Indicators of Road Safety as a Phenomenon of National Security of the State

Anatoli Kvitchuk, Margaryta Kvitchuk, Sergey Evtyukov, and Egor Golov

Abstract The article is devoted to the actual problem of ensuring road safety. In this article, on the basis of official statistical data, the issues of the organization of complex statistical analysis are considered. The following methods of statistical analysis were used to assess road safety: descriptive analysis (description of initial data, a priori analysis); relationship analysis (correlation and regression analysis, variance analysis); multivariate statistical analysis (linear and nonlinear analysis, cluster analysis, factor analysis, etc.); time series analysis (dynamic models and forecasting). The paper emphasizes the importance of quantitative analysis, and suggests some methods for assessing road safety. The study analyzed traffic accidents in Russia in the period from 2009 to 2019, the conclusions on the dynamics of change and also determined that, in assessing road safety as a phenomenon of national security used by each of the methods has its advantages and disadvantages, which are manifested in varying degrees, depending on purpose and depth of analysis of the research object, the technical capabilities, therefore, the most effective will be sharing discussed in the article methods.

Keywords Monitoring · Road safety · a priori analysis · Correlation and regression analysis · Time series

1 Introduction

Road traffic accidents cause colossal material, social and demographic damage to society. In Russia, according to the Main Directorate for Traffic Safety of the Ministry of Internal Affairs of Russia for 2019, the total number of road accidents was equal

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to 164,358 accidents [1]. The number of deaths due to road traffic accidents was 16,981 people.

The first stage of road safety analysis is statistical observation or monitoring—a system for observing indicators, which in turn is information and analytical support for the process of making managerial decisions in the departments of the State Traffic Inspectorate of the Ministry of Internal Affairs of the Russian Federation.

Of course, when organizing monitoring, it is necessary to use the usual principles of statistical research—representativeness and economy. This means that monitoring should be aimed at obtaining facts that are statistically significant for a given system, allowing them to be used to assess processes and phenomena of a system-wide nature and have a general focus and organization of observations [2].

During monitoring, such a problem arises as the manipulation of information reflected in quantitative indicators. In solving this problem, it is necessary to use methods of quantitative analysis to bring the observation results into an information-analytical form [3].

2 Methods

Let's list some methods of statistical analysis in assessing road safety: descriptive analysis (description of the initial data, a priori analysis); relationship analysis (correlation and regression analysis, analysis of variance); multivariate statistical analysis (linear and nonlinear analysis, cluster analysis, factor analysis, etc.); time series analysis (dynamic models and forecasting), etc.

The first group includes a priori analysis. What is the essence and significance of this method? By the methods of a priori analysis, we mean the totality of specific forms of theoretical and practical approach to the collection and analysis of information (data) on the scale of road traffic accidents, including:

- identification of economically justified and significant cause-and-effect relationships between signs and phenomena;
- assessment of the homogeneity of the studied population;
- analysis of the nature of the distribution of the population according to the studied characteristics.

An important task of research in the field of road safety at the stage of a priori analysis is to identify homogeneous groups [4]. Grouping is done to study the structure of a given population or for the relationship between the indicators that make up the population. Using this method, you can identify how individual units of the population affect the average total indicators.

When assessing the level of road safety using a priori analysis, it is possible to study the anomalies of the observed accident rate on the roads of Russia [5].

Average values are of no small importance in research, their calculation depends on the goal of the study, on the type and relationship of the studied characteristics, as well as on the nature of the initial data. Figure 1 shows the classification of average

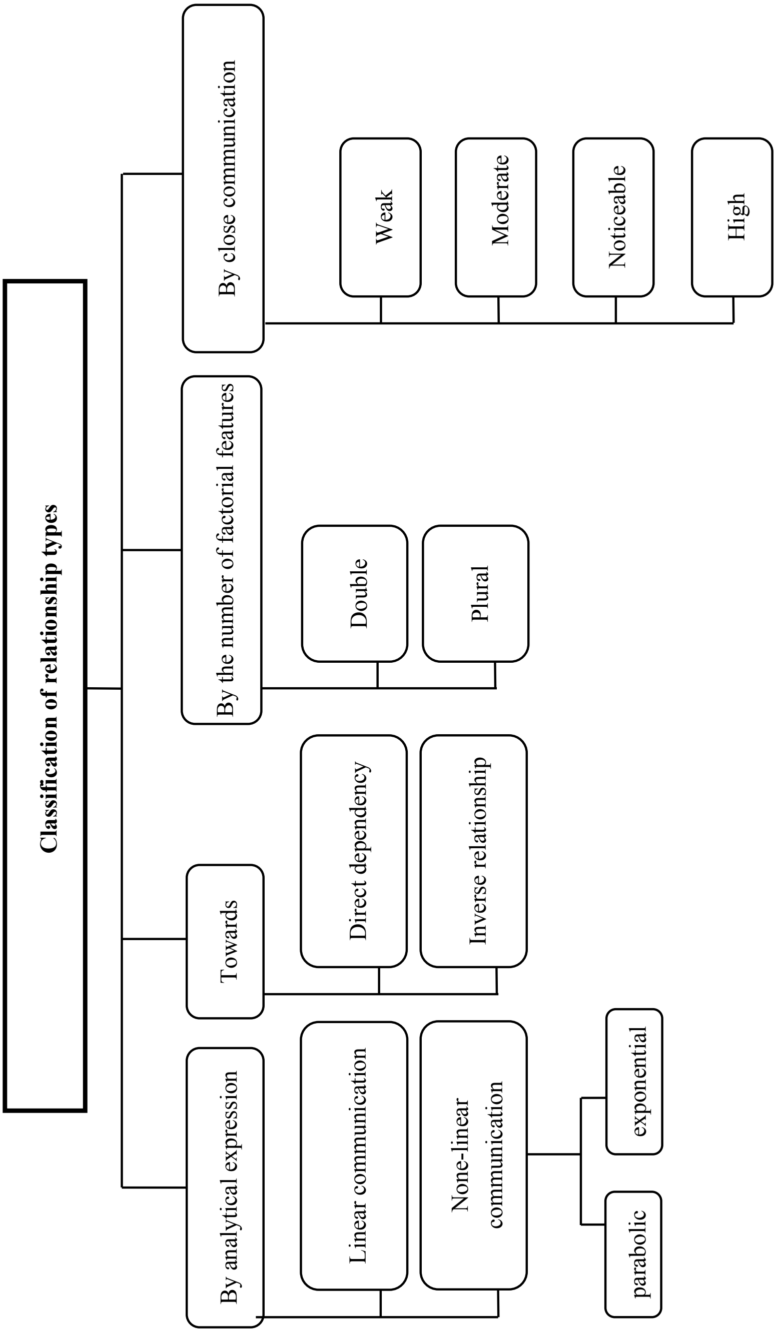

Fig. 1 Classification of relationship types

Table 1 Types of power averages and their applications

K	Name average	Average formula	
		simple	weighted
1	Arithmetic	$\overline{X}_{ar} = \frac{\sum X_i}{N}$	$\overline{X}_{ar} = \frac{\sum X_i f_i}{\sum f_i}$
It is used when replacing individual values of a characteristic; the total volume of the characteristic must be saved without changing			
− 1	Harmonic	$\overline{X}_{\mathbf{HM}} = \frac{N}{\sum \frac{1}{X_i}}$	$\overline{X}_{\mathbf{HM}} = \frac{\sum f_i}{\sum \frac{f_i}{X_i}}$
It is used when variants of a feature are known, its volumetric value, but frequencies are not known			
0	Geometric	$\overline{X}_{geom} = \sqrt[N]{\prod_{i=1}^{N} X_i}$	$\overline{X}_{geom} = \sqrt[N]{\prod_{i=1}^{N} X_i^{f_i}}$
Used for averaging chain dynamics indices			
2	Quadratic	$\overline{X}_{qd} = \sqrt{\frac{\sum X_i^2}{N}}$	$\overline{X}_{qd} = \sqrt{\frac{\sum X_i^2 f_i}{\sum f_i}}$
Used when measuring the variation of a feature			
3	Cubic	$\overline{X}_{cub} = \sqrt[3]{\frac{\sum X_i^3}{N}}$	$\overline{X}_{cub} = \sqrt[3]{\frac{\sum X_i^3 f_i}{\sum f_i}}$
Used to calculate population poverty indices			
1	Chronological	$\overline{X}_{CH} = \frac{\frac{X_1+X_N}{2}+\sum_2^{N-1} X_i}{N-1}$	$\overline{X}_{CH} = \frac{\sum (X_i+X_{i+1}) f_i}{2\sum f_i}$
Used for averaging moment statistics			

values [6].

The shape of the mean depends on the exponent k. Table 1 presents all the main averages used in socio-economic calculations.

One of the practical methods is correlation—regression analysis, which is used to identify factors affecting the number of road accidents. For example, the dependence of the number of accidents on the day of the week, month, type of incident or lighting [7]. The classification of the types of relationship is shown in Fig. 1.

3 Results

In the study, we will consider the impact of economic factors on the number of road traffic accidents in Russia for 2005–2019, using the multiple correlation method. The obtained official statistical data will be presented in Table 2. The resultant indicator (y), of course, will be the number of road accidents, as factor indicators we will take: the inflation rate (x1), the average monthly nominal wages of employees of organizations in Russia (x2) and the value living wage (average per capita; rubles per month) (x3) [8–14].

Table 2 Indicators for assessing relationships using multiple correlation

Year	Inflation rate	Average monthly nominal accrued wages of employees of organizations in Russia	Living wage (average per capita; rubles per month)	Number of road accidents in Russia
2005	10.91	8555	3018	223,342
2006	9.00	10,634	3422	229,140
2007	11.87	13,593	3847	233,809
2008	13.28	17,290	4593	218,322
2009	8.80	18,638	5153	203,603
2010	8.78	20,952	5688	199,431
2011	6.10	23,369	6369	199,868
2012	6.58	26,629	6510	203,597
2013	6.45	29,792	7306	204,068
2014	11.36	32,495	8050	199,720
2015	12.91	34,030	9701	184,000
2016	5.38	36,709	9828	173,700
2017	2.52	39,167	10,088	169,432
2018	4.27	43,724	10,287	168,099
2019	3.05	47,468	10,890	164,358

At the second stage, we build an empirical curve for each factor attribute separately (Figs. 2, 3 and 4).

According to the graphs presented, a preliminary conclusion can be made about the presence between the factor signs and the number of accidents in Russia in the first case of a direct strong relationship, and in the last two an inverse strong relationship. We will use the capabilities of Microsoft Excel and calculate the correlation coefficients (Tables 3, 4 and 5) [15–19].

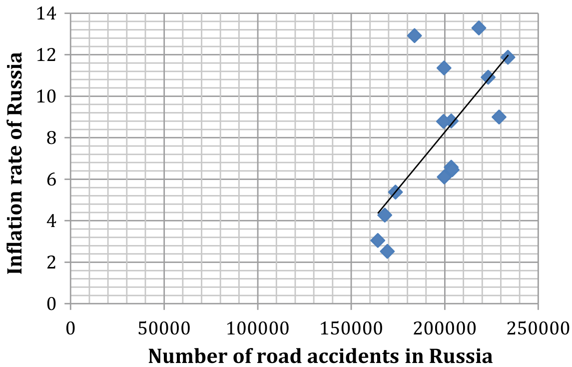

Fig. 2 An empirical curve and its direction. Inflation rate and number of road accidents in Russia

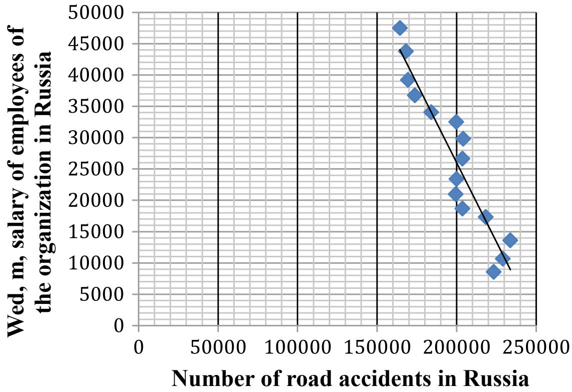

Fig. 3 An empirical curve and its direction. Average monthly nominal accrued wages of employees of organizations in Russia and the number of road accidents in Russia

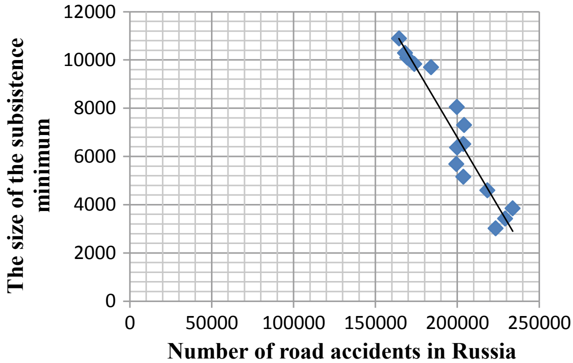

Fig. 4 An empirical curve and its direction. The value of the subsistence minimum and the number of road accidents in Russia

Table 3 Calculation table

R =	Y	X1	X2	X3
Y	1.000	0.700	−0.942	−0.956
X1	0.700	1.000	−0.650	−0.605
X2	−0.942	−0.650	1.000	0.985
X3	−0.956	−0.605	0.985	1.000

Table 4 Calculation table

R11	R22	R33	R44	R12	R13	R14	R23	R24	R34
0.015	0.002	0.040	0.057	0.003	−0.006	−0.019	−0.005	−0.006	0.043

Table 5 Calculation table

r y x1	0.700	r y x1/(x)	−0.562
r y x2	−0.942	r y x2/(x)	0.254
r y x3	−0.956	r y x3/(x)	0.634
r x1 x2	−0.650	r x1 x2/(yx)	0.461
r x1 x3	−0.605	r x1 x3/(yx)	0.533
r x2 x3	0.985	r x2 x3/(yx)	−0.893

$$\begin{aligned} ry(x) &= 0.970 \\ Ry(x) &= 0.941 \end{aligned} \tag{1}$$

Thus, the indicators of the inflation rate, the average monthly nominal accrued wages of employees of organizations in Russia, the value of the subsistence minimum (on average per capita; rubles per month) have a strong influence on the number of road accidents in Russia. To a greater extent, the number of road accidents is influenced by the subsistence minimum, in second place it is necessary to note the average monthly nominal accrued wages of employees of organizations, a moderate relationship is confirmed between the level of inflation and the number of road accidents. Multiple correlation proves that all phenomena in society are interconnected, i.e. there is a relationship between them, which is expressed in the form of causality. In general, the number of road traffic accidents in Russia is decreasing. But still, the state needs to take all measures to improve the situation on the roads, comprehensively covering all areas. This will greatly affect the national security of the state [20–24].

Let us consider the dynamics of the number of road traffic accidents in the Russian Federation as an element of the national security of the state using the time series method.

Table 6 provides information on the number of accidents on the territory of the Russian Federation for 2009–2019.

The dynamics of the number of road traffic accidents in the Russian Federation will be presented graphically by constructing a bar chart by chain rates of growth (Fig. 5).

4 Discussion

Thus, the number of road traffic accidents in 2010 compared to 2009 decreased by 2.049%; in 2011, the number of road accidents compared to 2010 increased by 0.219%; in 2012, the number again decreased by 24.878% in comparison with 2011, and in 2013, on the contrary, a large increase in road accidents (by 35.915%) is noticeable compared to 2012, these changes are clearly visible in the presented diagram. Since 2014, there has been a gradual decrease in road traffic accidents in comparison with the previous year: in 2014—by 2.131%, in 2015—by 7.871%, in

Table 6 Indicators of the dynamics of the number of road traffic accidents on the territory of the Russian Federation for 2009–2019

Year	Number of accidents on the territory of the Russian Federation (pcs)	Absolute gain		Growth rate (%)		Rate of increase (%)	
		Chain	Basic	Chain	Basic	Chain	Basic
2009	203,603	–	–	–	–	–	–
2010	199,431	−4172	−4172	97.951	97.951	−2.049	−2.049
2011	199,868	437	−3735	100.219	98.166	0.219	−1.834
2012	150,144	−49,724	−53,459	75.122	73.744	−24.878	−26.256
2013	204,068	53,924	465	135.915	100.228	35.915	0.228
2014	199,720	−4348	−3883	97.869	98.093	−2.131	−1.907
2015	184,000	−15,720	−19,603	92.129	90.372	−7.871	−9.628
2016	173,694	−10,306	−29,909	94.399	85.310	−5.601	−14.690
2017	169,432	−4262	−34,171	97.546	83.217	−2.454	−16.783
2018	168,099	−1333	−35,504	99.213	82.562	−0.787	−17.438
2019	164,358	−3741	−39,245	97.775	80.725	−2.225	−19.275

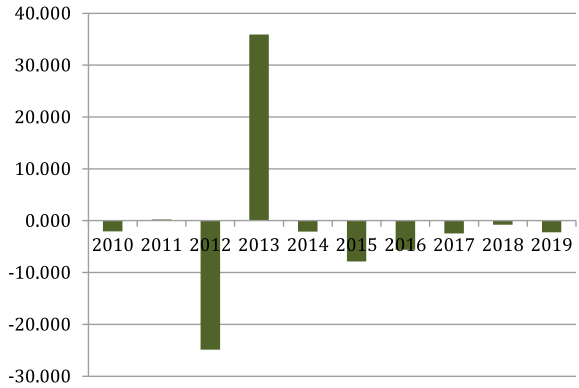

Fig. 5 Chain rates of increase in the number of accidents on the territory of the Russian Federation

2016—by 5.601%, in 2017—by 2.454%, in 2018—by 0.787%, and in 2019—by 2.225% [25–29]. Based on the basic indicators of growth rates, we conclude that the number of road accidents in the territory of the Russian Federation in 2019 decreased by 19.275% in comparison with 2009. Having calculated the average indicators of dynamics, we can formulate that over 10 years the number of road accidents on the territory of the Russian Federation has decreased by 0.807 times. On average, the number of accidents on the territory of the Russian Federation annually decreases by 3924.5 cases, which in relative terms amounted to a decrease of 2.12% per year.

5 Conclusions

Thus, when assessing road safety as a phenomenon of national security of the state, each of the listed methods has its own advantages and disadvantages, which are manifested to one degree or another depending on the purpose and depth of analysis, the object of research, and technical capabilities. Therefore, it will be most efficient to share the methods discussed in this article.

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