Road Traffic Accident Rate in Russia: Main Socio-Economic Factors of its Formation and Spatio-Temporal Features*

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Abstract. For more than a decade, the Russian state has been actively engaged in issues of preservation of people, but the positive effects of this work quickly disappeared (2014–2016), and the trend again changed to a negative one. The First (2006–2012) and the Second (2013–2020) Federal Target Programs on Road Safety were aimed at reducing the number of deaths in road traffic accidents, and made a positive contribution to the field of preservation of people. For instance, in 2006–2019, the annual number of deaths in road traffic accidents decreased from 32,724 to 16,981 people per year, or almost twice. Nevertheless, there are still many problems in ensuring road safety. One of them is the complexity of

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the system processes of road safety management in such a large country as the Russian Federation. Russia consists of 85 heterogeneously developed economically and socially entities on the territory of which representatives of 190 peoples live. The article analyses a wide range of issues related to the assessment of the impact of the sociocenosis features on one of the most important characteristics of road traffic accident rate − the severity. The purpose of the research is to study the influence of the characteristics of representative socio-economic factors on road traffic accident severity in Russian regions, and to develop the most effective differentiated approach to the financing of regional road safety programs on this basis. The scientific novelty of the research consists in the model confirmation of the previously put forward ideas about the positive impact of the basic socio-economic institutions that shape road users' transport behavior on its safety. The authors consider these ideas in relation to Russia as a whole and to the relationship of regional road traffic accident rate with the economic and demographic characteristics of Russians' life. The paper presents the rank patterns of influence on road traffic accident severity of such characteristics of regional sociocenosis as the population's median age, the share of population with income below the minimum wage, and the average monthly income. We show the conceptual considerations for improving road safety in the Russian Federation in the spatiotemporal continuum.

Key words*:* road safety, road traffic accident, Russian Federation, road safety management, road traffic accident severity, regional sociocenosis, impact factor, spatio-temporal features.

Introduction and problem urgency

Vital security is one of the most important modern global values[1]. The value of an individual's life is recognized almost everywhere [1], and its economic equivalent can reach values of 5−10 million dollars [2; 3]. Road traffic accident has been and continues to be one of the leading causes of death worldwide. "If an appropriate action is not taken, traffic injuries may become the third leading component of the global burden of disease and injury by 2025" [3, p. 16]. The paper notes that the socio-economic damage from road traffic accident rate in the world reaches hundreds of billions of dollars [3] (for example, in the United States in 2016 − 256 billion dollars, or about 1.5% of GDP [4]).

The problem of improving road safety and road traffic accident rate issues are also relevant for the Russian Federation[2]. Over the previous three years (2017−2019), a steady trend of natural population decline has been formed in Russia[3]. In 2019, the number of deaths exceeded the number of births by 316.16 thousand people (*Tab. 1*). Road traffic accident rate plays a very significant role in this negative process. The number of Russians, dead in road traffic accidents in 2019, amounted to 16.98 thousand people, or about 13.3% of the number of deaths from external causes (see tab. 1).

Despite the generally positive trends, expressed in a decrease in overall mortality ($\approx$ -6% in 2014−2019) and very impressive results in reducing the number of deaths from external causes ($\approx$-26% over 6 years), the structural share of road traffic accident injuries in Russia remained stable all these years,

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Table 1. Russian population dynamics in 2014–2019 and road traffic accident rate
contribution to the death rate of the country's population, people per year

Year	Population dynamics		Natural increase (+), decrease (-)	Number of deaths from external causes	Number of deaths in road traffic accidents	
	Number of births	Number of deaths			Absolute value	Share of the number of deaths from external causes, %
2014	1947301	1913613	33688	173523	26963	15.5
2015	1944136	1911413	32723	164276	23114	14.1
2016	1893256	1887913	5343	153517	20308	13.2
2017	1689884	1824340	-134456	138784	19088	13.8
2018	1604589	1827827	-223238	134916	18214	13.5
2019	1484517	1800677	-316160	128142	16981	13.3

According to: Natural population movement in the context of the entities of the Russian Federation. Available at: https://www.gks.ru/free_doc/2019/demo/edn12-19.htm; Road traffic accident rate in the Russian Federation for 12 months of 2019. *Informational and Analytical Review*. Moscow: Research Center of Road Security of the Ministry of Interior of the Russian Federation, 2020, 21 p. Available at: https://нцбдд.мвд.рф/dop_stranici/%D0%BE%D0%B1%D0%B7%D0%BE%D1%80%D1%8B-%D0%B7%D0%B0-2019-%D0%B3%D0%BE%D0%B4

amounting to 13–14%. In fact, the socio-economic damage of the Russian Federation from road traffic accidents reaches 1.5–2.0% of GDP[4], i.e. at least 1.5–2.0 trillion rubles per year[5].

Real statistics indicate a very serious role of the road safety in the life of Russian society. The study of the cause-and-effect links of ensuring road safety process and establishment of patterns of priority factors' influence on road traffic accident rate formation are the mechanism's spring for implementing the target function to improve the quality of Russians' life declared in the Road Safety Strategy in the Russian Federation[6].

The generally accepted approach to the features' analysis of the functioning of any road transport system [5] involves its differentiation into the subsystems "Driver – Car – Road – Environment". Over the past 50–80 years, scientists around the world paid maximum attention [6] primarily to the features of the subsystems' functioning "Car" and "Road" (separately and in conjunction) which contributed to a qualitative change in the design of vehicles and improved approaches to the construction and reconstruction of roads, and as a result there was a change in the road safety paradigms. At the same time, the influence of factors related to the "Driver" ("Person" will be more correctly) and "Environment" subsystems on road safety has not yet been fully studied [6].

E. van Beeck and the co-authors have shown that many factors, external to the car, can be conditionally differentiated into the enlarged groups "Economic conditions", "Social conditions", "Demographic features" [7]. These factors are more or less interrelated and have an indirect but very significant impact on the current level of road safety.

The authors repeatedly use such terms as "road safety", "road traffic accident", "sociocenosis". In this regard, it is necessary to give their definitions.

According to the Federal Law no. 196-FZ "On Road Traffic Safety", dated December 10, 1995[7], *road safety is the state of the process of moving people and goods with or without vehicles within roads reflecting the degree of its participants' protection from road traffic accidents and their consequences.*

[4] *Global Status Report on Road Safety 2015*. Geneva, World Health Organization, 2015. 326 p.

[5] Dynamics and structure of Russia's GDP. *Bulletin on Current Trends in the Russia Economy*, no. 48, April 2019. Available at: file:///C:/Users/E8E5~1/AppData/Local/Temp/21979-1.pdf

[6] *Road Safety Strategy in the Russian Federation for 2018–2024*. Available at: file:///C:/Users/E8E5~1/AppData/Local/Temp/g6BXGgDI4fCEiD4xDdJUwlxudPATBC12-1.pdf

[7] On road safety: Federal Law no. 196-FZ, dated December 12, 1995. Available at: http://www.consultant.ru/document/cons_doc_LAW_8585/

Unfortunately, in the article 2 of the "Key terms" of the act there is no definition of "road traffic accident". However, experts of Moscow Automobile and Road Construction State Technical University (MADI), the authors of reverence book of road terms[8], think that *"... the term "Accident" identifies the indicator of road safety in the absolute number of car accidents, number of deaths and injuries or as a ratio of the number of road traffic accidents to the number of vehicles, population or mileage vehicles for a certain period of time".*

In fact, in the world practice, there are some other criteria to assess road traffic accident. For example, in 1949, the English statistician R. Smeed [8] proposed using such indicators as transport (*TR*) and social (*HR*) risks. Their essence is to estimate the specific indicators "Number of deaths in road traffic accidents per 10 thousand vehicles" and "Number of deaths in road traffic accidents per 100 thousand inhabitants". Later, the indicator of "Road traffic accident severity" was introduced into the practice of assessing in road traffic accident [9]. This indicator reflected the proportion of deaths in the total number of injuries of road traffic accident.

It is the road traffic accident severity that is the most expressive indicator for assessing the road traffic accident state today [10−13]. J.G.U. Adams has given the most complete explanation of the priority importance of this assessment of road safety state among others: *"The road accident severity is the embodiment of a comprehensive approach to assessing the actual situation in the field of road safety. The percentage of deaths among the injuries of road traffic accidents indirectly indicates both the design level of the vehicle's quality (active and post-accident safety), used by road users, and the actual state of the system of injury's rescue in an accident by the medical aid forces"* [10, p. 83]. That is why the researchers join the authors' opinion and choose the criterion "Road

traffic accident severity" as the most important evaluation characteristic of road traffic accident.

Cenosis is a time-and space-limited community with weak ties and common goals [14]. The term "cenosis" originally came from biology, but at present there are already 42 essentially similar concepts with the ending "cenosis" including "technocenosis" which is a set of technical products generalized by any attribute, and "sociocenosis" is a set of any living entities united by a separate attribute [14; 15; 16].

Sociocenosis is a set of social individuals limited on any grounds. The peculiarity of cenosis is fuzzy boundaries between these individuals (both in technology and in society), their constant mixing in space [15; 16]. The experience proves that in sociocenosis, some of them are rarely not exactly the same, but even simply comparable in specific characteristics. However, sociocenosis significantly differ in some characteristics. For example, the median age is one of the characteristics of the sociocenosis of the region's population, and it is very different for the Chechen Republic (24.1 years in 2010 and 26.0 years in 2018) and the Tambov Oblast (42.3 years in 2010 and 43.7 years in 2018)[9].

Selection of impact factors, scientific novelty, purpose, and tasks of the research

One of the important issues of the research is the choice of characteristics of regional sociocenosis that have a significant impact on road traffic accident rate, in particular on road traffic accident severity. There are many indicators of territories' socio-economic development. For example, the collection "Russian Regions. 2019"[10] presents hundreds of indicators, differentiated by 23

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[8] *Reference Book of Road Terms.* Available at: file:///C:/Users/E8E5~1/AppData/Local/Temp/spravochnik_dorozhnykh_terminov.pdf

[9] *Russian Demographic Data Sheet, 2016.* Available at: https://yandex.ru/search/?text=Russian%20demographic%20data%20sheet%202016&lr=55; *Russian Demographic Data Sheet, 2019.* Available at: file:///C:/Users/E8E5~1/AppData/Local/Temp/RussianDemographicDataSheet2019_web.pdf

[10] *Russian Regions. Socio-Economic Indicators. 2019.* Available at: https://gks.ru/bgd/regl/b19_14 p/Main.htm (accessed: July 15, 2020).

sections. The analysis of the long-term work of foreign specialists[11] and the experts of the World Health Organization[12] allows distinguishing three most important characteristics from the group of socio-economic impact factors:

— Population's median age;

— Share of the population with income below the minimum wage;

— Average monthly income of the population.

Different sources often mention them [7; 17–22] in the context of their influence on the formation of potentially dangerous situations on the road as very significant. Let us try to argue their choice.

L. Evans writes: "The greatest risk is typical for the youngest drivers" [17]. This finding has appeared so frequently in studies of driver risk that it should be considered a "law of nature".

A.V. Korotaev and his colleagues conducted an in-depth analysis of changes in values under the influence of age in the context of psychosocial theories of ageing [18]. Analyzing 75 reputable sources (A.V. Pisarev, A.B. Kogan, R. Fischer, P.B. Baltes, J. Baltes, Brandtstädter, L.L. Carstensen, W.M. Evan, G.L. Zellman, J.C. Campbell, and others), devoted to the study of psychosocial theories of development in the process of growing up and ageing, they have proved that with age, the value of issues of safety, order, and health increases for almost any person. This statement has a significant impact on the correction of drivers' behavior.

The choice of the characteristics "Share of the population with income below the minimum wage" and "Average monthly income of the population" as representative of road safety is less obvious. These indicators belong to the group of economic indicators of which there are a lot. Nevertheless, their choice was determined by the recommendations of authors specializing in this research topic.

In the section "Impact of economic development on road safety: a literature review" of the report, prepared by specialists of the International Traffic Safety Data and Analysis Group (IRTAD)[13], the authors have considered the results of 50 works in details (among them such authoritative experts in the field of road safety as E. van Beeck, R. Elvik, W. Evans, J.G. Graham, S.C. Partyka, S. Peltzman, A.C. Wagenaar, G.J.S. Wilde, and others). With no details, the paper presents only a general conceptual scheme of the impact of economic conditions in the country on the final results in the field of road safety *(Fig. 1)*. The impact of the country's economic well-being on road safety is very clearly represented in the work of M.J. Koornstra *(Fig. 2)*.

A deep analysis of the foreign experts' works [7; 19–22] let arguing the choice as representative indicators of the society from the economic perspective, the criteria is "Share of the population below the minimum wage" and the "Average monthly income of the population".

The scientific novelty of the research lies in the pattern confirmation of the ideas of J.G.U. Adams [10] and M.Ya. Blinkin [6] about the positive impact of the basic institutions that shape the road users' transport behavior on road safety. In the course of this work, the authors of the article have tried to consider these ideas in relation to Russia taking into account its regional diversity and the connection of regional car accident with the economic and demographic characteristics of Russians' life.

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[11] El'vik R, Myusen A.B., Vaa T. *Reference Book on Road Safety. Overview of Road Safety Measures.* Ed. by Sil'yanova V.V. Oslo – Moscow – Helsinki, 2001. 754 p.

[12] *Principles and Instruments for Improving Traffic Safety on Rural Roads. The International Experiences.* Available at: www.ador.ru/data/files/static/bdd_01.pdf (accessed: July 19, 2020).

[13] *Why Does Road Safety Improve When Economic Times Are Hard? IRTAD Research Report.* OECD/ITF, 2015. 228 p. Available at: www.itf-oecd.org›sites…docs/15irtadeconomictimes.pdf (accessed: July 22, 2020).

Figure 1. Conceptual foundations of the link between economy and road safety
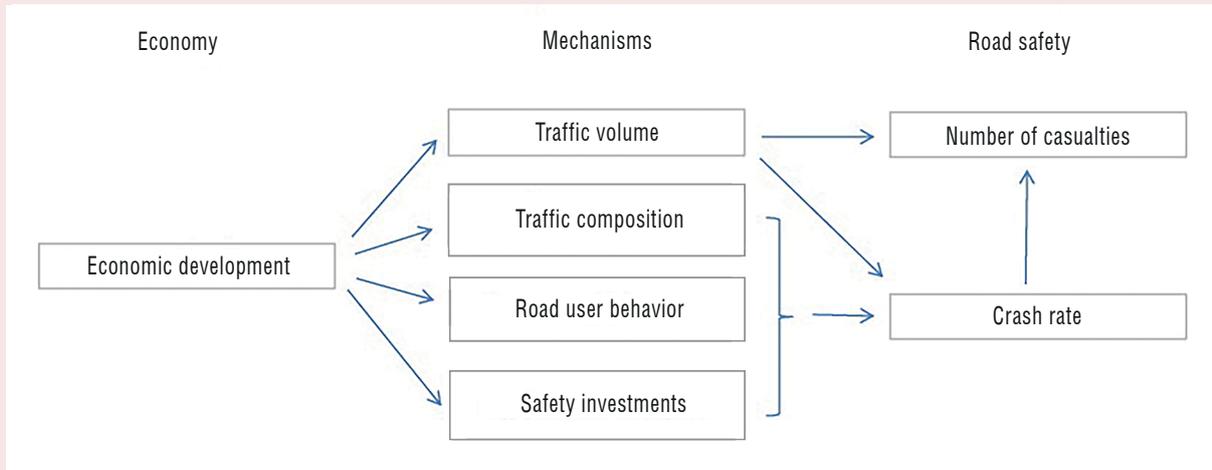
Source: Evans L. *Traffic Safety.* Bloomfield, Mich.: Science Serving Society, 2004. 457 p.

Figure 2. Impact of the specific gross national income on the citizens' death rate in road traffic accidents
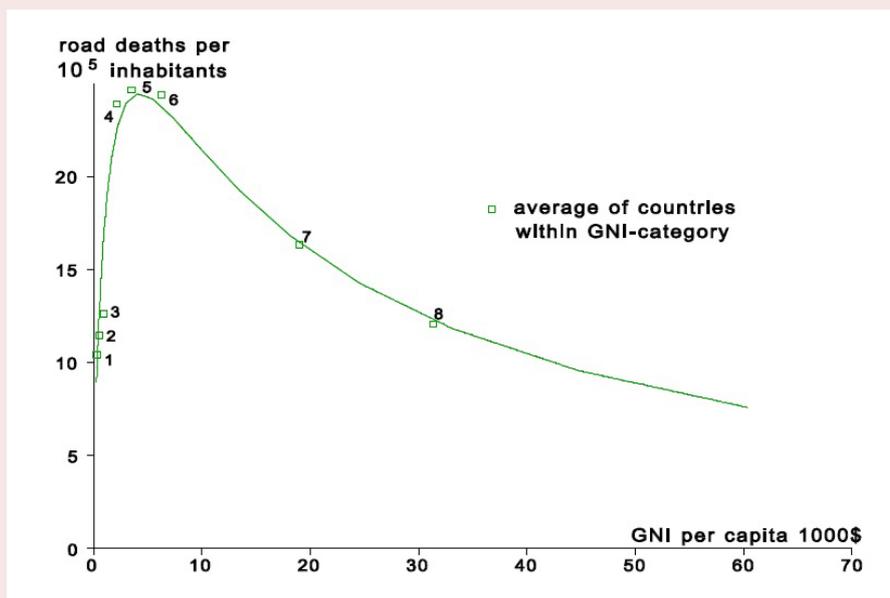
Source: Koornstra M.J. Prediction of traffic fatalities and prospects for mobility becoming sustainable safe. *Sadhana*, 2007, vol. 32, pp. 365–395.

The hypothesis of the research is formulated as follows: "The road traffic accident severity in Russian regions is statistically related to the characteristic features of the regional society".

The purpose of the research is to study the impact on road traffic accident severity in Russian regions of the selected characteristics of represen-tative socio-economic factors (the median age of the region's population; share of the population with income below the minimum wage; the average monthly income of the population) and on this basis to develop the most effective differentiated approach to financing regional programs for road safety.

The tasks of the research are structured as follows.

1. To conduct a primary analysis of the trends of changes in road safety in the Russian Federation in 1991–2019; compare the Russian trend of changes in road safety with analogues in other countries.

2. To justify the choice of a rank pattern in order to study the influence of regional sociocenosis on the car accident features.

3. To prepare data for analysis, process them and set the type of rank patterns *road traffic accident severity rank = f (Regional sociocenosis rank characteristics of the Russian Federation)*.

4. To analyze the results in the context of the "space of the territory of the Russian Federation – time (2010/2018)".

5. To present conceptual considerations for improving the road safety in the Russian Federation in the spatiotemporal continuum.

To solve these tasks, the researchers of the article propose a methodology based on the consistent use of such tools as the method of ranking features [23]; the method of conducting rank analysis [24]; the method of constructing regression rank patterns [25]; the method of pair comparison of patterns [26].

The results of the study can be used in the development of the Federal Target Program of the Russian Federation on Road Safety for the period 2021–2030, especially due to the necessity to achieve the targets set out in the Road Safety Strategy in the Russian Federation.

Primary analysis of trends in road safety changes in 1991–2019 in the Russian Federation. Comparison of the Russian trend of road safety changes with analogues in other countries

In 2019, in Russia, the level of social risk was HR_{2019} = 11.57 deaths in road traffic accidents per 100 thousand people, and road traffic accident severity in 2019 was 7.45%. *Table 2* shows statistical data describing the road safety state in Russia in 1970–2019.

The data in Table 2 clearly illustrate the positive dynamics of road safety indicators in Russia over the previous 15 years. At the same time, the Russian road transport system was changing qualitatively. In 1991–2019, Russian vehicle fleet grew from 12.1 to 61.8 million units, i.e. more than fivefold. However, the length of highways in the country did not grow so intensively. In particular, in the post-Soviet period, the network of public roads in the country increased from 455.4 thousand kilometers[14]

Table 2. Dynamics of road safety indicators in Russian in 1970–2019

Year	Population, thousand people	Vehicle fleet, thousand units	Number of road traffic accidents, cases per year	Number of injuries in road traffic accidents, people per year	Number of deaths in road traffic accident, people per year	Road traffic accident severity, %
1970 (RSFSR)	130079.2	2881.0	≈ 120000	≈ 140000	≈ 20000	14.29
1980 (RSFSR)	138126.6	7180.0	≈ 150000	167615	27615	16.48
1990 (RSFSR)	147665.1	11861.0	≈ 170000	250366	35366	14.13
1991 (RF)	148273.7	12098.0	≈ 171200	262754	37875	14.41
2000 (RF)	146890.1	24476.0	157596	208995	29594	14.16
2005 (RF)	143474.2	33355.3	222475	307667	33858	11.00
2010 (RF)	142856.3	41649.0	199083	276762	26544	9.59
2015 (RF)	146267.3	56470.0	184000	254311	23114	9.09
2019 (RF)	146780.7	61739.2	164358	227858	16981	7.45
According to: Indicator of road safety state. *Official website of the State Road Traffic Safety Authority of the Russian Federation*. Available at: http://stat.gibdd.ru/ (accessed: July 31, 2020).						

[14] Andrienko L. Period of change. What did the Soviet five-year plans bring to Russian roads? Available at: https://rg.ru/2010/10/18/avtoistoria.html

to 565.5 thousand kilometers[15], or 24%. According to R. Smeed's law [6; 8; 9] the road traffic accident risks are reduced with motorization growth, especially in conditions of a shortage of capacity of cities' street and road network. But this is not the only and, more important, not the main factor influencing the road safety characteristics. As table 2 shows, the annual number of people dead in road traffic accidents decreased from 23,114 to 16,981 people (or 26%) in four years (2015−2019) while during the same period the total length of roads in the country increased from 528.2 to 565.4 thousand kilometers (or 7%). To a much greater extent, other factors than the characteristics of the road transport system contributed to this process. In particular, the experts of the International Traffic Safety Data and Analysis Group (IRTAD) believe that socio-economic characteristics or the living standards have a prerogative in terms of importance over other impact factors. They also include demographic indicators that characterize the living standards

indirectly. As an argument, the authors can give an example of changes in the post-Soviet period of the macropsychological index of the state of modern Russian society. According to A.V. Yurevich [27], in 2005−2016 the index value increased from 5.47 to 7.04 *(Fig. 3)*. At the same time, road traffic accident rate decreased.

Assessing the global trends of road safety and comparing with them the similar Russian dynamics, it is necessary to note the following main points:

• In all economically developed countries of the world (especially with a specific per capita GDP of more than 30 thousand dollars), indicators characterizing road traffic accidents rates have been steadily decreasing over the previous 15−20 years *(Fig. 4)*.

• The rate of the downward trend *(Fig. 5B)* varies and depends mainly on the road safety level, actually achieved in the country (the higher road safety level, the lower rate of reduction of car accident). The leaders in the field of road safety

Figure 3. Dynamics of changes in the macropsychological index of the state of modern Russian society
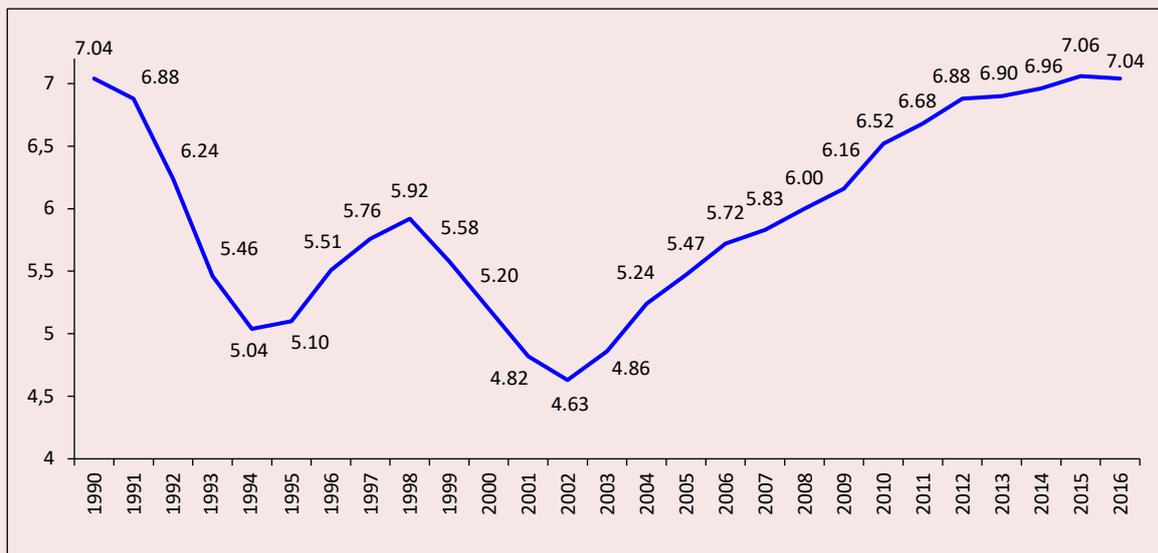
Source: Yurevich A.V. Methodology of quantitative assessment of psychological state of modern Russian society. *Methodology and History of Psychology*, 2018, vol. 1, pp. 155–173.

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[15] *Official website of the federal Road Agency "Rosavtodor"*. Available at: https://rosavtodor.gov.ru/

Figure 4. General dynamics of the HR social risk change in European countries
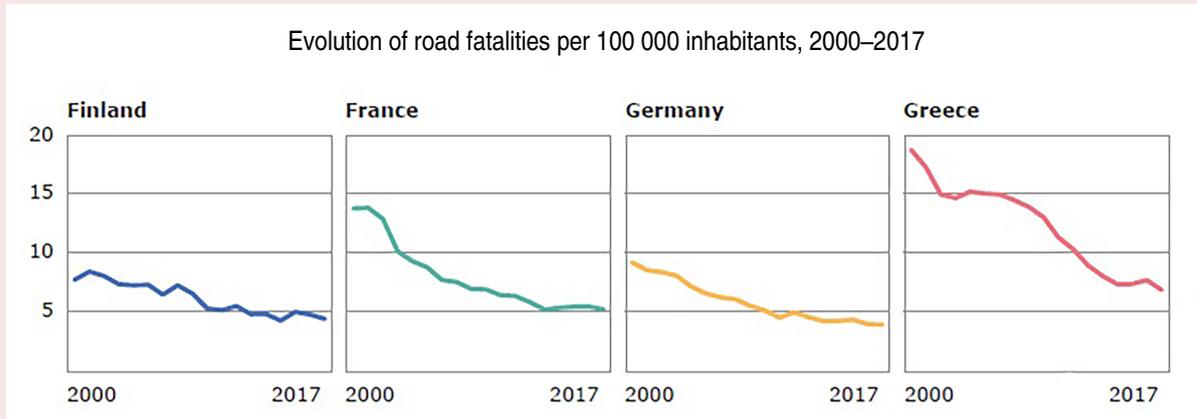
Evolution of road fatalities per 100 000 inhabitants, 2000–2017

Source: *Road Safety. Annual Report 2019.* IRTAD Research Report. OECD / ITF, 2020. 60 p. Available at: https://www.itf-oecd.org/road-safety-annual-report-2019 (accessed: July 31, 2020).

Figure 5. Current situation with road traffic accident rate in the countries
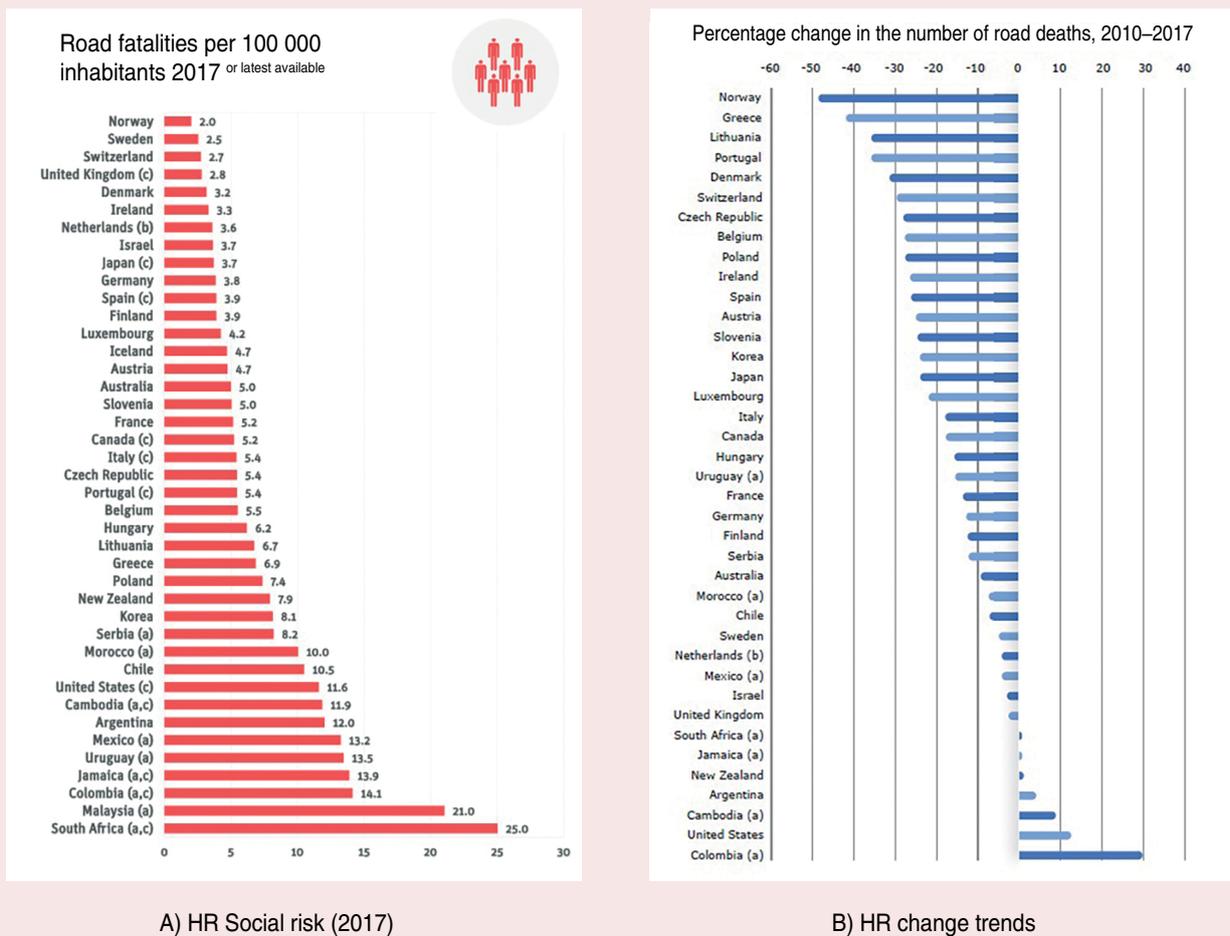
A) HR Social risk (2017)

B) HR change trends

Source: *Road Safety. Annual Report 2019.* IRTAD Research Report. OECD / ITF 2020, 60 p. Available at: https://www.itf-oecd.org/road-safety-annual-report-2019 (accessed: July 31, 2020).

Figure 6. Comparative dynamics of changes in HR social risk

Death rate changes of road accidents (number of deaths per 10 thousand people), 1975–1998

Country or region	Change (%)
Canada	−63.4
China	
Hong Kong Special Administrative Region	−61.7
Taiwan Province	−32.0
Sweden	−58.3
Israel	−49.7
France	−42.6
New Zealand	−33.2
USA	−27.2
Japan	−24.5
Malaysia	44.3
India	79.3[a]
Shri-Lanka	84.5
Lesotho	192.8
Columbia	237.1
China	243.0
Botswana	383.8[6]

Global and regional trends in road traffic accident deaths, 1987–1995

A) In separate countries of the world

B) In the continental context

Source: Peden M. et al. *World Report on Traffic Injury Prevention.* Moscow. Moscow: Ves Mir, 2004. 280 p.

are the Scandinavian countries (Sweden, Norway, Denmark), Switzerland and the United Kingdom, where the social risk is $HR_{2016-2018} = 2,0-3,2$ deaths in road traffic accident per 100 thousand people; the car accident severity$_{2018} = 2,0-3,5\%$ *(Fig. 5A)*.

In most countries of Africa and Asia (with a few exceptions), on the contrary, in the previous 20−50 years, the road traffic accident indicators have been gradually increasing *(Fig. 6)*, and to a greater extent in those states, where the specific per capita GDP does not exceed 1−3 thousand \$, and the median age does not exceed 20−22 years[16].

In the sphere of ensuring road safety, Russia belongs to the group of countries with catching-up development (HR$_{2019}$ = 11.57 deaths per 100 thousand people, and the road traffic accident severity$_{2019}$ = 7.45%), gradually approaching the leading countries (HR$_{2019}$ = 2.0−2.5 deaths per 100 thousand people, and the road traffic accident severity$_{2019}$ = 2−3%). An important role in this

process is played by a gradual increase in living standards, improving macroeconomic state of modern Russian society [27] and related effects (e.g., the gradual improvement of the vehicle fleet quality with a corresponding increase in the level of active and passive safety; reducing the number of "drunken accident"; the overall growth of the driving culture).

Data and methods of their processing. Rank patterns advantages in the research of sociocenosis features

The problem of qualitative analytics is always related to the quality of quantitative estimates. Any measurement is carried out using the appropriate scales, i.e. an ordered series of marks corresponding to the ratio of successive values of the measured values. There are five types of scales: names, order, intervals, ratios, and absolute values.

Considering the relationship between the sociocenosis features and regional road traffic accident rate, it is worth noting that the most acceptable tool for its assessment is rank patterns,

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[16] Peden M. et al. *World Report on Traffic Injury Prevention.* Moscow: Izd. "Ves Mir", 2004. 280 p.

based on the use of an ordinal scale (or rank, or non−metric). The seats of the estimated values in the timeline of the order, referred to as ranks. In such a scale, its constituent numbers are ordered by rank (i.e., occupied places), but the intervals between them cannot be accurately measured. Scale of order or ranking scale allows determining the nature of inequality in the form of judgments of "more − less", "better − worse", etc. Given the fact that sociocenosis has no exact boundaries, and, for example, the drivers from a particular region may cause an accident in another region, it is irrational to use the scale relations or absolute values for building pattern link *the Road traffic accident severity = f (Socio-economic development characteristics of the Russia's population)*. S.D. Haitun says the following about it: "Rank patterns show a fundamental tendency of impact factor on the resulting one, discarding everything small and unimportant for the purposes of analysis" [28, p. 106].

The specifics of parametric identification of the distribution function based on rank analysis are considered in [29], and examples of identification of rank distribution patterns in problems of car accident analysis are considered in [30].

The standard methodology for conducting rank analysis and subsequent construction of rank patterns includes the following stages-procedures [31]:

• *The definition of the boundaries of the regional sociocenosis*. In this case, the authors use the division of Russian territory and its population by the entities of the Federation.

• *The definition of species forming signs of sociocenosis*. The population's median age, the share of the regional population with income below the minimum wage and the average monthly income of the regional population were selected as such indicators.

• *A parametric description of the regional sociocenosis*. It is worth creating a database on regional sociocenosis and adding all of the numerical values of the selected representative characteristics of car accident, car accident severity Y and species forming signs of sociocenosis X_i (listed above).

• *Plotting the rank distribution in the form of a table*. The tabulated rank distribution is a table of several (in this case, four) columns: the parameters of the regional characteristic Y, arranged by rank, and the rank number r of the signs of sociocenosis X_{1-3}. At the same time, the researchers keep the rule of assigning the first rank to Russian region that is characterized by the maximum rating (parameter value), and then in descending order. The most important circumstance to pay attention to is a clear justification of the fundamental relationship between the predictor and the resulting one (an increase or decrease in Y with an increase in the values of X).

• *Plotting a graphical rank distribution*. This step is desirable, but not mandatory.

• *Carrying out the procedure for approximating the desired pattern, the Road traffic accident severity rank = f (Rank of the species-forming sociocenosis feature)*. The method's essence is to find such parameters of the analytical dependences that minimize the sum of squares of deviations observed in the course of the ranking analysis of sociocenosis of empirical values of Y from the values calculated by the approximation dependences.

Tables 3 (2010 data) and *4* (2018 data) present sample data (the first and last ten regions of the Russian Federation in the accounting order) used in the construction of the declared dependencies.

The authors have processed the regions' data in order to construct the corresponding rank distributions. For example, for the 2018 data, the researchers have obtained pairs of values "Median age" − "Road traffic accident severity" (the first and last dozen values), arranged in rank order *(Tab. 5)*.

Table 3. Road traffic accident severity in the entities of the Russian Federation
and the values of representative characteristics of regional sociocenosis, 2010

No.	Entity of the Russian Federation	Road traffic accident severity, dead per injuries, %	Values of the characteristics of regional sociocenosis		
			Median age of the regional population, age	Share of the population with income below the minimum wage, %	Average monthly income of the population, rubles per month
1	Belgorod Oblast	12.17	39.8	8.4	16,993
2	Bryansk Oblast	10.85	39.9	13.6	13,358
3	Vladimir Oblast	9.16	41.0	18.3	12,956
4	Voronezh Oblast	10.02	41.4	19.1	13,883
5	Ivanovo Oblast	6.28	40.8	20.5	11,124
6	Kaluga Oblast	10.24	40.7	11.4	15,477
7	Kostroma Oblast	6.45	40.5	17.3	13,315
8	Kursk Oblast	8.69	41.7	10.8	14,685
9	Lipetsk Oblast	8.81	40.7	10.0	15,936
10	Moscow Oblast	12.09	39.4	10.3	22,641
	....				
76	Republic of Sakha (Yakutia)	9.82	31.2	19.1	23,088
77	Zabaykalsky Krai	13.41	32.9	19.3	14,205
78	Kamchatka Krai	8.04	36.1	19.8	27,010
79	Primorsky Krai	8.25	37.5	16.3	17,298
80	Khabarovsk Krai	9.39	36.3	15.8	22,479
81	Amur Oblast	9.46	35.7	24.3	14,323
82	Magadan Oblast	7.36	37.1	13.8	27,801
83	Sakhalin Oblast	10.02	37.1	10.9	30,727
84	Jewish Autonomous Okrug	10.23	34.8	19.7	15,348
85	Chukotka Autonomous Okrug	20.83	33.6	10.5	38,147

According to: Indicator of road safety state. *Official website of the State Road Traffic Safety Authority of the Russian Federation*. Available at: http://stat.gibdd.ru; *Russian Regions. Socio-Economic Indicators. 2019*. Available at: https://gks.ru/bgd/regl/b19_14 p/Main.htm

Table 4. Road accident severity in the entities of the Russian Federation
and the values of representative characteristics of regional sociocenosis, 2018

No.	Entity of the Russian Federation	Road traffic accident severity, dead per injuries, %	Values of the characteristics of regional sociocenosis		
			Median age of the regional population, age	Share of the population with income below the minimum wage, %	Average monthly income of the population, rubles per month
1	Belgorod Oblast	8.83	41.1	7.5	30,778
2	Bryansk Oblast	10.56	41.6	13.6	26,585
3	Vladimir Oblast	7.69	42.1	13.1	23,539
4	Voronezh Oblast	10.31	41.7	8.9	30,289
5	Ivanovo Oblast	4.45	41.9	14.7	24,503
6	Kaluga Oblast	8.66	41.4	10.4	29,129
7	Kostroma Oblast	6.24	41.4	12.7	23,716
8	Kursk Oblast	8.98	42.2	9.9	27,275
9	Lipetsk Oblast	9.52	42.0	8.7	30,010
10	Moscow Oblast	11.44	39.3	7.3	44,707
	....				
76	Republic of Sakha (Yakutia)	8.52	33.1	18.6	42,669
77	Zabaykalsky Krai	12.52	34.8	21.4	23,992
78	Kamchatka Krai	6.64	37.9	15.8	48,758
79	Primorsky Krai	7.91	39.2	13.9	34,619

End of Table 4

80	Khabarovsk Krai	6.31	37.3	12.2	39,084
81	Amur Oblast	8.1	37.4	15.6	30,937
82	Magadan Oblast	8.7	39.0	9.5	59,774
83	Sakhalin Oblast	9.53	38.7	8.5	51,783
84	Jewish Autonomous Okrug	9.61	37.2	23.7	24,696
85	Chukotka Autonomous Okrug	5.71	36.1	8.8	78,812
According to: Indicator of road safety state. *Official website of the State Road Traffic Safety Authority of the Russian Federation*. Available at: http://stat.gibdd.ru; *Russian Regions. Socio-Economic Indicators. 2019*. Available at: https://gks.ru/bgd/regl/b19_14 p/Main.htm					

Table 5. Sample data used in the construction of rank dependencies, 2018

No.	Median age of the regional population, age	Road traffic accident severity, dead per injuries, %		No.	Median age of the regional population, age	Road traffic accident severity
1	26.0	21.76		76	42.1	5.86
2	28.4	18.41		77	42.2	5.71
3	28.8	14.39		78	42.2	5.67
4	30.4	13.55	…	79	42.2	5.52
5	33.1	12.52		80	42.3	5.22
6	33.6	12.27		81	42.3	5.21
7	34.4	11.44		82	42.7	4.65
8	34.8	10.82		83	42.8	4.45
9	34.8	10.56		84	43.2	4.25
10	34.9	10.56		85	43.7	2.93
According to: Indicator of road safety state. *Official website of the State Road Traffic Safety Authority of the Russian Federation*. Available at: http://stat.gibdd.ru; *Russian Regions. Socio-Economic Indicators. 2019*. Available at: https://gks.ru/bgd/regl/b19_14 p/Main.htm						

It is important to focus on the fact that, when constructing a rank distribution, it is necessary to understand in advance the fundamental physical meaning of the relationship between the variables *X* and *Y*. For example, for the dependence of the *Road traffic accident severity = f (Median age of the regional population)*, the leftmost points identify the Chechen Republic (Y_1 – Road traffic accident severity = 21.76 deaths per 100 injuries; X_1 – Median age = 26.0 years) and the Republic of Tyva (Y_2 – Road traffic accident severity = 18.41 deaths per 100 injuries; X_2 – Median age = 28.4 years). The rightmost point rank based on identify most regions of the Central Federal District of the Russian Federation, for which Y_i is the minimum value, X_i is the highest in the data set values. It means that according to *the Road traffic accident severity rank = f (Rank of the median age of Russian population)* characteristic is inversely proportional to a linear connection.

The subsequent analysis has showed that for the dependence of the *Road traffic accident severity = f (Rank of the share of Russian population with income below the minimum wage)* characteristic is directly proportional linear connection, and according to the *Road traffic accident severity = f (Rank of the average monthly income of the population)* – a power connection.

Research results and their analysis

This section presents rank patterns of the impact on the road traffic accident severity of such characteristics of regional sociocenosis as the median age; the share of the population with income below the minimum wage; the average monthly income of the population.

Figures 7–12 graphically show the rank patterns. For the convenience of identifying temporary changes in the situation in the field of road safety, the patterns are constructed for a set of data from 2010 and 2018.

Comparing the patterns of *the Road traffic accident severity rank =f (Sociocenosis characteristic rank)* in 2010 and 2018 *(Tab. 6, 7, 8)* the authors note the main fact for all three patterns. In general, the severity of the road traffic accident outcome in 2018 decreased slightly compared to 2010.

The parameter value *a* of the patterns (1)−(3) proves this statement. At the same time, each of the patterns is characterized by certain specifics.
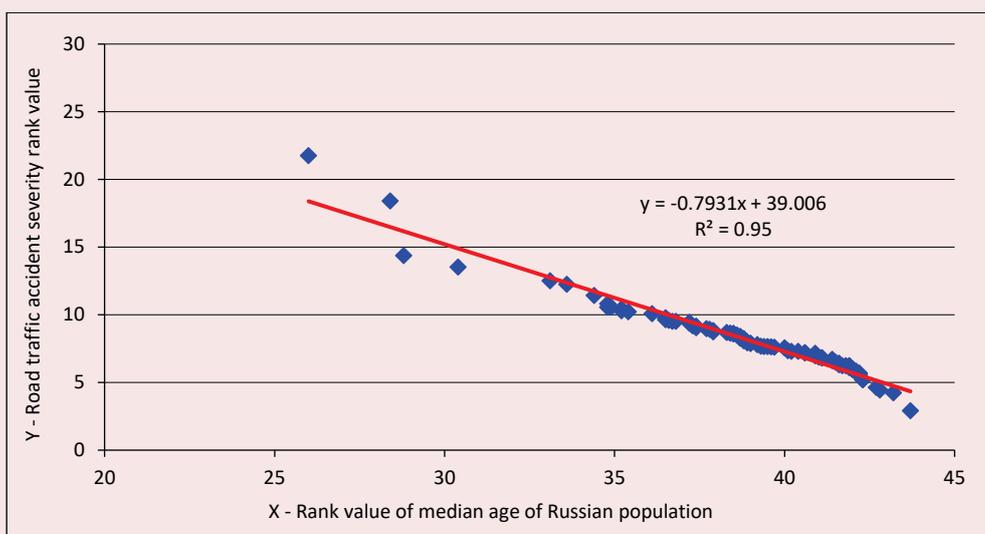
Road traffic accident severity rank pattern = f (Rank of the median age of Russian population). Figures 7−8 show graphic images of the pattern (1).

Figure 7. Rank pattern (according to 2010 data)
Road traffic accident severity rank = f (Rank of the median age of Russian population)

$$y = -0.9555x + 46.181$$
$$R^2 = 0.9659$$
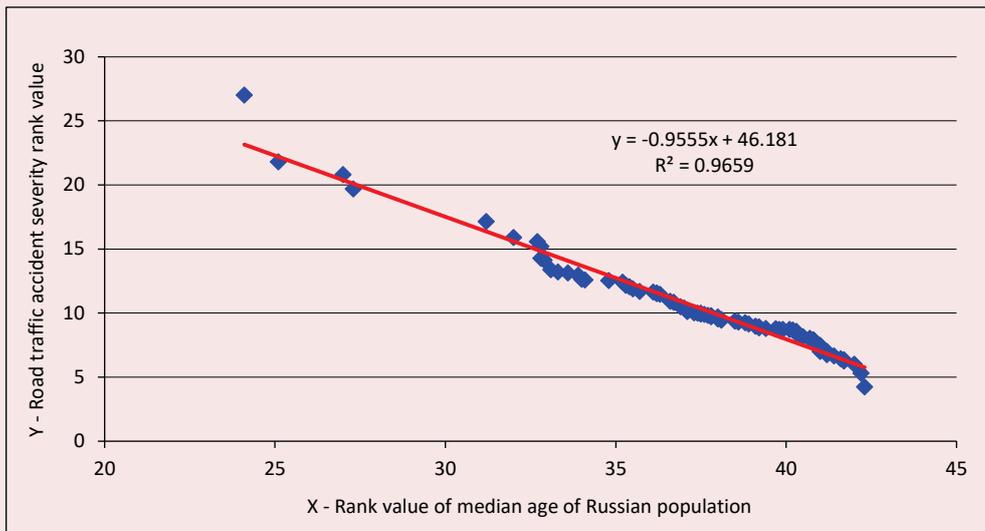
Source: own calculations.

Figure 8. Rank pattern (according to 2018 data)
Road traffic accident severity rank = f (Rank of the median age of Russian population)

$$y = -0.7931x + 39.006$$
$$R^2 = 0.95$$

Source: own calculations.

Table 6. Parameters and coefficient of determination R^2 of the pattern (1)
Road traffic accident severity rank = f (Rank of the median age of Russian population)

Year	Numerical values of the pattern parameters (1) $Y = a - b \cdot X$		R^2
	a	*b*	
2010	46.18	0.955	0.965
2018	39.00	0.793	0.950
Source: own calculations.			

Table 6 shows the numerical values of the pattern parameters (1) that are typical for the compared databases taking into account the median age of the regional sociocenosis.

Comparing the patterns of the *Road traffic accident severity rank = f (Rank of the median age of Russian population)* in 2010 and 2018, it is worth noting the following:

• In 2018, the median age played a much smaller role in determining the road traffic accident outcome in terms of severity than in 2010. The value of the pattern parameter *b* proves it (1).

• Both in 2010 and in 2018 in a number of Russian regions (about 10% of the total number) the car accident severity was significantly different from the typical national level. These are mainly national republics with a fairly young population.
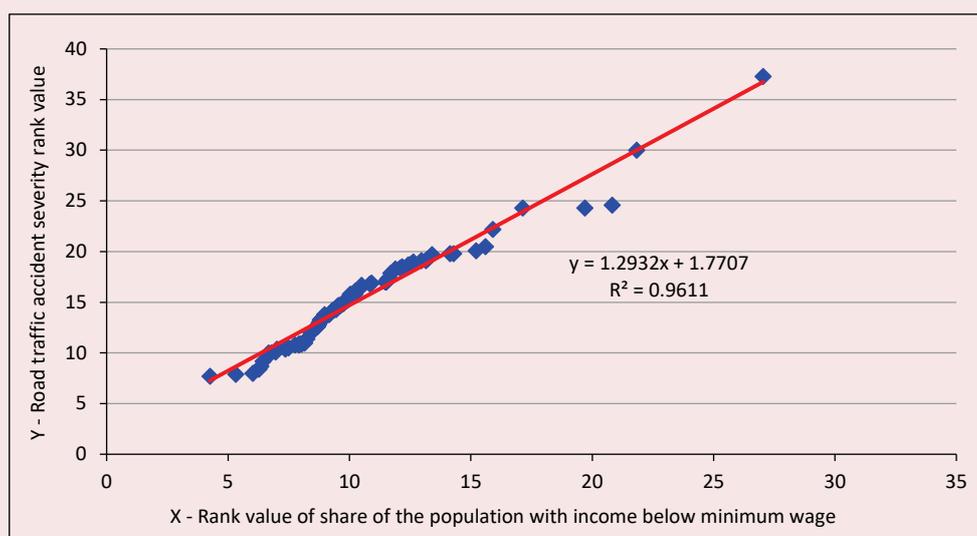
Road traffic accident severity rank pattern = f (Rank of the share of Russian population with income below the minimum wage). *Figures 9–10* show the graphic images of the pattern (2).

Table 7 shows the numeral values of the required pattern parameters (2).

Comparing the patterns of *the Road traffic accident severity rank = f (Rank of the share of Russian population below the minimum wage)* in 2010 and 2018, it is worth noting the following:
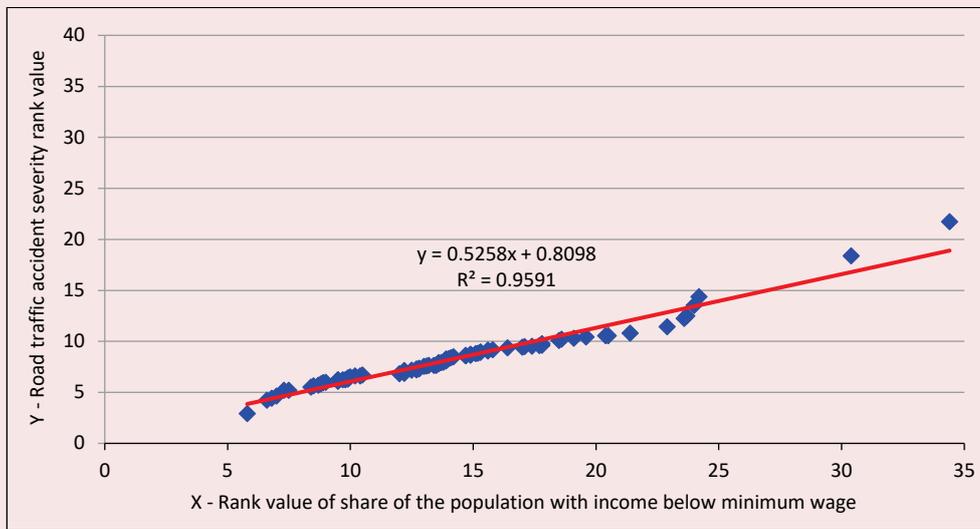
• In 2018, the share of Russian population with income below the minimum wage played a significantly smaller role in shaping the road traffic accident outcome in terms of severity than in 2010. The value of the pattern parameter *b* indicates it (2).

• In the pattern of 2018, the number of Russia's regions, where the road traffic accident

Figure 9. Rank pattern (according to 2010 data)
Road traffic accident severity rank = f (Rank of the share of Russian population below the minimum wage)

Source: own calculations.

Figure 10. Rank pattern (according to 2018 data)
Road traffic accident severity rank = f (Rank of the share of Russian population below the minimum wage)

y = 0.5258x + 0.8098
R^2 = 0.9591

Source: own calculations.

Table 7. Parameters and coefficient of determination R^2 of the pattern (2)
Road traffic accident severity rank = f (Rank of the share of Russian population below the minimum wage)

Year	Numeral values of pattern parameters (2) $Y = a + b \cdot X$		R^2
	a	*b*	
2010	1.770	1.293	0.961
2018	0.809	0.525	0.959
Source: own calculations.			

severity significantly differs from the typical national level, decreased slightly compared to 2010. It means that the impact of the "share of poor people" factor on the car accident severity in 2018 was somewhat leveled, compared to 2010.

Road traffic accident severity rank pattern = f (Population's average monthly income rank). *Figures 11−12* show graphical representations of the pattern (3). *Table 8* shows the numerical values of the pattern parameters (3) of the Road traffic accident *severity rank = f (Population's average monthly income rank).*

It is necessary to note that the numerical values of the exponent of the patterns (indicator *b*) for 2010 and 2018 are the same (*b = -0.82*). This suggests that the spatial heterogeneity of the

regional road traffic accident severity in relation to the average income has not changed. The "right tail" of dependence has lengthened which characterizes both an increase in the living standards and inflationary processes in Russian regions.

Conceptual considerations for improving road safety in the Russian Federation in the spatiotemporal continuum

The purposes of the Road Safety Strategy are highly specific and incredibly ambitious. Russia should achieve 4.0 deaths per 100 thousand people (or about 6 thousand deaths in road traffic accidents per year) for 2024 in the field of road safety target levels of social risk, and 0 deaths per 100 thousand people − by 2030. It took Russia a decade and a half to double the annual death toll (2005−2019),

Figure 11. Rank pattern (according to 2010 data)
Road traffic accident severity rank = f (Population's average monthly income rank)

$y = 29847x^{-0.826}$
$R^2 = 0.8411$
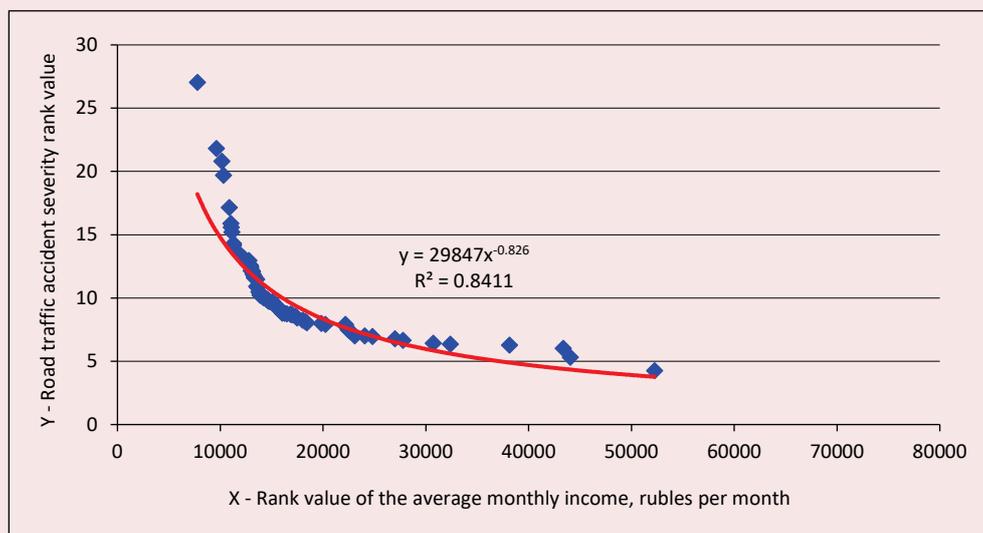
Source: own calculations.

Figure 12. Rank pattern (according to 2018 data)
Road traffic accident severity rank = f (Population's average monthly income rank)

$y = 36791x^{-0.823}$
$R^2 = 0.8695$
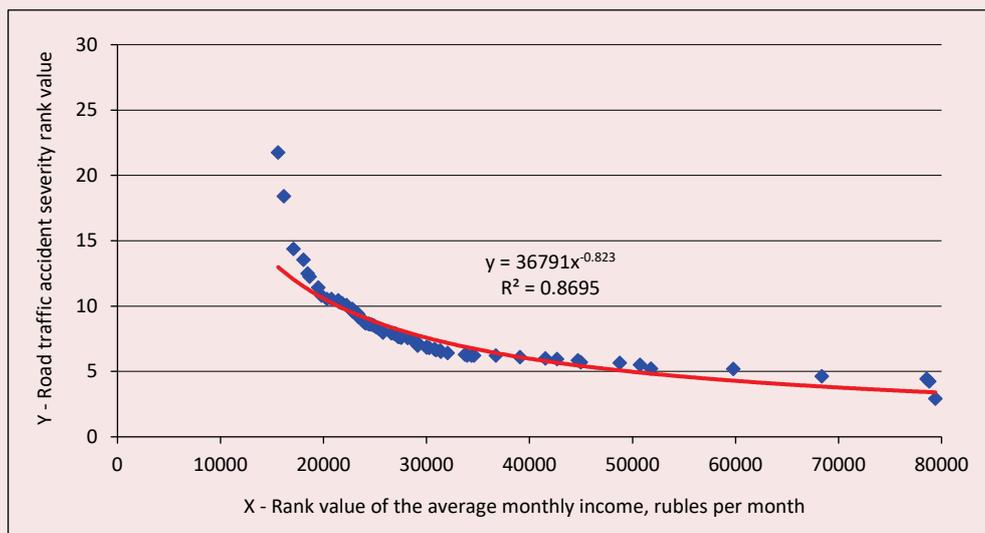
Source: own calculations.

Table 8. Parameters and coefficient of determination of R2 pattern (3)
Road traffic accident severity rank = f (Average monthly income rank)

Year	Numeral values of pattern parameters (3) $Y = a \cdot X^b$		R²
	a	*b*	
2010	29847	- 0.82	0.841
2018	36791	- 0.82	0.869

Source: own calculations.

and no more than five years are provided for a further three-fold reduction (from 16.9 to 5.9 thousand people per year). It is almost impossible to reach the level of zero mortality. In the road safety position the safest countries are: Norway, Sweden, Denmark, Great Britain, and Switzerland. In 2017–2018 the social risk level was 2.0–3.2 deaths in car accidents per 100 thousand people (despite the fact that in the Scandinavian countries there is the so-called "Vision Zero", or the concept of zero mortality, that has been working for more than 20 years [32]). Today, discussing the future development prospects toward achieving zero mortality, foreign experts come to the conclusion that car accident acquires a specific ethnic and economic-social character in European countries [32; 33].

Using the methods of synectics [34] and analogies [35], and the results of the author's research [36; 37], the article states that, in Russia's spatiotemporal continuum, the problems of improving road safety are largely determined by the demographic and socio-economic specifics of Russian living conditions. It is practically impossible to imagine that relatively young and poor society of the republics of the North Caucasus will daily manifest the safe behavior principles on the roads in the same way as relatively more mature and economically successful citizens that form the sociocenosis basis of the regions of Central and Northwestern Federal Districts of the Russian Federation. In this regard, the researchers note the need to differentiate the state policy in the field of ensuring road safety taking into account the regional characteristics of the population's behavior of federal districts and even particular Russian regions.

Currently, the federalization principles imply the Russian Federation as a single state political and legal legislative space, within the boundaries of which all aspects of public administration are uniform. However, despite some slight convergence of the country's regions in terms of road traffic accident characteristics, the gap between the relatively safe regions and their antipodes-regions with a high risk of death in a road traffic accident is still very high. The statistics of the State Road Traffic Safety Authority of the Ministry of the Interior of the Russian Federation and the pattern (2) show a four-fold difference in the car accident severity between the most and least safe regions.

In fact, currently, all measures to improve the road safety in the regions have three sources of funding: from the federal, regional and municipal budgets. Relatively rarely, funds for measures to improve road safety are allocated from extra-budgetary sources. How should the share of budget expenditures for items related to road safety provision correctly be determined? Nowadays, in most Russia's regions, the share of budget expenditures for ensuring the regional programs' implementation does not exceed 0.1–0.3% of the budget resources. For example, according to the Federal Target Program for Road Safety (2013–2020)[17], in 2017, the maximum amount of actual expenditures under the Road Safety Program among the regions was recorded in the Republic of Tatarstan – 1,722 million rubles with annual budget expenditures in the amount of 231,088 million rubles[18]. In 2017 in the Republic of Tatarstan the unit costs of measures to road safety improvement were 0.745% of the total amount of annual budget expenditures. Perhaps, it is this factor that has allowed the territory to be in the group of leading regions for road safety for a decade. Of course, it is necessary take into account the regional budgeting opportunities which are very different for the

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[17] Efficiency assessment of Federal Target Program implementation in 2013–2020. *Official website of the Federal Target Program on Road Safety*. Available at: http://www.fcp-pbdd.ru/achievements/efficiency

[18] On the budget execution of the Republic of Tatarstan in 2017: Law of the Republic of Tatarstan, dated May 28, 2018, no. 36-ZRT. Available at: https://minfin.tatarstan.ru/byudzhet-2017.htm?pub_id=1411001

Table 9. Differentiated approach to financing of regional road safety programs

Group of entities of the Russian Federation	Example of a representative entity of the Russian Federation	Actually achieved level (2018) of road traffic accident severity	The share size of regional budget expenditures under the item "Road safety ensuring", %
I	Moscow	4.25	0.20
II	Republic of Tatarstan	6.24	0.35
III	Republic of Bashkortostan	9.06	0.50
IV	Zabaykalsky Krai	12.52	0.65
V	Chechen Republic	21.76	0.80
Source: own calculations.			

Russian entities. Nevertheless, it is the entities of the Federation that ought to bear the main burden of responsibility for solving regional problems, and it is the regional budget that should be rationally structured.

Table 9 shows the authors' proposals for the specific amount of budget expenditures under the item "Road safety ensuring" taking into account the current car accident state in the regions.

Conclusion

Summarizing the results, presented above in the form of final conclusions, the authors note the following.

Road traffic accident, as an objective manifestation of the achieved road safety level, is changing in time and space. The specific of this change depends on the dynamics of sociocenosis characteristics. In turn, the sociocenosis is changing in time and space, primarily essentially, at the level of universal values. Not only the results of this article, but also data of R. Fisher and D. Beer [38], confirm the conclusion.

In recent years (2010−2019), Russia has achieved quite serious success in the field of ensuring road safety, but it is still among the countries of catching up development.

Road traffic accident severity, as a very representative indicator of car accident, varies in a very wide range of values in Russian regions (even without considering the federal cities of Moscow and St. Petersburg in 2018, this range was [4,5-21,5]). This fact once again characterizes Russia as the largest country in the world, and it is extremely heterogeneous in the manifestations of life conflicts.

Road traffic accident severity rank patterns = f (Socio-cenosis characteristics rank) identify the statistical relationship between demographic and socio-economic living conditions in Russian regions and car accident as a generalized abstract resultant of living standards.

Analysis of *the road traffic accidents severity rank patterns = f (Sociocenosis characteristics rank)* showed that in 2018, compared to 2010, has changed the degree of influence of the Russian sociocenosis on the road traffic accident formation. In particular, the numerical values of the pattern parameter *b,* which identifies the connection degree between the predictor and the outcome, decreased for the influence cases of the median age and the share of the population with income below the minimum wage. At the same time, in 2010−2018, the impact on the road traffic accident severity of the regional average monthly income of the population did not change. This fact once again suggests that the criterion "The average monthly income of the population" can not fully be an economic indicator.

Road traffic accident severity rank patterns = f (Socio-cenosis characteristics rank) also illustrate the spatial features of road traffic accident in Russia. In particular, the road traffic accident severity varies very widely in the spatial context reaching maximum values in the national border regions (republics of the North Caucasus, Kalmykia, Tyva, and Buryatia).

The proposed differentiation of the regional approaches to the required financing of road safety programs is based on the research results of the statistical relationship between the results achieved by 2018–2020 in the field of road safety provision and actual sociocenosis characteristics. The authors believe that, if Russia's regions focus management attention on the need to improve the road safety (their importance awareness, the formation of targeted approaches, increased funding), the country will form objective conditions for achieving the ambitious goals of the Road Safety Strategy of the Russian Federation.

In conclusion, it is necessary to note that the methods and practices of road safety management in the constituent entities of the Russian Federation should take into account regional specifics not only in terms of financing regional road safety programs, but also at the level of organizing traffic and pedestrian flows, means of influencing violators of traffic regulations, and other specific aspects of road safety.

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