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WAYS TO IDENTIFY FACTORS CONTRIBUTING TO THE OCCURRENCE OF ROAD TRAFFIC ACCIDENTS

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Abstract. The article deals with the issues of determining the factors contributing to the occurrence of road accidents. On the basis of statistical studies, the main factors most fully reflecting the process of occurrence of road traffic accidents were identified. For this purpose, an expert-statistical method was used. Road safety assessment was carried out on the example of the roads of the city of Pavlodar. The results obtained allow, in the future, to build a mathematical model that characterizes the possibility of a traffic accident.

Keywords: Car, accident, driver, road, traffic accident, traffic safety.

1. Introduction

The movement of cars on the road is considered as a complex interconnected system. The structure of this system includes the following elements: "Driver", "Car", "Road" and "Environment". The driver of a motor vehicle is the main link in the "Driver-Car-Road-Environment" (DCRE) system, the sustainable functioning of which determines the efficiency and safety of road traffic. The driver, driving the car, is in constant tension. In motion, he continuously perceives and comprehends the rapidly changing traffic situation, position, speed and condition of his vehicle, instantly makes decisions and implements them. Such an active and continuous course of psychic phenomena in conditions of rapidly changing conditions and danger increases the tension of the nervous system and leads to fatigue, and sometimes to overfatigue of the driver.

When driving a car, the driver must receive and adequately analyze a large amount of information (the road, controls, road signs and markings, control devices and the operation of the car's systems and mechanisms, meteorological traffic conditions, etc.). In addition, he must be able to predict the development of the road situation and choose the safest driving modes. With high dynamism, variable conditions and tight time constraints on decision-making, the driver is constantly under great emotional stress. The complexity of the Driver-Car-Road-Environment system lies in the fact that it contains ambiguous relationships and patterns of interconnection between its elements, the system is multicriteria and the processes occurring in it are of a stochastic nature, it is difficult to model the DCRE system. The DCRE system can be classified as complex due to its multidimensionality, the diversity of the nature of elements, connections, structural heterogeneity, and also due to the fact that the system operates under conditions of significant uncertainty of the environmental impact. Its complexity is exacerbated by the random nature of the change in its indicators [1, 2].

2. Materials and methods

2.1. Study of the interrelations between the elements of the DCRE system

In an environment characterized by high traffic intensity, in which huge masses of people and vehicles are involved, road safety activities are multifaceted and diverse. Assessing the importance of road safety, it should be noted that this problem has specific features of both a legal and organizational and managerial nature. Indicators of the level of road safety are a function of many variables, a number of models for assessing and predicting accidents for interstate comparisons take into account the dynamics of changes in accidents over time, as well as other indicators that affect changes in the level of traffic safety (models of practical actions). Such models make it possible to monitor trends in the level of traffic safety in the country and take into account the possibilities of future development of the situation [3].

For motor vehicles, human errors are the cause of 90 % of all accidents. At the same time, in 57 % of accidents, human error is almost the only factor that could lead to an accident. Only 2.4 % of accidents can be explained solely by a technical malfunction,

and an unfavorable environment (that is, phenomena like ice) is the cause of 4.7 % of road accidents. The remaining 35.9 % of accidents occur due to a complex combination of various factors [4]. Considering the human factor in the context of the Driver-Car-Road-Environment system, the phenomenon is multifaceted. Any component of this system has a multifaceted effect on the level of safety of road users.

The human factor has a very strong influence on the occurrence of accidents on the roads, despite the fact that recently the level of control automation allows technology to prevent collisions and other accidents.

When studying the factors influencing the occurrence of road traffic accidents (RTA), the reliability of the system P_s depends on the degree of influence of each element, which in general can be expressed as a derivative of the probability of failure-free operation of the car P_c, the driver P_d and the road P_r [5, 6]:

$$P_s = P_c \cdot P_d \cdot P_r. \tag{1}$$

The probability of failure-free operation of each element of the system is estimated by the derivative of the probability of failure-free operation of each element

$$\begin{aligned} P_c &= \Pi \cdot P_{ci}, \\ P_d &= \Pi \cdot P_{di}, \\ P_r &= \Pi \cdot P_{ri}. \end{aligned} \tag{2}$$

In this system, the "Driver" element has been studied in detail as a very complex element. Also introduced the concept of "defect" in the work of the driver, which arose as a result of changes in loads, psychophysiological indicators under the influence of road conditions.

Considering the relationship between the elements of the DCRE system from the point of view of assessing the safety of traffic modes, eight significant relationships can be distinguished [7, 8]. But the study of the relationship between the elements of the system is a difficult task, so it is necessary to study the course of the environmental impact on the road and consider the relationship of elements in the "environment-road", "road-driver", "road-car" systems. It has been established that safe movement is ensured by the causes of a constant or changing DCRE system within the minimum intermediate limits, and this trend can be represented as the following function

$$P_{red} = \mathrm{f}\,\{\mathrm{DCRE}\} = \mathrm{const}. \tag{3}$$

Examination of the system approximation when considering the transport process, as well as road safety, shows that it is difficult to distinguish the main one from the total number of accidents due to a number of reasons. Violation of even one indicator of the elements of the DCRE system can lead to an accident. Therefore, for a comprehensive assessment of the influence of various elements of the system on the accident rate, it is necessary to identify the main causal factors of the DCRE system [9–11].

We form a mathematical problem as follows. It is required to find an expert transformation of the cause-and-effect relationships of the occurrence of road accidents, their determining causes, i.e., to find a function of the following type

$$TA = f(X_1, X_2, X_3, \ldots, X_n), \tag{4}$$

where TA – traffic accident; $X_1, \ldots, X_n$ – mutual set of causes affecting the occurrence of an accident, carried out in two stages.

2.2. Study of the interrelations between the elements of the TA system

Let's consider the results of the examination of statistical data on the registration of road traffic accidents.

The work at the first stage consists of an examination of the primary documentation and statistical data on the accounting of accidents in order to select the main causes that are the causes of the accident from among the causes in the DCRE system.

Since the traffic safety assessment was carried out on the example of the roads of the city of Pavlodar, the assessment of the factors of the "road" system was carried out based on the road conditions of the considered road junction.

Statistical materials of the Traffic Police Department of the city of Pavlodar were used as conditional values for the research, the subdivisions of highways in the places of occurrence of accidents were studied.

As a result of statistical studies, 19 factors were selected that determine the process of occurrence of an accident in more detail. They are listed below in Table 1.

Professional expertise is required to select a small number of the most informative factors. During the research of the second stage aimed at achieving this goal, an expert statistical method of constructing the objective function was used, based on the methodology described in [12]. Each accident is largely characterized by a mutual combination of factors $X_1, \ldots, X_n$. Some factors are much more common in road accidents than others. Many of them are not subject to direct quantitative measurement, which makes it difficult for further research to determine the true factor that caused the occurrence of an accident. Therefore, in order to obtain maximum information about the factors influencing the occurrence of an accident, it is necessary to determine them essentially in descending order, that is, to obtain an inequality of the following type

$$X_1 < X_2 < X_3 < \cdots < X_n. \tag{5}$$

According to experts, the factors that make the greatest contribution to the phenomenon under study have the smallest sum of degrees X_1, and the factors with the least effect have the largest sum X_n.

The collection of opinions on the factors that most affect the occurrence of an accident was carried out by conducting a survey among employees of the Traffic Police Department, specialists of the automobile

X	Factors	System
X_1	Driver's experience	
X_2	Driver's class	
X_3	Driver's age	
X_4	Driver's gender	"Driver"
X_5	Driver's condition (drunk, sober)	
X_6	Driving time before the accident	
X_7	Non-compliance with traffic rules	
X_8	Technical condition of the car	"Car"
X_9	High traffic intensity	
X_{10}	Insufficient width of the roadway	
X_{11}	Presence of road signs	
X_{12}	Low coefficient of adhesion	"Road"
X_{13}	Non-compliance of road conditions with the requirements of the traffic regime	
X_{14}	Road irregularities	
X_{15}	Visibility conditions	
X_{16}	Narrow bridges and railway crossings	
X_{17}	Weather conditions (blizzard, fog, precipitation)	
X_{18}	Time of day (light, dark)	"Environment"
X_{19}	Season	

TABLE 1. Factors affecting the accident rate according to statistics.

enterprise, road managers, teachers and staff of the Department of Transport Engineering and Logistics of Toraigyrov University. The number of experts is determined based on the following criteria.

The number of experts $N_э$ should be 3 times more than the n reasons included in the register

$$N_э = 3 \cdot n = 3 \cdot 19 = 57. \tag{6}$$

Therefore, 60 expert specialists represented in the survey were involved in the experiment.

Based on the survey data, a comparative questionnaire or a matrix of degrees has been compiled. A sign of the correctness of filling in the tables is the equality of the amounts received for all columns

$$\sum_{j=1}^{n} X_{ij} = \frac{(1+n) \cdot n}{2}, \tag{7}$$

where X_{ij} is the degree of the j-th reason of the i-th expert; n is the number of reasons.

Determining the significance of the influence of the selected factors on the occurrence of emergency situations from the point of view of the interviewed experts is performed only after calculating the sum of the rows and the sum of each row, which should coincide with the amount received by the columns

$$\sum_{j=1}^{n} X_{ij} \sum_{i=1}^{m} X_{ij} = \sum_{i=1}^{n} X_{ij} + \sum_{j=1}^{m} X_{ij}. \tag{8}$$

Let's build a histogram based on the values of the degree matrix and enter into the database of the Microsoft Excel program the law of distribution of the sum of the degrees of influence of the selected factors on the occurrence of an accident.

2.3. Definition of interoperability of examiners

One of the important elements of the survey is the degree of mutual compatibility between experts, which is determined using concordance coefficients, which are calculated using the formula below

$$W = \frac{12 \cdot S}{m^2(n^2 - n)}, \tag{9}$$

$$S = \sum_{j=1}^{n} X \left(\sum_{i=1}^{m} X_{ij} \frac{\sum_{j=1}^{n} X_{ij} \sum_{i=1}^{m} X_{ij}}{n} \right)^2. \tag{10}$$

With full compatibility between specialists, the concordance coefficient is equal to one, in the absence of this compatibility – zero, i.e., the intervals of changing the value of W lie within $0 \leq W \leq 1$.

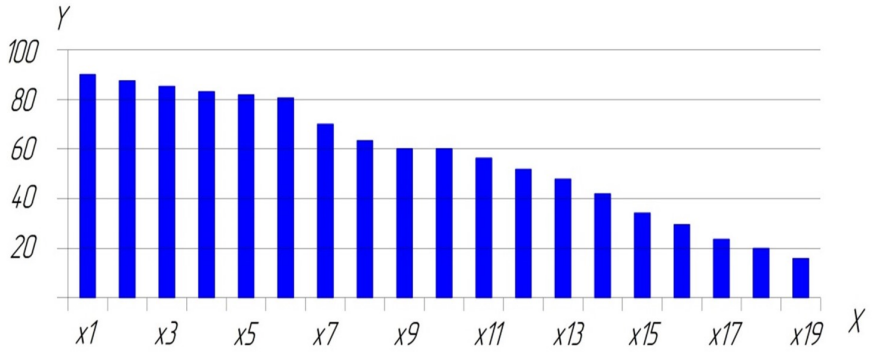
The significance of the concordance coefficients is determined using the Pearson sign ξ^2, which has the number of degrees of freedom $n = 1$, according to the formula given below

$$\xi^2 = m(n-1)\omega = \frac{S}{\frac{1}{12}mn(n+1)}. \tag{11}$$

If the calculated value of ξ^2 is higher than the table value, then the assumption of randomness in the mutual consistency of expert opinion is refuted.

As a result of the experiment conducted to collect expert opinions on Formulas (9), (10), the value of the concordance coefficient was calculated

$$W = \frac{12 \cdot 210632}{60^2(19^3 - 19)} - 0.10265. \tag{12}$$



Y is the degree of significance, X is the factors provoking an accident.

Figure 1. Histogram of the significance of factors affecting the accident rate, according to the results of expert examination.

X	Factors	Degree of significance
X_1	Driver's experience	73 %
X_2	Driver's class	53 %
X_3	Driver's condition (drunk, sober)	87 %
X_4	Driving time before the accident	45 %
X_5	Non-compliance with traffic rules	98 %
X_6	Technical condition of the car	85 %
X_7	High traffic intensity	78 %
X_8	Low coefficient of adhesion	66 %
X_9	Non-compliance of road conditions with the requirements of the traffic regime	60 %
X_{10}	Road irregularities	57 %
X_{11}	Visibility conditions	49 %
X_{12}	Weather conditions (blizzard, fog, precipitation)	79 %
X_{13}	Time of day (light, dark)	48 %

Table 2. Important factors affecting the accident rate in Pavlodar.

Also, according to the Formula (11), its significance was checked by the Pearson sign ξ^2

$$\xi^2 = \frac{210632}{\frac{60 \cdot 19 \cdot 20}{12}} = 110.86. \tag{13}$$

Comparing the calculated value of the Pearson sign ξ^2 for the 5 % significance level with the tabular value $\xi^2 = 26.3$, it can be concluded that when assessing the significance of factors affecting the occurrence of an accident with a probability of $p = 0.95$, the opinion of experts is not accidental.

$$\begin{gathered} \xi^2_{cur} = \xi^2_{tab}, \\ 110.86 > 26.3. \end{gathered} \tag{14}$$

2.4. Factors influencing accident rates

Analyzing the values of Table 1 and the histogram in Figure 1, it is possible to determine the most important factors affecting the accident rate. Factors with a degree of significance below 40 % have also been identified. We exclude them from the table.

Less significant reasons are: "insufficient width of the roadway" – 31 %, "presence of road signs" – 26 %, "driver's age" – 28 %, "driver's gender" – 18 %, "narrow bridges and railway crossings" – 16 % and "season" – 13 %. Each of the listed reasons is, to one degree or another, only a factor accompanying the other.

The results of the traffic safety assessment on the example of the roads of the city of Pavlodar are presented in Table 2. As mentioned above, this table does not take into account the factors affecting the accident rate, in which the degree of significance is below 40 %. As a result, the number of the most important factors affecting the accident rate in the city of Pavlodar is 13.

3. Conclusions

According to the latest data, there is an increase in the number of cars of all forms of ownership in the Republic of Kazakhstan.

The growth of the country's car park and the constant increase in traffic intensity have brought to the fore the problem of road safety as the most important state task. In this regard, work aimed at ensuring the reliability and safety of the driver's activities is of paramount importance.

Using the results of the study to determine the factors influencing the accident rate in the conditions of the city of Pavlodar, it is possible, in the future, to determine the expert function and build a mathematical model of road accidents.

Therefore, such research needs to be accelerated.

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