Innovative approaches to optimizing the road safety monitoring system

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Abstract. The article presents a statistical analysis of innovative approaches to optimizing the system for monitoring the level of accidents and social risk, which is aimed at improving the predictive capabilities of the existing system for monitoring road safety indicators on the State Traffic Safety Inspectorate website. The purpose of this study in the field of studying the dependence of the number of social risk and road accidents is a quantitative increase in this kind of accidents on the road network in the Federal Districts. Based on the data obtained, through the use of innovative methods and calculations of social risk, such as artificial intelligence and big data analysis for constructing a safer and more optimal road safety control system. The results of the intellectual research in the field of road safety in the Federal Districts of Russia under consideration allow us to conclude that there are significant opportunities in the work of innovative approaches in the field of ensuring road safety through the introduction of intelligent systems and effective algorithms.

1 Introduction

Road traffic accidents (RTA) are one of the most significant problems in Russia, which consist in the complete conjugation of social and economic spheres, due to the fact that in such accidents people are injured or killed, which has a significant impact on the lives of citizens in Russia. Based on the analyzed statistical data regarding the subjects, a significant level of road accidents is recorded. In the context of progressive urban development, growth of automation and traffic intensity, the issue of accidents and road safety is gaining momentum in relation to the considered accidents that occurred in federal districts and in the context of regions [1]. Changing the number of accidents in a positive direction requires a combined solution, which includes improving the road infrastructure, introducing innovative technologies, expanding existing educational programs for all road users, high-quality control and effective application of measures regarding compliance and violation of traffic rules, respectively. It is important to take into account the specifics of each region, because the factors affecting road safety can vary significantly depending on population density, income level, road network conditions and migration processes [2].

The quality of road infrastructure plays a key role in ensuring road safety. The presence of modern and well-maintained roads, as well as lighting systems, signs and markings can

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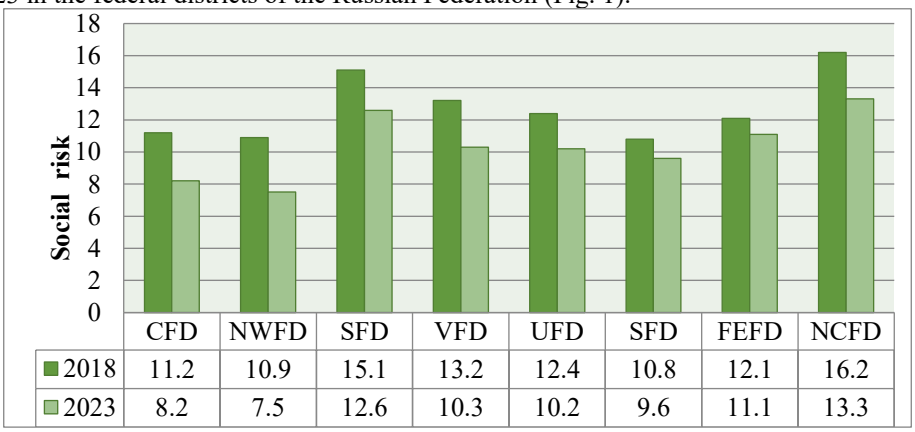
significantly reduce the likelihood of accidents. Analysis of the current state of the road network allows us to identify areas with a high accident rate where improvements are needed. With the introduction of new technologies, such as automated traffic management systems, traffic monitoring equipment and the use of artificial intelligence to analyze big data on accidents, it is possible to significantly improve the level of safety. Intelligent transport systems (ITS) allow us to optimize vehicle flows and immediately respond to changes in the situation on the road. Educational programs are aimed not only at drivers, but also at pedestrians, cyclists and other road users [3]. Programming high-quality training, promoting safe behavior on the road and understanding the consequences of traffic violations can significantly change citizens' attitudes towards safety issues and reduce the number of accidents. Raising awareness of road safety and the consequences of violations of rules is necessary. Including road safety topics in school programs and public information campaigns form a culture of safe behavior on the roads. Road traffic accidents cause significant economic losses for the state and society. The costs of treating accident victims, compensation for damage, and the costs of eliminating the consequences of accidents (including infrastructure restoration and rehabilitation of victims) can significantly affect budgets at both the local and federal levels. Investment in road safety can not only reduce the number of accidents, but also lead to economic growth by reducing the costs of treatment and rehabilitation [4].

The purpose of this study is a qualitative and combined analysis of the influencing causes and accompanying factors that influence the formation and growth of accidents in federal districts and regions. Explication of the influencing factors that contribute to the organization and provision of safe road traffic conditions is a primary aspect on the path to minimizing road accidents and preserving the social and economic sphere.

2 Materials and methods

Road traffic accidents and measures taken to minimize them and improve road safety in the federal districts were considered through the prism of social risk [5]. In order to clearly illustrate the topic under consideration and for a clearer understanding of its essence, we will provide an example of statistical data and a comparative analysis for the period from 2018 to 2023 in the federal districts of the Russian Federation (Fig. 1).



	CFD	NWFD	SFD	VFD	UFD	SFD	FEFD	NCFD
2018	11.2	10.9	15.1	13.2	12.4	10.8	12.1	16.2
2023	8.2	7.5	12.6	10.3	10.2	9.6	11.1	13.3

Fig. 1. Level of social risk in the Federal Districts of the Russian Federation

The graph shows that the level of social risk in 2023 is significantly lower compared to the analyzed 2018. And if in 2018 in the Central Federal District the level of social risk was 11.2, then in 2023 the data has changed significantly - 8.2 (-26.8%). The same situation is

observed in other federal districts: Northwestern - 31.1%, Southern - 19.2%, North Caucasian - 21.9%, Volga - 17.7%, Ural - 11.1%, Siberian - 8.2% and Far Eastern - 17.9%. Each subject of the Russian Federation in relation to the increase in accidents is focused on reducing the quantitative data of fatalities to 4 cases per 100 thousand people.

Measures to improve and enhance the level of road safety include: prevention (events, tests and lectures), traffic management (implementation of advanced and modern strategies in the development of vehicles), technical and road supervision (use of special equipment, monitoring the movement of road users) [6]. A significant part of our intelligent statistical analysis in the VADS system are preventive measures and work with drivers, functioning as a component in the field of work to minimize social risk. The Driver-Car-Road-Environment System (VADS) [7] consists of a complex and interconnected connection of elements, where each component performs leading functions in ensuring road safety (Fig. 2).

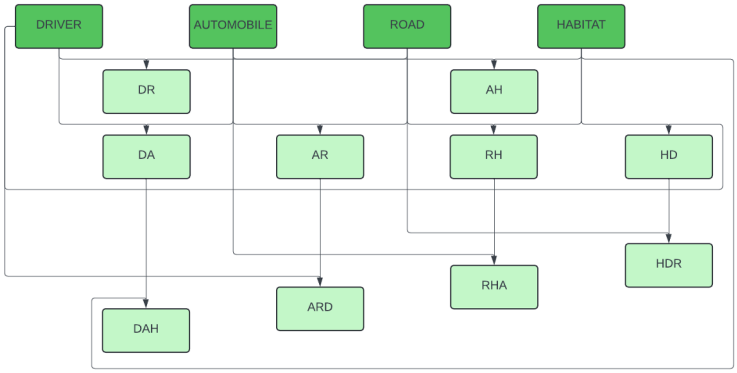


Fig. 2. Structural component of the VADS system

The system under consideration covers several primary components: driver, vehicle, road and environment. The purpose of these ongoing and considered activities is to ensure safety and strive to reduce the number of road accidents to zero. Consequently, if all components of the system work properly and are improved in terms of minimizing the occurrence of accidents on the roads in a specific region and, in general, in the district, then it will be possible to talk about achieving a conditionally safe state on the road in the subjects. Analyzing these components according to the VADS system, it is possible to establish the influencing causes and accompanying factors for the occurrence of road accidents and changes in the level of social risk in the context of federal districts of Russia. Within the framework of 89 subjects of the Russian Federation, it is possible to identify a number of influencing causes for the occurrence of accidents on the road, and most importantly, in different areas they can have different levels of importance and relevance, and also not coincide in key factors. Factors that influence the occurrence of road accidents:

1. Human factor (driver fatigue and drowsiness, failure to comply with traffic rules, sudden braking, failure to maintain distance between vehicles, stress, etc.);
2. Technical reasons (vehicle malfunction, unfavorable road and weather conditions, etc.);
3. External factors (increased traffic intensity, uneven distribution of traffic flow) [8].

Some aspects may be critical for one area, but not play a significant role in another. For example, in some areas the main reason for the increase in road accidents may be problems with the condition of the road infrastructure, and in others - failure of drivers to comply with traffic rules.

If we analyze certain road accidents, which in turn are caused by one element of the VADS system - the driver - we can make an intelligent statistical analysis based on the data

provided by the State Traffic Safety Inspectorate, including key indicators of the state of road safety associated with the participation of various types of vehicles, namely: trucks, cars, passenger cars, motorcycles, mopeds, etc. [9].

Furthermore, it is worth noting that the analysis of accident data directly by vehicle type can reveal deeper problems faced by various federal districts. For example, in some regions there is an increase in the number of accidents involving motorcycles and mopeds, which requires attention to the specifics of drivers of these vehicles, who are often insufficiently trained in traffic rules and safety.

In addition, the so-called "human factor" remains one of the main causes of road accidents. Driver errors, such as speeding, failure to take into account weather conditions and road surface conditions, lead to serious consequences. Using data mining methods, it is possible to identify those factors that influence violations by drivers: these can be both time intervals (for example, evening rush hour), and meteorological conditions (rain, snow), as well as the influence of alcohol and drugs.

By clustering the data, it is possible to identify groups of drivers who are most at risk of participating in accidents. This can be useful for developing targeted programs to improve safety, including training, preventive actions and enhanced enforcement of traffic rules.

It is also important to consider the age structure of drivers involved in accidents. Young people are generally more prone to risky behavior on the road, which can be aggravated by a lack of experience. Such an analysis will allow us to focus efforts on educating and supporting this group.

Thus, intelligent statistical analysis of road accidents will not only characterize the current state of road safety, but will also become the basis for developing comprehensive measures aimed at reducing the number of accidents. This emphasizes the importance of not only monitoring statistics, but also a deep understanding of the causes, consequences and possible solutions to the problems facing the road safety system in Russia.

Intelligent analysis of the relative number of road accidents by federal districts in the Russian Federation for the period from 2018 to 2023 will allow us to give an accurate assessment regarding the dynamics of accidents in the subjects and determine various trends and causes of their occurrence. As a clear example of the number of road accidents for 2018-2023 in federal districts, we will provide a statistical analysis and calculation regarding relative units in road accidents (Fig.3).

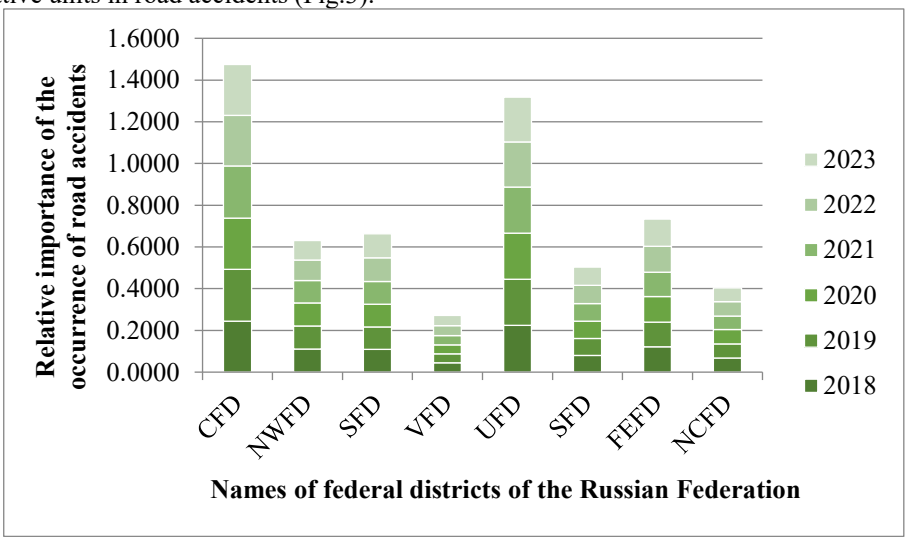


Fig. 3. Relative importance of road accidents by federal districts in the Russian Federation for 2018-2023.

This problem can be visualized in the form of a certain hierarchical ladder based on the selected indicators of the state of road safety, which, equally, focuses on the versatility of this system and the relationship between its components.

As a clear example, regarding statistical data on indicators of the state of road safety, we can consider the calculations of quantitative data in the Central Federal District by region for the period under review 2018-2023.

1. The calculation of the share of road accidents in the regions (Belgorod Region) relative to federal districts (Central Federal District) is calculated using the method:

$$B_s = \frac{R_a * 100}{N_k}, \qquad (1)$$

where R_a is the selected region in the federal district under consideration for road accidents in 2023, units; N_k is the total number of road accidents in the federal district under consideration for 2023, units.

The solution to formula (1) is:

$$B_s = \frac{1\,098 * 100}{32\,255} = 3.4 \; units \; (fig.4)$$

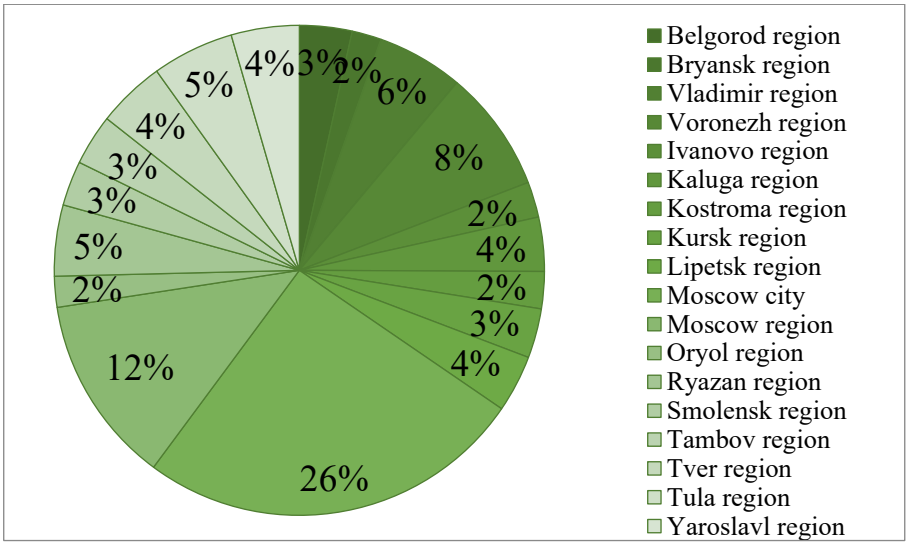


Fig. 4. Calculation of the share of road traffic accidents in the regions of the Central Federal District for 2023.

In the period under review from 2018 to 2023, based on the statistical analysis of the road safety indicators of the State Traffic Safety Inspectorate statistics, relative to the selected Central Federal District and, in particular, the studied Belgorod Region, it can be recorded that the dynamics of road accidents expresses a certain stable dependence (Fig. 5).

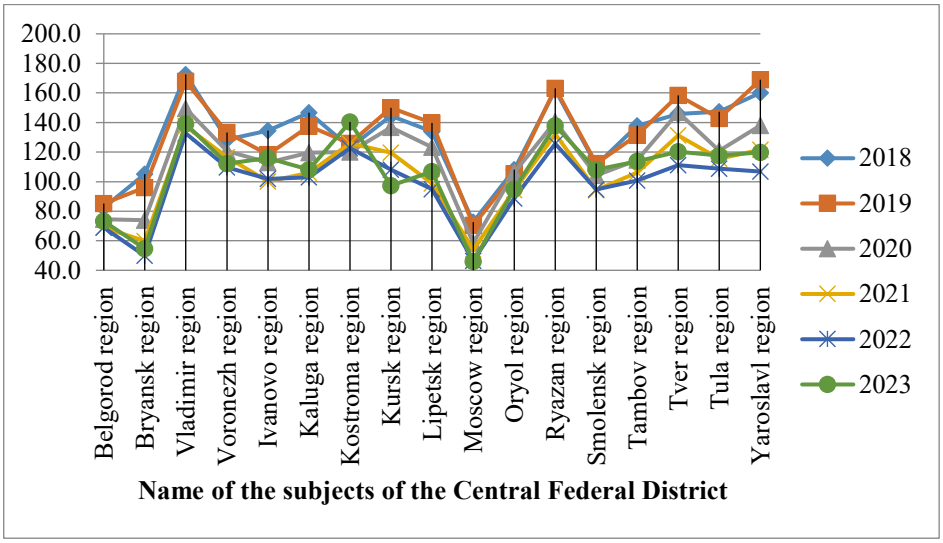


Fig. 5. Number of road accidents with casualties in the Central Federal District for the period from 2018 to 2023.

Nevertheless, based on statistical data on road safety in federal districts, the number of traffic accidents demonstrates a tendency in quantitative change. However, it is worth emphasizing that the calculated share of social risk and the probability of accidents involving drivers, which, in turn, occurred due to their fault, is fixed at unchanged positions - 85%.

Despite the effective and efficient work in the field of road safety, the human factor continues to be one of the determining elements of most road accidents [10]. Conditional indicators indicate the recorded state in the field of road safety, and also emphasize the need for a deeper intellectual statistical analysis of the factors and causes influencing the occurrence of accidents in the subjects of the Russian Federation. Within the framework of traffic management and preventive measures to rapidly reduce the total number of road accidents in the regions, it is imperative to focus attention on aspects that, in turn, determine the behavior of drivers, which, equally, can become the initial vector of further observations, the creation and implementation of effective preventive measures in the field of road safety.

The impact of the road infrastructure on driver behavior is no less significant. Incorrect road design, lack of clear signaling, lack of sidewalks and pedestrian crossings can contribute to an increase in the number of accidents. Therefore, it is important not only to introduce new technologies and control means, but also to comprehensively improve the road infrastructure.

In addition, it is necessary to conduct regular educational programs for drivers, which would emphasize responsibility, accuracy and respect for other road users. Encouraging responsible behavior, for example, through social campaigns or incentive programs for safe driving, can bring positive results [11].

The need to integrate all these factors into a single road safety management system should also be emphasized. The creation of interdepartmental coordination councils, uniting representatives of the State Traffic Safety Inspectorate, local authorities and public organizations, can become a systemic approach to solving the problem. Such an approach will ensure not only a decrease in the number of accidents, but also the integration of opinions of various stakeholders, which will allow the most effective application of practices that have proven their effectiveness in other regions or countries.

3 Results

In the course of this study, it was found that the introduction of innovative approaches to improving the road safety monitoring system allows for a quantitative reduction in the number of road accidents. Intelligent analysis of statistical data regarding the Federal Districts of the Russian Federation showed that there is a direct relationship between the number of accidents and social risk in the regions. However, it is worth recalling that, according to the statistical data and calculation formulas, the share of social risk and the probability of accidents involving drivers, which, in turn, occurred due to their fault, is fixed at unchanged positions in the regions - 85%.

The proposed and considered innovative approaches to road safety monitoring, which, in turn, are based on calculations and analysis of statistical data, allow for more accurate identification of high-risk road sections, targeted measures to improve them, and accident prevention. This approach helps reduce road injuries and ensure a higher level of safety for road users.

4 Discussion

The study on the development and implementation of an innovative approach to optimizing the road safety monitoring system, conducted in the field of road safety by calculating the number of road accidents in Federal Districts and by regions, as well as the dependence of social risk on statistical data of the Russian Federation, is a significant contribution to the field aimed at regulating the situation on the road network.

According to the results of the calculations, it was revealed that there is a direct relationship between the number of road accidents and the level of social risk.

In fact, by studying the direct relationship of two variables (the number of road accidents and the level of social risk), one can focus on how innovative approaches and the latest technologies in the field of monitoring can reduce the number of road accidents and reduce social risk on the roads. Important aspects of such approaches may include the use of artificial intelligence (calculation of matrices and formulas for solving complex problems and combined queries), big data analytics (comparison of several indicators of the state of road safety), cloud technologies and other innovations. Thus, the research in this area confirms the urgent need to implement innovative approaches to optimize the road safety monitoring system, which will further help reduce the number of accidents and improve the level of road safety.

5 Conclusions

The income level of the population, population density, gross domestic product (GDP) per capita and migration processes have a significant effect on changing the statistics of road accidents both in the federal districts of the Russian Federation and in the regions. Intelligent analysis clearly shows that economic and social aspects, such as income level and quality of material well-being of citizens, are directly related to the frequency of accidents on the roads [12]. Population density, in addition, is of key importance and is accompanied by increased traffic flow intensity and, as a consequence, a negative increase in the number of accidents on the road by all road users. Population migration, in this regard, can affect the organization of transport communications, which ultimately clearly shows a change in the level of social risk and accidents [13]. Thus, the introduction of innovative approaches to the road safety monitoring system is a critical step in creating a safer and more efficient road infrastructure. The use of modern technologies, such as big data analytics and real-time monitoring systems,

will allow for a more accurate identification of trends and patterns affecting road safety. This will also provide the opportunity for a comprehensive approach to developing strategies aimed at reducing accidents, adapting the road network to rapidly changing conditions, and effectively allocating resources for preventive measures. As a result, improving road safety will not only improve the quality of life of citizens, but will also create the basis for sustainable economic growth by reducing the social and economic costs associated with road accidents [14].

Thus, given the complexity of the problem, it can be argued that a multi-level strategy is needed, covering both preventive measures and work with the human factor. Intelligent statistical analysis of road accidents will not only characterize the current state of road safety, but will also become the basis for developing comprehensive measures aimed at reducing the number of accidents [15]. This will allow us to create a safe and comfortable road environment in the future, which will have a positive impact on the overall state of safety on the roads of the Russian Federation [16].

Based on this, it can be concluded that a combined study of these causes and factors, as well as the comparative position of a certain relationship, to a greater extent contributes to a deep understanding of the aspects influencing the occurrence of accidents and the development of optimal approaches and new strategies to improve the state of road safety.

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