TECHNOLOGY, CREATIVITY, IMPLEMENTATION

SCORING METHOD OF EVALUATING ROAD SAFETY AS PART OF MANAGEMENT SYSTEM

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Summary
Known methods of assessing the level of traffic safety on highway sections are considered. Factors that can significantly affect forecasting accuracy have been identified. It is proposed to improve the existing method by introducing additional parameters, which were obtained as a result of the formalization of accident statistics at the places of traffic accidents concentration. The purpose of the work is to provide traffic safety specialists with an effective express method of evaluating the level of traffic safety with points directly on the road. The proposed scoring method of evaluating road safety also arouses interest due to the recent implementation in Ukraine of a road safety audit at the stage of operational maintenance, which is specifically designed to conduct an independent inspection of dangerous sections of highways and prescribe low-cost and effective measures to reduce accidents. This will help to make decisions in the road safety management system that will relate to effective measures.

Key words: accident rate, place of concentration of traffic accidents, traffic intensity, statistics, traffic safety assessment.

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1. Introduction

The assessment of the degree of traffic safety on the road is of primary importance for the services of road operation and traffic organization when identifying dangerous areas and developing measures to improve traffic conditions. On recently built roads, designed according to modern construction norms and rules, dangerous areas can arise only if designers or builders violate the regulatory requirements for road elements. Also, they become dangerous as a result of drivers exceeding the calculated speeds or speeds corresponding to the coefficients of adhesion of tires to the surface in deteriorating weather. Thus, the road safety management system lacks an effective evaluation method that would take into account the listed factors.

2. Analysis of research and publications

The study of the existing standards in Ukraine *(Methodology, 2008; Procedure, 2003; Standard, 2002)* and the world *(European Transport Safety Council, 2001; Elvik, 2009)*, which provide the possibility of identifying dangerous areas on highways, shows that these standards have not been properly reviewed for a long time. However, modern works *(Syyed Adnan Raheel Shah, 2018; Handbook, 2023; Osipov V. & Melnichenko O., 2019)* can only serve as a basis for improving the method of traffic safety assessment, as they do not take into account many factors. The purpose of the work is to provide traffic safety specialists with an effective express method of evaluating the level of traffic safety with points directly on the road.

3. The main results of the study

When developing or improving road safety assessment methods, it is necessary to establish, among other things, the influence of variable road factors on traffic safety and to give a quantitative assessment of their change degree. These factors determine the choice of a further mathematical model, which must meet the following requirements:

- the use of random values characterizing the level of accidents on highways and allowing to identify a dangerous area;
- operation with the minimum necessary sample of data on road accidents;
- the use of the type of mathematical distribution curves that will provide a description of the distribution of "accidental" road accidents on the highway network with the necessary approximation;
- identification of sections of roads on which there is an excess of a stable number of road accidents.

All the methods of identifying dangerous areas that are offered today are based on traffic accident statistics. At different times, the following methods were proposed: analysis of statistical data by the methods of probability theory; use of multivariate correlation analysis data; analysis of traffic speed charts (methods of safety factors and "acceleration noise"); analysis using coefficients of relative impact of individual road elements (method of accident coefficients); method of conflict situations.

Today, in Ukraine, it is proposed to evaluate the levels of emergency according to the following micro-indicators *(Methodology, 2008)*:

- determination of the adventure factor;
- determination of the main statistics of the kilometer-by-kilometer distribution of accidents on sections of public roads and the share of road accidents that occurred under conditions of unsatisfactory road maintenance;
- determination of the accident rate.

The accident rate, which is used to evaluate highway sections according to the degree of traffic danger, is determined for highway sections with homogeneous traffic intensity, respectively, for the number of road accidents with victims or their total number according to the formula:

$$K_{ac} = \frac{10^6 \times z}{t \times 365 \times N \times L}, \qquad (1)$$

where K_{ac} – the number of road accidents per 1 million car-kilometers;

z – the number of traffic accidents on the section of the road, pcs.;

N – average annual daily traffic intensity for the last year of the monitoring period for the distribution of traffic accidents on the road section, cars/day;

t – the number of years of monitoring the distribution of traffic accidents (three years is recommended);

L – length of the section, km (not taken into account for short sections less than one kilometer long).

The method requires the collection of statistical material before each trip to the road section to be evaluated.

As can be seen from (1), to determine the risks of the impact of various factors on accidents in all proposed methods of evaluating the road safety level, such a component as traffic intensity is required. This parameter is also necessary for the below-proposed evaluation of road safety with points in the form of an impact factor. A characteristic feature of the traffic intensity influence on accidents is a natural increase in traffic accidents with increasing traffic intensity. This fact has been established by numerous studies *(Osipov V. & Melnichenko O., 2019)*.

The effect of traffic intensity on the number of accidents is described by the study using the elasticity of accidents relative to traffic intensity. This elasticity shows the percentage change in adventures when traffic changes by 1% (Figure 1).

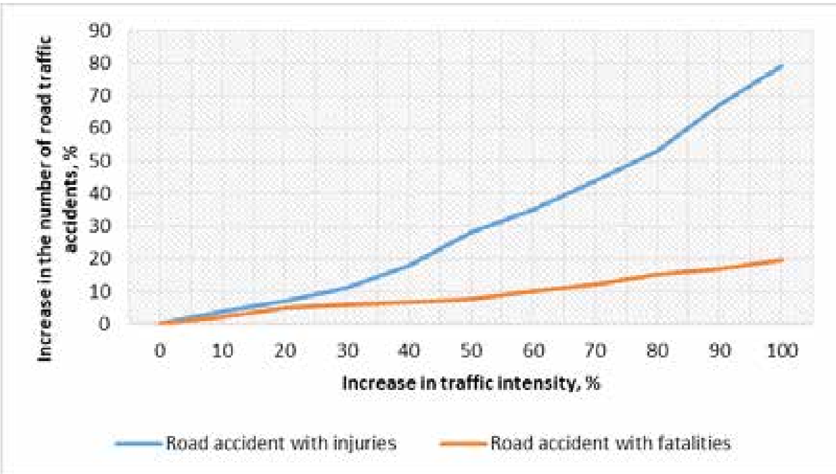

Fig. 1. The relationship between the intensity of traffic and the number of accidents according to (*Osipov V. & Melnichenko O., 2019*)

In 2012, Ukraine developed the Methodology for auditing traffic safety at the stage of operation of public highways *(Methodology, 2012)*. Among other things, the methodology proposed an express method of determining the intensity of traffic. This method has been tested by the authors and has already been proposed as an effective means of determining one of the parameters when assessing the risk of a road accident.

The intensity of movement per day is calculated according to the formula:

$$N_D = N_t \times K_1 \times K_2 \times K_3, \tag{2}$$

where N_t – intensity per hour, auto/hour;

K_1 – the coefficient of change in the intensity of movement per hour per day (Table 1);

K_2 – coefficient of change in traffic intensity by day of the week (Table 2);

K_3 – coefficient of change in traffic intensity by month of the year (Table 3).

The intensity of movement per hour is calculated according to the formula:

$$N_t = \frac{\grave{a}_t \times 60}{t}, \quad (3)$$

where a_t – the number of cars during the accounting period (recommended 15–60 minutes);

t – recording duration, minutes;

60 – the number of minutes in an hour.

Table 1

Correction coefficient, K_1

hours	**8–9**	**9–10**	**10–11**	**11–12**	**12–13**	**13–14**	**14–15**	**15–16**	**16–17**	**17–18**	**18–19**
K_1	2,67	6,31	14,95	16,89	16,0	14,49	16,70	14,0	11,63	15,11	19,72

Table 2

Coefficient of change in traffic intensity by day of the week, K_2

days	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
K_2	1,036	1,029	1,074	1,116	1,122	0,996	0,657

Table 3

Coefficient of change in traffic intensity by month of the year, K_3

months	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
K_3	1,00	0,92	0,79	1,00	1,26	1,01	0,99	1,02	1,01	0,98	1,03	1,00

By their nature, the tasks of risk assessment and prediction of the consequences of road accidents exclude full-scale field experiments due to their danger, and the use of mathematical modeling. This approach is the only method of obtaining a picture of the development of both hypothetical emergency situations and the analysis of accidents that have taken place in the past. According to the model approach, the forecast is made regarding the specific conditions in the "driver-road" subsystem *(Procedure, 2003)*.

According to *(Procedure, 2003)*, a linear analysis of accidents and an assessment of traffic safety conditions should be carried out by the road owner or a road company within the scope of its maintenance in order to quickly identify the places of concentration of traffic accidents, in which deficiencies in the operational maintenance of the road section could be associated factors. The analysis should be performed monthly with a cumulative total during the year.

It is proposed to evaluate traffic safety conditions by the final sum of points (on a 100-point scale), which takes into account a number of characteristics of road construction. In our opinion, in conditions where the assessment of road traffic safety conditions according to *(Procedure, 2003)* is entrusted to the representatives of the road owner, this method looks more effective, since the road owner does not always or does not fully possess reliable statistical information about road accidents on the area being evaluated.

For example, according to the data of the Patrol Police Department, in 12 months of 2020, 459 road accidents occurred on the highways of the Kyiv region, during the inspection of which deficiencies in the operational maintenance of the roads were revealed. However, according to the Highway Service Agency in the Kyiv region, there were 386 road accidents. The discrepancy was 73 road accidents, or 16.2%. Of course, with such facts, the road owner should proceed with caution. That is why, we can talk about systematic measurement errors due to incomplete registration of incidents in road safety management system.

In addition, in connection with the intention to introduce "Europrotocols" on the territory of Ukraine, it is not possible to investigate the causes of some categories of road accidents due to the lack of information about them. Since the action of the Europrotocols provides for the registration of road accidents without representatives of the National Police and, accordingly, the owners of the roads in the absence of dead and injured and a small amount of damage. During the development of the scoring method for evaluating road safety, maps of places of concentration of traffic accidents in the period from 2007 to 2013 were analyzed. Maps of places of traffic accidents concentration appear to be the most reliable source of information, as they are compiled simultaneously by representatives of the highway owner, the State Traffic Inspection and the road design organization, and are the object of government statistical reporting.

A total of 28 places of concentration of traffic accidents on state and local highways were covered by the analysis. Based on the analysis, it was found that 95% of the measures involved the installation of new or replacement of existing means of preventing road accidents.

Thus, 30.43% of the proposals regarding the use of road signs in the maps of the places of traffic accidents concentration; the use of horizontal road markings was 30.43%; the use of guide posts was 8.69%; the use of traffic lights was 8.69%; the use of fencing was 8.69%; the use of means of forced speed reduction was 4.34%; the use of anti-glare screens was 4.34%; the use of noise bands was 4.34% (Fig. 2).

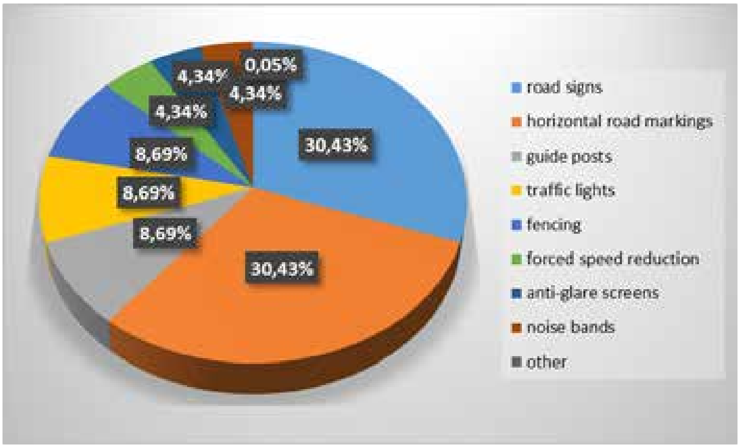

Fig. 2. Distribution of the use of means of road accident prevention

The algorithm for building a scoring method for evaluating the level of road safety has the following form. To obtain the values for the implementation of the 100-point emergency rating system, we convert percentages into points by rounding them to the nearest tenth. Accordingly, we get an assessment of the implementation of individual technical means in points (Table 4).

Table 4

Scale of conditional points for technical means

N	technical means	Conditional score assigned
1.	road signs	30
2.	horizontal road markings	30
3.	guide posts	7
4.	traffic lights	7
5.	fencing	7
6.	forced speed reduction	4
7.	anti-glare screens	4
8.	noise bands	4
9.	other	2

However, these points can be considered correct when all technical means have one hundred percent visibility in various weather and time conditions according to existing regulations. The more time the arranged technical means is on the road, the higher the probability that the driver will not receive information from it due to a decrease in its operational properties.

Indicators of technical means that ensure road traffic safety (in the dark or in adverse weather conditions) include:

- reflective effect of the surface of road signs according to National Standard;
- visibility distance of vertical and horizontal markings according to National Standard;
- reflective effect of road marking inserts according to National Standard;
- signal strength of traffic lights according to National Standard;
- visibility distance of guiding devices according to National Standard;
- visibility of means of forced reduction of speed according to National Standard;
- noise level when a vehicle hits noise lanes in accordance with Local Standard;
- reduction of blinding of drivers when using anti-dazzle screens.

Therefore, there is a need to introduce a reducing coefficient of visibility during the survey, provided that a new technical device manufactured according to the standards of 1 is accepted. When applying the reduction factor, it is recommended not to measure the visibility of technical means with special devices, but to use only a tester with an average degree of vision. So, it can simulate the conditions of visibility of the object by an average driver. This is a very important factor, because according to the time analysis of traffic accident cards, accidents accounted for 61.4% during the day, 21.4% at night, and 17.1% at dark.

It is also necessary to introduce a lowering factor separately, which would take into account the degree of danger for the transport of the technical means itself in the event of a probable collision with it (degree of deformability). According to 1, in this case, it is possible to accept road accident prevention tools made from materials that are recognized as the most dangerous according to modern comparisons and studies.

The lowering coefficient is proposed to be determined by the formula:

$$K_f = 1 - (K_D + (1 - K_i)), \tag{4}$$

where 1 – a new (reference), the most dangerous in terms of deformability, a newly installed technical device, manufactured according to the standard;

K_D, K_i – components of the decrease in the operational state of the technical means (visibility) and its deformability (reduction coefficients).

It should be noted that according to the cards, the effect of the implementation of measures at the places of traffic accidents concentration was 76.03%. That is why, we can talk about a stable correlation between the implementation of these measures and a decrease in accidents, and vice versa, an increase in accidents when these measures are not carried out.

The effectiveness of the implementation of measures was calculated according to the formula:

$$E = \frac{Z_b - Z_a}{Z_b} \times 100\%, \qquad (5)$$

where E – social efficiency from the implementation of road safety measures, %;

Z_b – the number of traffic accidents in the area "before" the implementation of measures to improve traffic safety;

Z_a – the number of traffic accidents in the area "after" implementation of measures to improve traffic safety.

Road safety assessment as road safety management system part must be carried out with the road traffic organization project, which will serve as a benchmark. If the project does not provide for the installation of means of road accident prevention on the inspected section, then the section is considered safe by definition from the point of view of the impact of the road factor on accidents; other component systems should be studied.

It is recommended to carry out an assessment: on a flat area – up to 1 km long (a potentially accident-dangerous area with zones of influence is studied); intersections, railroad crossings, junctions and other accident-prone areas are recommended to be investigated as separate objects *(Standard, 2002)*. Indicators of the degree of danger of road sections by points are suggested to be used according to the table 5.

Table 5

Indicators of the degree of danger of road sections according to the determined points*

Number of points	Evaluation criterion*	Traffic safety level
0–25	means of road accident prevention installed according to the dislocation, meet regulatory requirements, materials with a safe level of deformability	Safe
25–50	means of road accident prevention available, some need updating	Low risk
50–75	means of road accident prevention are partially missing, the existing ones need to be updated or installed	Dangerous
75–100	Practically complete (or complete) absence of means of road accident prevention. The existing ones are not visible enough or are blocked by something. means of road accident prevention with a dangerous level of deformability	Very dangerous

* the main (typical) criteria are formulated in the table, but they can change and be composed

To determine the risks of the impact of other factors on accidents in all proposed methods of assessing the level of road safety, such a component as traffic intensity is required; this parameter is also necessary for evaluating road safety with points in the form of an impact factor.

4. Conclusions

The proposed method of evaluating the level of traffic safety is an undoubted step forward on the path of simplification and clarification of existing methods. In the future, work on the construction of a simulation model of the interaction of the driver and the road as a subsystem of the general system "driver-car-road-environment" looks promising, by relying on criteria that were previously neglected – technical means of traffic management. This will make it possible to calibrate the proposed method and transfer its action to the software environment. In this way, the research will receive a significant platform for the involvement of additional variables – taking into account the road category, time of day, informativeness of technical means, their deformability, etc.

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