the analysis showed that Tuesday and Sunday are among the peak days of the week in terms of the probability of traffic accidents. Calculations based on mathematical statistics and probability theory have shown that there is a correlation between the number of accidents and the proposed characteristic hours of the day. To improve road safety, an information model was developed, an information model for reducing traffic accidents in places of concentration of traffic accidents.

Keywords: traffic accident, types of traffic accidents, vehicle, mathematical statistics, information model

1 INTRODUCTION

Traffic accidents today belong to the main cause of death of young people under the age of 29 around the world. According to statistics, there were 133 thousand traffic accidents with victims in Russia in 2021. Almost 15 thousand people died in them and about 168 thousand more were injured. The economic development of agglomerations, regions and the country as a whole depends on the indicators of traffic accident statistics.

Mortality as a result of traffic accidents has a scale and is among the top ten causes of death worldwide, according to the World Health Organization (WHO). The phased implementation and realization projects of national road safety programs had a significant impact on reducing the results of statistical data on the number of accidents, which corresponds to the Traffic Safety Strategy of the Russian Federation for 2018-2024 and the Transport Strategy of the Russian Federation until 2030 with a forecast for the period up to 2035.

The Covid-19 has also had a significant impact on changing traffic accidents. The analysis of statistical data on the situation with those killed on the roads showed that from 2004 to 2022, the situation in the field of road safety has changed significantly, reducing the number of deaths by more than 2 times (Fig. 1).

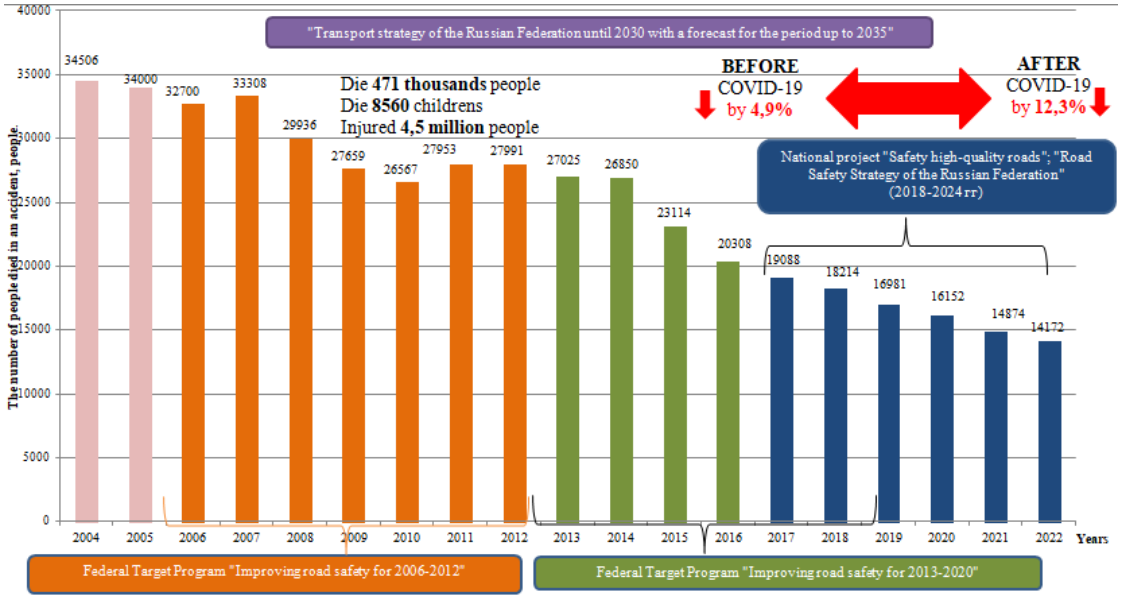

Fig. 1. The number of deaths in traffic accidents trend from 2004 to 2022

Motor transport is the main component of a person's daily life. The global automotive industry annually produces more than 50 million cars [1]. It is impossible to imagine the modern world without transportation, which ensure the normal functioning of industry, the construction industry, trade and other spheres of activity [2]. The main issue for many years has been the issue of increasing traffic safety. A special cell has been allocated to the issue of ensuring and improving traffic safety, since the development of the country is closely linked to the successful citizens' life.

The development of individual housing construction on the territory of the Belgorod agglomeration does not allow to leave the issue of improving the transport infrastructure and increasing the level of traffic safety, since the greatest daily migration of people just happens along the transport networks of the agglomeration at different speed modes of vehicles, as evidenced by the results of a sociological survey in the Belgorod agglomeration by the type of transport used and availability of the number of vehicles shown in Fig. 3,4.

2 BACKGROUND

2.1 Collection of statistical data on the traffic situation in the Belgorod agglomeration

Today, almost all large settlements are merging into a single, multicomponent and dynamic structure that plays a huge role in the principles of the formation of the whole state. Such modules are overgrown with intensive production, economic, transport and cultural ties, creating benefits by reducing costs

Within a radius of 30 kilometers from Belgorod, plots were formed for individual housing construction, and as a result, the suburb and parts of municipal territories became sleeping areas of Belgorod (Fig. 2).

In this regard, according to a study by the Belgorod Research Institute of Urban Planning, about 93,000 people enter and leave the city every day, about 52,000 of them by private transport, another 41,000 by public transport. This situation on the roads leads to congestion, deterioration of the environmental situation and the likelihood of traffic accidents [3], [4].

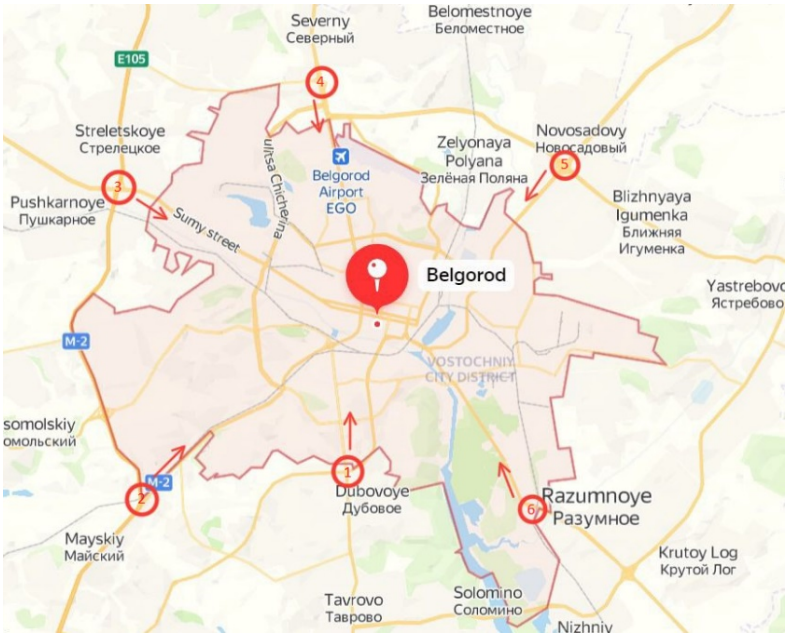

Fig. 2. Diagram of settlements of the Belgorod agglomeration

During the sociological survey, in which respondents were distributed as follows: 42.7% of women and 52.8% of men, it was found that 54.3% of the population use public transport in the Belgorod agglomeration, and 34.4% use private transport [5], [6]. More than 30% of the population daily move by private transport from nearby settlements to the city center and are in danger, namely, the probability of becoming a participant in a traffic accident [7], [8].

The percentage ratio of the number of cars available in each family indicates the relevance of the studied problem of increasing traffic safety. Almost every family has two cars (11.7%), and some have three (2.6%), which significantly affects the traffic situation in the urban agglomeration (Fig. 3) [9], [10].

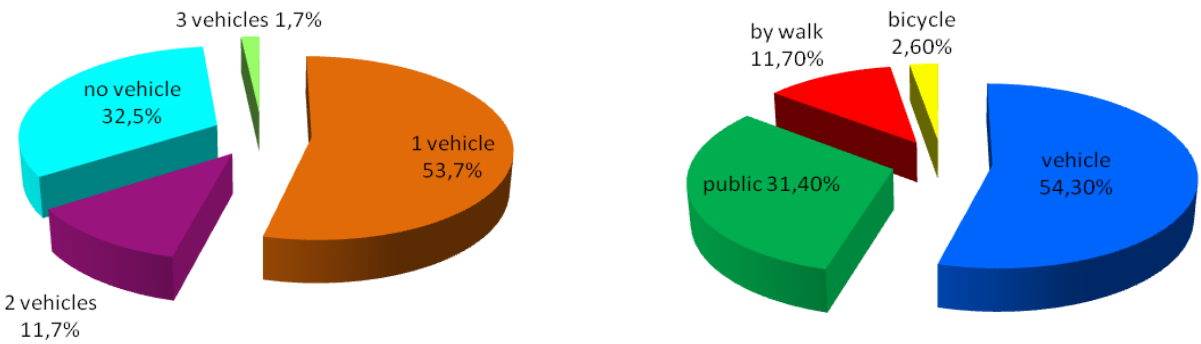

Fig. 3. Results of a sociological survey of the Belgorod agglomeration residents

2.2 Analysis of the main types accidents with a high mortality rate

In the course of studying the types, causes, factors and conditions contributing to the occurrence of traffic accidents, it was found that most deaths occur as a result of collisions and collisions with pedestrians. In scientific papers [11], one of the main factors affecting the severity of the consequences of the traffic accident is considered – exceeding the speed limit. Drivers often exceed the speed limit to reduce time, not perceiving and underestimating the possible consequences.

This fact, in turn, leads to the greatest probability of the traffic accident outside the core of the agglomeration, as evidenced by the statistics of accidents in the Belgorod agglomeration, namely, the number of deaths is 19.4% of the total number of traffic accidents. The leading positions by types of traffic accidents in the urban agglomeration are collisions (55 people died) and hitting pedestrians (22 people died) to a greater extent at unregulated intersections (51.8%) and unregulated pedestrian crossings (57.8%), respectively. -Every third accident on Russian roads is connected with hitting pedestrians, and the reason for a large number of such accidents, namely, every eighth is the absence, poor visibility or improper use of road signs in the pedestrian crossing area. Drivers do not notice them and hit people right at the pedestrian crossing.

Pedestrians (regardless of whether or not they have a driver's license) are required to know and comply with the relevant requirements of Traffic Rules, traffic lights, road signs and markings, as well as follow the orders of traffic controllers.

Road users such as pedestrians are unprotected compared to drivers. As a result, traffic accidents involving pedestrians have serious consequences, sometimes incompatible with life.

In most cases, the pedestrian is responsible for the traffic accident. The task of the traffic police and specialists in the field of traffic management is to find the causes of an accident and further change the traffic pattern, the use of technical means of traffic management, as well as measures that improve the quality and increase road safety, which will prevent the likelihood of a traffic accident.

Since 2011, the traffic police and the volunteer movement have been holding an annual campaign aimed at reducing the number of traffic accidents involving pedestrians, paying special attention to the operational condition of crossings [12], [13]. When carrying out such events, the incorrect installation of signs or their absence is revealed, which makes it impossible to inform the driver in time for timely decision-making, while the pedestrian determines the wrong place to cross the road. All these circumstances lead to tragedy [14], [15]. Nowadays 90% of pedestrian crossings have been surveyed [16]. Every third one revealed shortcoming in the organization, violations that contradict regulatory requirements and GOST standards. 62% are in the proper form [17], [18].

So, the analysis of the organization of pedestrian traffic and the correct schemes of pedestrian crossings showed that the current standards were not appropriate to today's conditions and situation [19,] [20]. Thus, the traffic police develop proposals and measures that have new standards, which have proven themselves well from a practical point of view in countries with a high level of motorization [21].

2.3 Analysis of traffic accidents at the entrance to the urban agglomeration from 2018 to 2021

To analyze the types, location and time of all traffic accidents that occurred over the past four years from 2018 to 2021, detailed information was collected throughout the Belgorod region, namely, adjacent sections of the road network to the borders of Belgorod. This article presents the data obtained through documentary study (Fig. 4) and calculations on the example of one direction (Dubovoye) of the Belgorod agglomeration.

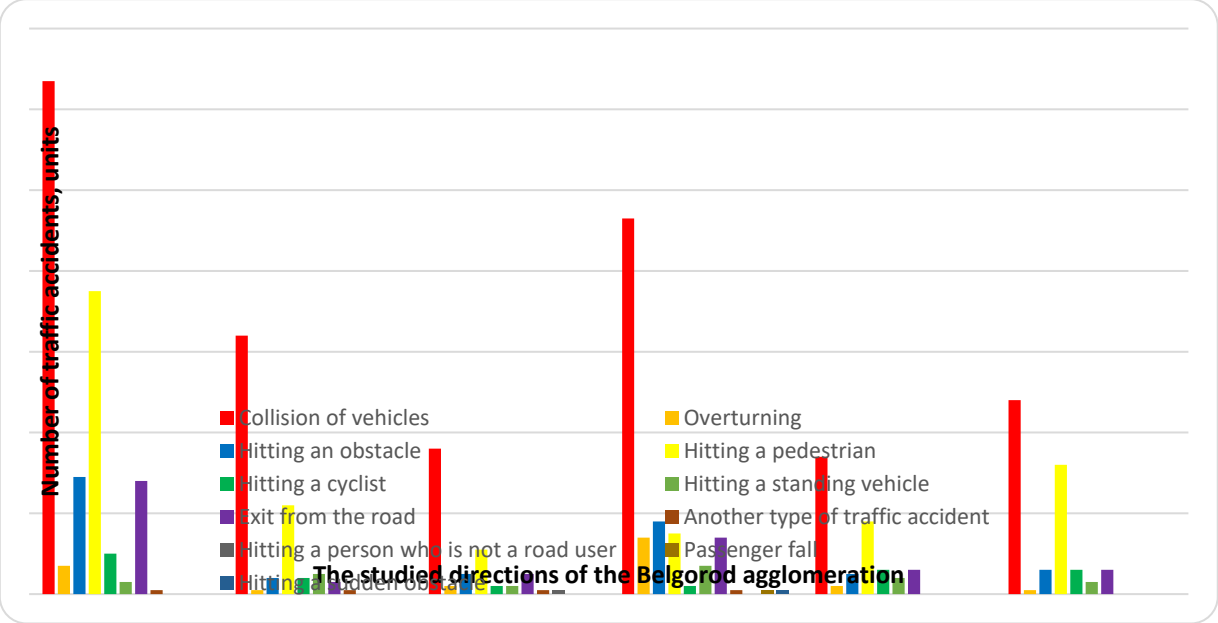

Fig. 4. Types of traffic accidents in the studied directions of the Belgorod agglomeration

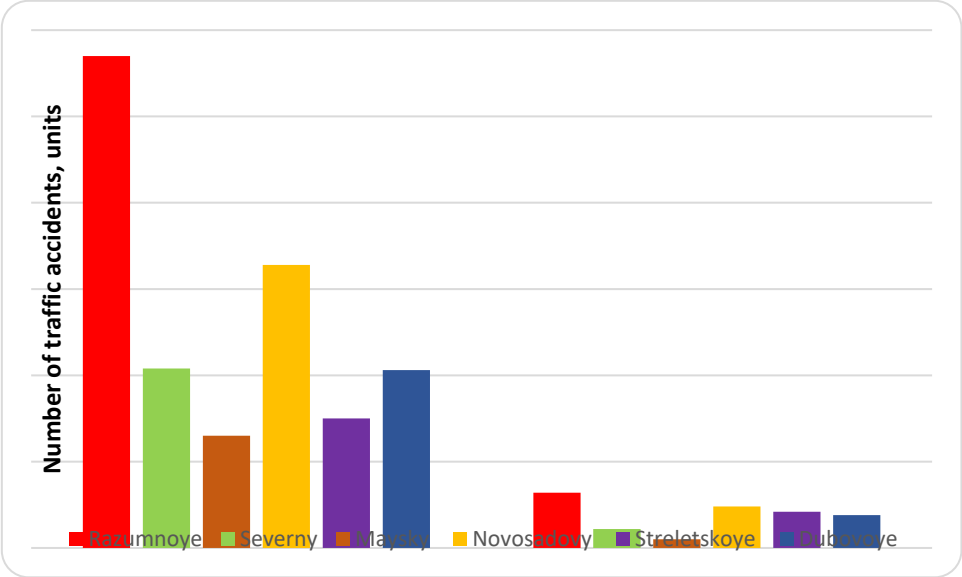

Fig. 5. The number of traffic accidents and deaths in the incoming directions in the core of the agglomeration

Table 1. The number of traffic accidents in the Belgorod agglomeration, depending on the type of traffic accident, distributed by days of the week for 2018-2022

Type of traffic accident	Day of the week						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Number of traffic accidents / deaths						
Collision of vehicles	7	10	4/1	6	7/1	4/2	13/2
Exit from the road	1	1	0	0	1	0	3
Hitting a pedestrian	6	7/3	5	3/1	5	4	5/2
Hitting a cyclist	2	0	2	2	0	0	1
Hitting a sudden obstacle	1/1	0	0	1	1	2/1	1/1
Hitting a standing vehicle	0	1	0	1/1	0	1	0
Vehicle rollover	0	0	0	0	0	1	0

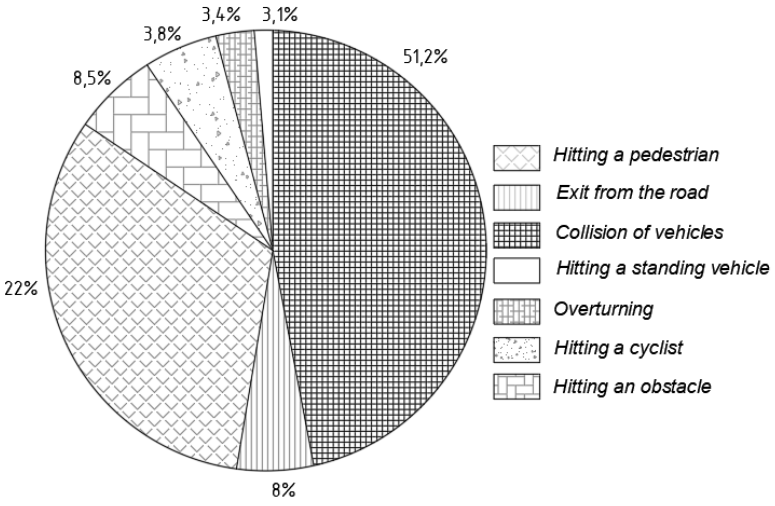

Fig. 6. The ratio of the number of accidents types on the example of the road network in the Dubovoye direction of the Belgorod agglomeration

After analyzing the statistics of traffic accidents at one of the above sections of the rjad network, it was revealed that most of the traffic accidents occur in the same places almost from year to year and have the same type of the traffic accident.

The results obtained indicate that 109 traffic accidents have occurred in the studied area over the past four years, of which 51 collisions of vehicles, 35 hits on a pedestrian, 7 hits on a cyclist, 6 hits on an obstacle, 3 hits on a standing vehicle, 6 exits from the road (Table 1, Fig. 6).

2.4 *Methodology for assessing the traffic situation based on sample data of the number of traffic accidents depending on the characteristic hours of the day. Results of calculations of statistical data on the number of traffic accidents.*

The next stage of the study was to establish the characteristic hours of the day with the largest number of incidents on the territory of the Belgorod urban agglomeration (Fig. 7). The probabilistic method allowed to solve the problem. Probabilistic methods for determining the patterns characterizing random processes in the traffic flow are still being developed. Using mathematical statistics and probability theory, the following indicators were calculated: mathematical expectation, variance, correlation coefficient, which made it possible to determine the strongest correlation dependence of the events of a random process.

Table 2. The number of traffic accidents that occurred in the Belgorod agglomeration (Dubovoye direction) during the week at characteristic hours of the day from 2018 to 2022

Time ranges	Day of the week							Total
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
06.00-10.00(1)	5	3	3	2	1	1	4	19
10.01-14.00(2)	3	3	1	1	1	0	3	12
14.01-18.00(3)	3	7	3	2	6	3	3	27
18.01-22.00(4)	3	4	4	6	4	7	8	36
22.01-02.00(5)	3	2	0	2	2	1	5	15
Total	17	19	11	13	14	12	23	109

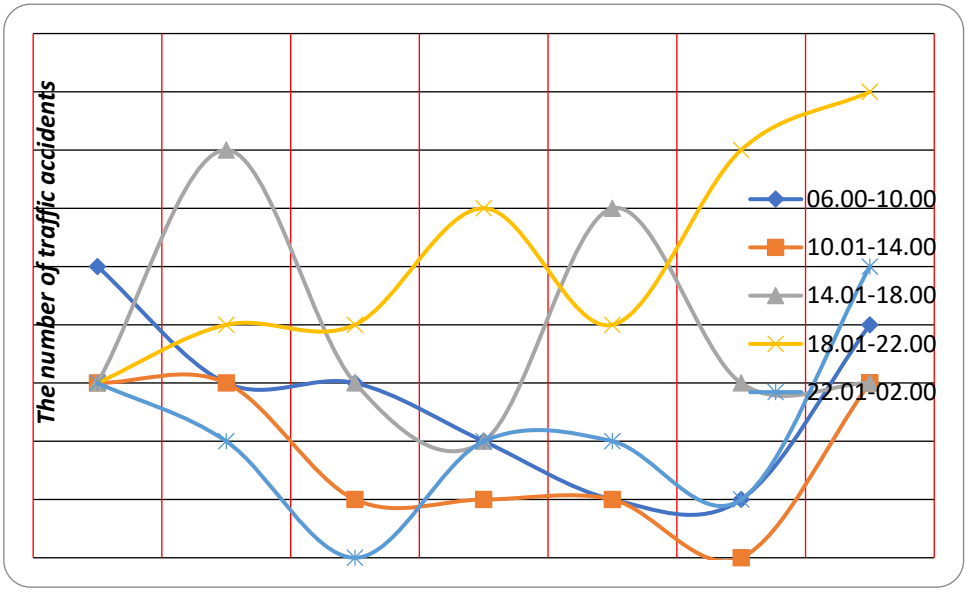

Fig. 7. The number of traffic accidents that occurred during the week for different time sections in the Belgorod agglomeration

In Table 2, each row corresponds to a specific experience, that is, the implementation of the process, each column corresponds to a specific time value, that is, the cross section of the process. So, the mathematical expectation will be calculated by the formula [22], [23]:

$$m_x(t_k) = \sum_{i=1}^{n} x_i(t_k)/n \quad (1)$$

The variance for the t_k section is calculated by the formula (2):

$$D_x(t_k) = \sum_{i=1}^{n} [x_i(t_k) - m_x(t_k)]^2 (n-1) \quad (2)$$

Correlation coefficient for cross sections t_k and t_t

$$\rho_x(t_k, t_t) = \frac{\sum_{i=1}^{n} [x_i(t_k) - m_x(t_k)][x_i(t_t) - m_x(t_t)]}{(n-1)\delta_x(t_k)\delta_x(t_t)} \quad (3)$$

According to formulas 1-3, the calculations presented below are made. Considering the accident rate as a random process, it is possible to predict in what period of time the greatest traffic accident rate will be observed.

$$M_1 = \frac{5+3+3+2+1+1+4}{7} = 2{,}71$$

Calculate the variances by formula (2) and get the expression:

$$D_1 = \frac{(5-2{,}71)^2 + (3-2{,}71)^2 + (3-2{,}71)^2 + (2-2{,}71)^2 + (1-2{,}71)^2 + (1-2{,}71)^2 + (4-2{,}71)^2}{(7-1)} = 2{,}238$$

Find the correlation coefficients according to the formula (3):

$\rho_{12} = 0{,}838$; $\rho_{15} = 0{,}516$; $\rho_{25} = 0{,}7$.

Similarly, all other calculations are performed.

Thus, the strongest correlation occurs between 1 and 2, 1 and 5, 2 and 5 sections/

If there were 3 traffic accidents in the second section, then we will find the mathematical expectation according to the formula (4) the number of traffic accidents that occurred in the fifth section.

$$M_y(\varepsilon) = r\left(\frac{\delta_\eta}{\delta_\varepsilon}\right)(x-a) + b, \tag{4}$$

where a and δ_ε – mathematical expectation and standard deviation of the value ε;

b and δ_η - mathematical expectation and standard deviation of the value η.

$$M_{P2}(P_5) = \rho_{25}\left(\frac{\delta_5}{\delta_2}\right)(3-1{,}71) + 2{,}14 = 0{,}7\left(\frac{1{,}574}{1{,}254}\right)(3-1{,}71) + 2{,}14 = 3{,}27.$$

Thus, collisions and collisions with pedestrians occur most often on the considered section of the road section. According to Table. 2 it can be seen that from 10.01 h. to 14.00 h. the least traffic accidents are occur, and the most in the time interval from 18.01 h. to 22.00 h. The most peak weekday is Tuesday from 14.01 h. to 18.00 h., and the weekend is Sunday from 18.01 h. to 22.00 h.

2.5 Information model of traffic accident reduction in places of traffic accident concentration

The results showed that there is need to develop theinformation model that allows you to warn the driver about driving on dangerous section of the urban agglomeration road network. The model includes preventive measures to attract the driver's attention, as a result, reduce the speed of the vehicle, as well as reduce the severity of the consequences of an accident and prevent the likelihood of a traffic accident (Fig. 8).

These measures are carried out using the following devices and organizational and technical measures to improve road safety:

1) a device located in a vehicle and informing the driver about a certain number of measures, approaching and driving through a dangerous section of the road network (calculates the GPS coordinates of the car's position and notifies by voice accompaniment about: a decrease in speed, concentration of attention; the frequency of traffic accidents on the site (listing the types of traffic accidents); weather conditions; cyclists' movement; pedestrians' movement; existing fixed obstacles;
2) about the installation of signs with LED elements at the beginning and end of dangerous sections of the road network;
3) about the device of the emerging artificial road roughness;
4) about the installation of information boards with LED elements, which will show diagrams of types of traffic accidents (collision, rollover, hitting a pedestrian, etc.).

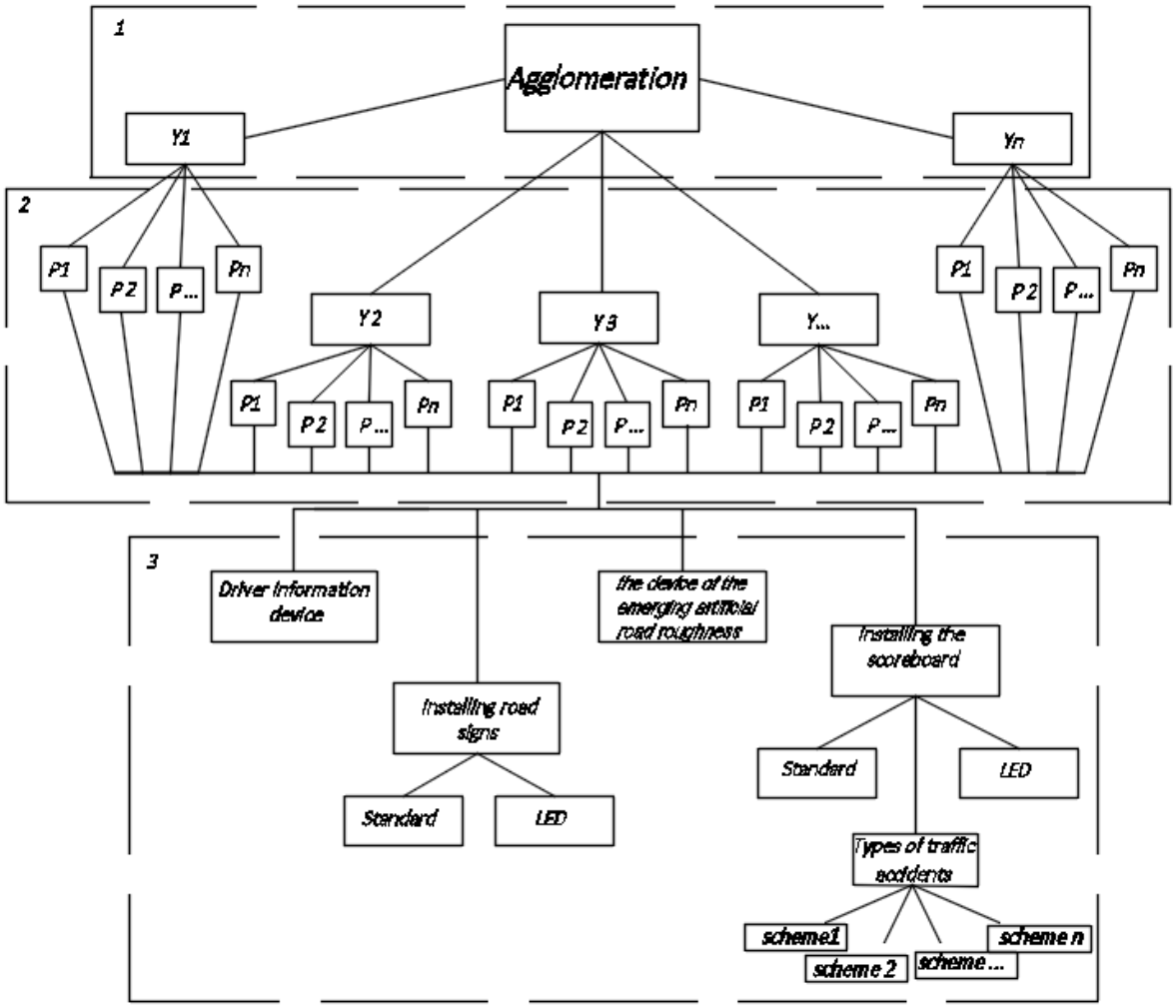

Fig. 8. Is a graphical diagram of an information model that allows you to warn the driver about driving along a dangerous section of the road network: 1-initial data (conditions); 2 – causes affecting the driver and his vehicle; 3 – measures that increase road safety

Let's take a closer look at some of the activities included in the information model. For example, the device of the emerging artificial road roughness will allow all drivers to develop discipline, forcing them to reduce the speed to the required one immediately before an unregulated pedestrian crossing.

Placards with types of accidents should be installed on road sections where certain types of accidents regularly occur. The proposed scoreboard shows a diagram of the type of accidents that constantly occur on a separately considered road section. This will attract the driver's attention not only in the daytime, but also in the dark.

The emerging artificial road roughness allows not to reduce the capacity of the road in traffic-laden periods of time, to maintain a safe speed in areas near schools and kindergartens, and also contributes to the increase of traffic safety at unregulated pedestrian crossings during hours of increased traffic through the pedestrian crossing.

Thus, the result of this information model will be an increase in road safety and the desire for «zero mortality» (minimizing deaths and road traffic injuries), acting according to the Transport Strategy until 2030.

3 CONCLUSIONS

So, vehicle collisions and collisions with pedestrians are most often occur on the considered section of the road network. According to Table. 2 it can be seen that from 10.01 h. to 14.00 h. the least traffic accidents are occur, and the most in the time interval from 18.01 h. to 22.00 h. The most peak weekday is Tuesday from 14.01 h. to 18.00 h., and the weekend is Sunday from 18.01 h. to 22.00 h.

As a result of the conducted research, it was found that the activities carried out within the framework of national projects have a positive impact on improving traffic safety.

According to the results of mathematical calculations, the correlation between the accident and the cross-sections of time intervals was established. The strongest correlation is traced between the first and second, first and fifth, second and fifth sections.

Thus, through the developed information model, the number of traffic accidents will be reduced by achieving the discipline of the driver and his choice of safety driving speed.

The analysis of the traffic accident statistics, the causes of their occurrence and the study of the road network sections, allowed us to develop an information model for reducing the emergency situation in the places of traffic accidents concentration. The model includes preventive measures to attract the driver's attention, as a result, reduce the speed of the vehicle, as well as reduce the severity of the consequences of the traffic accident and prevent the probability of the traffic accident.

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