Evaluation of the impact of anti-alcohol policy in the regions of the Russian Federation on road traffic accidents

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Abstract Based on the earlier works performed by the authors, in which the role of socio-economic factors in road traffic accidents was noted, an analysis was carried out, models were developed. On their basis the analysis is developed and models are carried out. Regression equations allow highlighting the main factors affecting the number of deaths in accidents caused by drunk drivers in the regions of the Russian Federation.

1. Introduction

The order of the Government of the Russian Federation from 08.01.2018 № 1-p approved the Strategy of traffic safety in the Russian Federation for 2018–2024. This determined the main activities of various authorities till 2024 by achievement of reduction of social risks up to 4 deaths per 100 thousand of the population, and by 2030 – the zero death toll in the road accidents (RA).

The main tasks for the implementation of the Strategy are related to the improvement of the road safety management system, the change in the behaviour of its participants, the modernization of the street-road network, as well as the change of organizational and legal mechanisms for the admission of vehicles and their drivers to participate in road traffic.

The adoption of management decisions in the field of road safety makes it necessary to develop models reflecting the connection of accidents with the state of the DCRE complex (“driver-car-road-environment”). Statistical modelling techniques are used to evaluate this relationship [5, 7, 9, 10]. At the same time, regions of the Russian Federation have been selected as objects of research, which provides an opportunity to obtain a large volume of statistical information and significant conclusions.

2. Methods

In order to analyze, develop and justify a set of measures aimed at improving road safety, methods of correlation and regression analysis and worked-out approaches to the construction of a regional accident model are used [18].

In this article, the number of deaths in road accidents is taken as a criterion of the state of road traffic accidents.

Different options were considered to approximate the number of deaths in road accidents, but the best accuracy characteristics provide dependence [18]:

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Different options were considered to approximate the number of deaths in road accidents, but the best accuracy characteristics provide dependence [18]:
where \( a_0, \ldots, a_i \) (\( i = 1, \ldots, n \)) — parameters; 
\( y \) — number of deaths; 
\( n \) — number of parameters; 
\( x_i \) — indicators of the process under consideration (\( i = 1, \ldots, n \)).

For the regions of Russia, the relationship between the number of deaths in road accidents \( y_1 \) with the population \( x_1 \) and number of vehicles \( x_2 \) for the 2015–2018 period is as follows:

\[
y_1 = 0.427676 \cdot x_1^{0.93329} \cdot x_2^{0.296665},
\]

for the period 2014-2017, this formula is almost the same

\[
y_1 = 0.419425 \cdot x_1^{0.60419} \cdot x_2^{0.302095}.
\]

There is a satisfactory match between the calculated and actual values of the considered accident indicator (rank correlation coefficient is 0.870906). However, additional indicators are used to improve the accuracy of calculations and to understand the nature of the process. For this purpose, an array of data was formed from 2015 to 2018, characterizing the socio-economic, natural and climatic state of the regions, as well as the measures taken to influence road users. 340 data sets relating to all subjects of the Russian Federation were considered. Later, the Republic of Crimea, the Chechen Republic and the city of Sevastopol were removed from consideration, as the statistics related to them introduce significant distortions in the results of the calculation, forming statistical emissions. Then 328 sets of indicator values (82 regions) were analyzed.

The following procedure for modelling road traffic accidents has been carried out.

A list of indicators is formed and a criterion (number of deaths in an accident) is determined. Correlation analysis is performed. For construction of regression models, indicators are selected, which correspond to the rank coefficient of Spirman correlation exceeding the threshold value at significance level 0.05 (for data array of dimension 328 the threshold value is 0.1095) [7].

Based on the results of the rank correlation analysis (rank correlation of Spirman coefficient values are given below in parentheses for data (2014–2017)/(2015–2018)), it is proposed to use the following indicators (factors) [1]:

- environment conditions, in points \((0.440019/0.436966; x_9)\) [15];
- average annual temperature in the capitals of the constituent entities of the Russian Federation, degree Celsius \((0.308329/0.311892; x_{10})\) [16];
- density of public roads of federal, regional or inter-municipal and local importance with hard surface for the constituent entities of the Russian Federation, km of roads per 1000 km² of territory \((0.406005/0.390925; x_{11})\) [6];
- investment potential of Russian regions, share in all-Russian potential, % \((0.790042/0.79297; x_1)\) [14];
- investment risk of Russian regions \((-0.57448/-0.59530968; x_3)\) [14];
- level of socio-economic status \((0.608389/0.630639; x_5)\) [2];
- final quality of life score, rating score \((0.518697/0.51704; x_4)\) [4];
- number of registered administrative offences in the field of road safety, thousands \((0.786226/0.806142; x_7)\) [3];
- number of registered administrative offences by means of automatic photo and video recording, thousands \((0.671661/0.6754; x_8)\) [3];
- age of vehicles fleet \((-0.35013/-0.34021; x_{13})\) [12];
- annual sales of petrol in the regions \((0.7936113; x_6)\). Data on the volume of gasoline sales in the regions correspond to 2015 [13].

The paper [19] also used indicators: level of economic development and sale of alcoholic beverages (beer). Due to the change in statistical accounts, these indicators are excluded from consideration.
In a number of works of the authors [1, 8, 11, 19] an attempt was made to assess the impact of the situation related to alcohol consumption on road traffic accidents. The main problem encountered is the choice of an adequate criterion for assessing the situation. In particular, the following were considered:

- the number of deaths due to alcohol;
- beer sales volume;
- sales of alcoholic beverages (vodka and other products) and beer;
- number of patients registered in medical and preventive institutions with the diagnosis of alcoholism and alcoholic psychosis.

Satisfactory correlation of the number of deaths in road accidents was noted only with the volume of beer sale. As for the sale of other alcoholic products, there seems to be a high share of counterfeiting in this part of the alcoholic market (according to experts, about 70 % [17]), as well as fake excise stamps [17]. Therefore, there is a lack of correlation between official statistics and road traffic accidents.

In connection with the above, the result of the expert and analytical study "Rating of Sobriety of Regions-2018", carried out by the federal project "Sober Russia" together with "The Russian Television and Radio Broadcasting Company" (RTR), is of interest. The rating was the result of analysis, synthesis and systematization of regional and federal statistics. The rating used 6 criteria:

1. "Number of deaths by major class and individual causes of death (alcohol poisoning)";
2. "Number of patients registered in medical and preventive institutions diagnosed with alcoholism and alcoholic psychosis”;
3. "Number of offences committed by intoxicated persons (unit)";
4. "Regional volume of all alcoholic products sold in litres of pure alcohol”;
5. "Number of offences related to illegal production and trafficking of ethyl alcohol and alcoholic products;"
6. "Strength of regional anti-alcohol legislation, – calculated on the basis of 6.1. sub-indicators "Number of hours of prohibition of sale of alcohol per day" and 6.2. "Number of days in the year when the sale of alcoholic products is completely prohibited".

In order to increase objectivity and representativeness, sales volumes of all types of alcoholic products for which official statistics were available were taken into account. At the same time, each of the types of alcoholic products was studied separately, and then was integrated into one criterion A4: "Sale of alcoholic products in litres of pure alcohol per capita". Sales volume for the following types of alcoholic products was taken into account:

- vodka;
- alcoholic beverage products with content of ethyl alcohol up to 25 %;
- alcoholic beverage products with ethyl alcohol content above 25 %, cognac and cognac beverages;
- cognac and cognac drinks;
- wine (natural);
- sparkling wines (champagne);
- a wine beverage produced without adding ethyl alcohol;
- a wine beverage produced with the addition of ethyl alcohol;
- liqueur wines, fruit and others;
- cider, poire, honey;
- beer;
- beer-based beverages.

The values of A1, A2, A3 and A5 were used as per 100,000 population for each subject of the Russian Federation. The value of indicator A4 was used as per capita of the subject of the Russian Federation, and the sub-indicators A6.1. and A6.2. were used in absolute form.

The coefficient of rank correlation of sobriety of regions rating $x_2$ and the number of deaths in road accidents is $-0.32935$, which is higher than the threshold value.
In this paper, a significant number of indicators are used for modelling, including interrelated ones, which makes it difficult to interpret the results. In many multivariate statistical processing tasks, the key figures that change most when an object changes are generally of interest. Therefore, it is a question of the possibility to reduce the dimension of the problem being solved. For this purpose, the method of main components [10] is applied, using which projections of observation points are built on directions of the largest data spread. Of the total number n, the principal components leave the most significant, that is, making the maximum contribution to the dispersion. The work [10] notes that the use of key components is most useful in situations where indicators share a common physical nature. On this basis, the indicators below are divided into three groups – socio-economic, administrative and other. At that algorithm of construction of main components is used, which is given in [10].

As a result, it is necessary to note the high values of the coefficient of rank correlation of gasoline annual sales in regions with a list of socio-economic indicators (investment risk of Russian regions is -0.64941283, final assessment of quality of life is 0.6139, investment potential of Russian regions is 0.829505, level of socio-economic situation is 0.715485), which is the basis for inclusion of this indicator in the mentioned list.

For the list of socio-economic indicators, the main components are:  
\[ y_1^1 = -0.442 \cdot x_3 + 0.501 \cdot x_4 + 0.403 \cdot x_1 + 0.504 \cdot x_5 + 0.371 \cdot x_6; \]
\[ y_2^1 = 0.568 \cdot x_3 - 0.234 \cdot x_4 + 0.531 \cdot x_1 - 0.116 \cdot x_5 + 0.573 \cdot x_6; \]
\[ y_3^1 = 0.228 \cdot x_3 + 0.118 \cdot x_4 + 0.622 \cdot x_1 + 0.121 \cdot x_5 - 0.729 \cdot x_6; \]
\[ y_4^1 = 0.530 \cdot x_3 + 0.015 \cdot x_4 - 0.370 \cdot x_1 + 0.762 \cdot x_5 - 0.022 \cdot x_6; \]
\[ y_5^1 = 0.387 \cdot x_3 + 0.825 \cdot x_4 - 0.177 \cdot x_1 - 0.370 \cdot x_5 + 0.042 \cdot x_6. \]

The relative fractions of the total dispersion due to one, ..., five main components are 0.677, 0.826, 0.935, 0.970, 1.0, respectively. Acceptable accuracy is achieved by the first three components used below.

For the considered indicators characterizing the law enforcement practice of the State Automobile Inspection, the main components are as follows:
\[ y_1^2 = x_1 + 0 \cdot x_3; \]
\[ y_2^2 = x_2 + 0.001 \cdot x_3. \]

The relative fractions of the total variance due to one, two principal components are 0.999, 1.0, respectively. The first component was used.

As a result, the regression equation (statistical model) for the accident death toll \( y \) in the region is:
\[ y = 1.3731368 \cdot y_1 - 7.9096146 \cdot x_3 + 4.54522087 \cdot x_{10} + 0.9232238 \cdot x_2 - 0.00472717 \cdot x_{11} + 0.548287544 \cdot x_{13} + 14.51177757 \cdot y_1^2 - 21.302621275 \cdot y_2^2 - 96.755847 \cdot y_3^1 - 0.0175580478 \cdot 6 \cdot x_7 + 31.9557. \]

Moving from the main components to the key figures, we get the regression equation in expanded form:
\[ y = 1.3731368 \cdot y_1 - 7.9096146 \cdot x_3 + 4.54522087 \cdot x_{10} + 0.9232238 \cdot x_2 - 0.00472717 \cdot x_{11} + 0.548287544 \cdot x_{13} - 40.5744 \cdot x_3 - 0.838 \cdot x_4 - 65.6456 \cdot x_1 - 1.9224 \cdot x_5 - 63.7125 \cdot x_6 - 0.0175580478 \cdot 6 \cdot x_7 + 31.9557. \] (1)

The correlation coefficient of actual values of the death toll in road accident in territorial subjects of the Russian Federation in 2018 and calculated values (using formula (1)) is equal 0.88881944, the Spiran coefficient of rank correlation is equal to 0.875255744.

Figure 1 graphically shows the estimated and actual accident deaths.

Weight in the % of composed values (components) in a formula received as the component relation to the death toll, at summation on regions (i.e. values for Russia): a component with population and number of vehicles is 136; socio-economic indicators (including gasoline) is 45.4 (investment risk of
Russian regions is 4.51; final assessment of life quality is 15.6; investment potential of Russian regions is 32.6; socio-economic status is 34.3; gasoline – 10.5); law enforcement practice of the State Automobile Inspection (considered indicators) is 8.71; environment conditions is 12.3; average annual air temperature is 5.75; sobriety rating is 13.7; road density is 5.1; the age of the vehicles fleet is 3.1. At the same time it must be kept in mind that depending on the sign of the component, the role of the factor in the accident (increase or decrease) differs in the formula.

Let us note that the weight contribution of undescribed (unknown) indicators included in the free term in the regression equation is within 13.3 %, which is quite good with such a large amount of data.

It should be mentioned that socio-economic indicators (investment potential, level of socio-economic situation of the region, annual sales of gasoline), sobriety rating, natural conditions and average annual air temperature, density of roads and others have the most significant impact on accidents within the framework of the macro approach. Since formula (1) includes the sales of petrol, transit flows and actual vehicle use are taken into account.

A similar approach was used to model the number of deaths caused by drivers driving vehicles with signs of intoxication \( y' \) [3]. The significant variation of regional statistics in 2015–2018, as well as the relatively small value of this indicator, leads to the need to average its values by year when building the model. With this in mind, the model is as follows:

\[
\begin{align*}
y' &= 0.289 \cdot x_1 + 0.50478 \cdot x_2 + 4.30823 \cdot x_3 + 0.61 \cdot x_1 - 0.02243496 \cdot x_11 + 0.356928 \cdot x_13 \\
&+ 1.491247 \cdot y_1^1 - 6.8342156 \cdot y_2^1 - 16.039655 \cdot y_3^1 - 0.000973949 \cdot y_7^1 - 39.85758
\end{align*}
\]

(2)

The factors of rank correlation of the considered indicator and model parameters are equal: natural conditions \( (x_9) \) is 0.363736; sobriety rating \( (x_2) \) is -0.10896; road density \( (x_{11}) \) is 0.19348; age of vehicle fleet \( (x_{13}) \) is 0.30402; main components for the list of socio-economic indicators \( y_1^1, y_2^1, y_3^1 \) – are 0.578662, 0.50325, 0.56612, respectively; law enforcement practice of the State Automobile Inspection \( (x_7) \) is 0.681336; the number of road fatalities according to population and number of vehicles \( y_1 \) is 0.761247; average annual air temperature \( (x_{10}) \) is 0.016998.

The analysis showed that the population, the number of vehicles, the sobriety rating (48.52 %), natural conditions (36.07 %), the level of socio-economic situation of the region (–25 % – including gasoline), density of roads (–13 %) have a significant impact on the criterion under consideration. The impact of the remaining indicators is relatively small. In particular, the law enforcement activity of the State Automobile Inspection (the considered indicator) is –2.6 %.

Correlation coefficient of actual and calculated values is 0.802353, coefficient of rank correlation is 0.7867.

Figure 2 shows the estimated (formula (2)) and actual (4-year average) values of the fatalities number caused by drivers driving vehicles with signs of intoxication.

It should be noted that there is a close relationship between the total number of deaths in road accidents \( \bar{x} \) and the number of deaths in road accidents caused by drivers in the state of intoxication and who refused to undergo a medical examination for the state of intoxication [3] \( \bar{y} \) in the region (the correlation coefficient of actual and estimated values is 0.823949, the rank correlation coefficient is 0.793005). The corresponding relationship is as follows:

\[
\bar{y} = 0.137345257 \cdot \bar{x} + 11 \cdot 0.6808778
\]

(3)

and the results of the calculations are presented in figure 3, the estimated and actual (average for 4 years) values of the deaths number in road accidents due to the fault of drivers in the intoxication state, as well as those who refused the medical examination.
Figure 1. Estimated and actual values of the number of deaths in road accidents in the constituent entities of the Russian Federation in 2018.

Figure 2. Estimated and actual values of the number of deaths in road accidents caused by drivers driving vehicles with signs of intoxication.
Figure 3. Estimated (formula (3)) and actual values of the deaths number in road accidents caused by drivers driving vehicles with signs of intoxication.
3. Conclusion
In order to intensify anti-alcohol work, the federal project "Sober Russia" offered expert, legal, analytical and information support in the development of measures to protect the life and health of citizens within the framework of agreements with the regions of the Russian Federation. The agreements can contribute to the activation of new approaches aimed at protecting the life and health of Russian citizens, including the field of road safety.

The presented results of the study, according to the authors, can be used to assess the role of alcohol in road traffic accidents in relation to a specific region, as well as in Russia and to make appropriate decisions.

References
[1] Chubukov A B, Kapitanov V T, Monina O Yu and Silyanov V V (2014). Calculation of the Number of Fatalities in Road Accidents on the Basis of Socio-Economic Indicators Sci. and Technol. in the Road Sector 3
[2] Rating of investment attractiveness of Russian regions Retrieved from: http://www.riarating.ru (viewed on 10.08.2019).
[3] Official site of the State traffic inspectorate Retrieved from: http://www.gibdd.ru.
[4] Income level, final rating score of regions on quality of life, level of economic development, demographic situation Retrieved from: Iprime.ru/ratings/20131217/773219432.html (viewed on 25.07.2019).
[5] Dubrov A M et al 2011 Multidimensional statistical methods (Moscow: Finance and Statistics) 352 p
[6] Federal State Statistic Service [Rosstat] 2018 Retrieved from: http://www.gks.ru (viewed on 10.08.2019)
[7] Kobzar A I 2006 Applied Mathematical Statistics (Moscow: Fizmatlit) 816 p
[8] Chubukov A B, Kapitanov V T, Monina O Y and Kosheleva P I 2012 Qualitative and quantitative analysis of accidents in the Russian Federation Sci. and technol. in the road industry 4
[9] Ivchenko G I and Medvedev Yu I 1984 Mathematical Statistics (Moscow: Higher School) 248 p
[10] Ayvazyan S A 1989 Applied Statistics.Classification and Reduction of Dimensionality (Moscow: Finance and Statistics) 607 p
[11] Chubukov Al, Kapitanov V, Silyanov V and Monina O 2016 Simulation of region mortality rate in road accidents identifies the relationship of the vehicles which have arrived from other regions Sci. J. of Transport. Especial issue no. 07 International cooperation Journals MADI–SWJTU–UTC 129–136 (ISSN 2410-9088) (Moscow – Chengdu – Hanoi) Retrieved from: http://lib.madi.ru/sjt/index.html
[12] Retrieved from: https://www.autostat.ru (viewed on 27.07.2019)
[13] Oil products and natural gas market in Russia results 2015 Retrieved from: http://www.fuelbroker.ru/upload/iblock/ (viewed on 27.07.2019)
[14] Rating agency "Ekspert" Retrieved from: https://raexpert.ru/rankingtable/region_climat/2018/tab03 (viewed on 27.08.2019)
[15] Classification of regions of the Russian Federation by natural conditions Retrieved from: http://www.geoteka.ru/text.html?ident=usl (viewed on 20.08.2019).
[16] SNiP 23-01-99. Construction climatology 2000 (Moscow: Gosstroi of Russia)
[17] National sobriety rating of subjects of the Russian Federation 2018 Retrieved from: http://www.trezvros.ru/ (viewed on 20.08.2019)
[18] Chubukov A, Kapitanov V, Silyanov V and Monina O Approaches to assessing status and prediction of road traffic accidents rate Transportation Research Procedia (in print)
[19] Kaptains V T, Chubukov A B, Silyanov V V and Monina O Y 2017 Forecast of the number of deaths in road accidents based on socio-economic indicators Sci. and technol. in the road industry 4(82) 4–6
[20] Chubukov A, Kapitanov V, Silyanov V and Brannolte U 2016 Simulation of Regional Mortality Rate in Road Accidents *12th International Conference “Organization and Traffic Safety Management in large cities”* SPbOTSIC-2016, 28–30 September (St. Petersburg) pp 112–4 Retrieved from: www.sciencedirect.com