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Simulation of Regional Mortality Rate in Road Accidents

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Abstract

The paper gives the results of scientific research, which, being based on probabilistic and statistical modeling, identifies the relationship of certain socio-economic factors and the number of people killed in road accidents in the Russian Federation regions. It notes the identity of processes in various fields, in which there is loss of life. Scientific methods and techniques were used in the process of data processing and study findings: systematic approach, methods of system analysis (algorithmization, mathematical programming) and mathematical statistics. The scientific novelty lies in the formulation, formalization and solving problems related to the analysis of regional road traffic accidents, its modeling taking into account the factors of socio-economic impact.

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*Keywords:*Road traffic accidents, modeling, loss of life in accidents, correlation, statistical analysis, socio-economic aspect, factors.

1. Introduction

Improving road safety is one of the priorities of state policy of the Russian Federation, the economic and social importance of which cannot be overestimated.

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Bringing transport and social indicators of road safety in the Russian Federation to the European average values will help save thousands of human lives, qualitatively improve the security of the social environment of the state.

The road accidents analysis takes one of the leading places in forming a set of measures aimed providing road safety in the conditions of intensive motorization. Identifying the causes of accidents is the main component of the study, as well as the most important stage of analytical work, providing assessment of an emergency condition involving vehicles to determine the set of conditions and circumstances that influenced the occurrence of road accidents and the severity of their consequences, the removal of which would greatly reduce the likelihood of accidents.

The impact of motorization on the accident rate has been the subject of research since late 1940s. Until recently, the analysis of traffic safetyhasbeen mainly confined to the study of dynamics and structure of accidents by separate indicators. Currently, however, when the traffic safety problem worsened, requirements as to the quality of the analysis and the preparation of proposals for management solutions increased significantly. Mathematical statistics give the opportunity to build models for statistical information. Indeed, the characteristics of accidents, obtained by processing a sufficiently large group of accidents, are subject to statistical regularities. The existence of statistical regularities is determined by the fact that although each particular accident is the result of a combination of many factors and therefore may have a random nature, but these factors take a sustained nature for sufficiently large sets of traffic accidents, which creates prerequisites for building mathematical models obtained using methods of correlation and regression analysis, in order to develop and validate a set of measures aimed at improving traffic safety.

The authors conducted analysis of statistical data on deaths for various reasons,which found their significant dependence and the overall pattern of change over time.

On this basis, it has been hypothesized that there was an interdependence of road safety and the socio-economic and climatic factors that influences the state of road traffic accidents, in particular: the quality of life index; the final assessment of the natural environment; the sales of beer (per capita); the average annual air temperature; the density of paved public roads and other.

2. Factors under consideration

Studies have shown the ability to use (besides thoseindicators already mentioned above) the comparison of the results of investment policy indicators of the subjects of Russian Federation for making some regions attractive [RIA Rejting (2014)]to simulate the state of the road and transport accidents.

Two relatively independent characteristics are used as constituting components of the investment policy: investment potential and investment risk [EXPERT RA (2014)].

Investment potential is a quantitative characteristic that takes into account the region's saturation with natural resources, labor, fixed assets, and other infrastructure, as well as consumer demand and other factors that affect the potential volume of investment in the region.

Investment potential is the amount of nine private capacities (eight, up to 2005). Each of them, in turn, is characterized by a group of parameters:

- natural resources (average supply of balance reserves of basic natural resources);
- labor (human resources and their level of education);
- production (aggregate result of population and economic activity in the region);
- innovation (level of development of science and implementation of scientific and technological progress in the region);
- institutional (degree of development of the leading institutions of the market economy);
- infrastructure (economic and geographical situation of the region and its infrastructure security);
- financial (amount of the tax base, profitability of companies in the region and personal income);

- consumption (combined purchasing power of population of the region);
- travel (availability for tourists and travelers, as well as entertainment venues and accommodation for tourists).

Investment risk is a qualitative characteristic, it depends on the political, social, economic, financial, environmental and criminal situation; it reflects the likelihood of loss of investments and the income from them.

The following risk types are calculated:

- economic (tendencies in the economic development of the region);
- financial (degree of balance of the regional budget and finances of companies);
- social (level of social tension);
- ecological (environmental pollution, including radiation);
- criminal (crime rate in the region, taking into account the gravity of offence, economic crime and crimes related to drug trafficking);
- management (quality of budget management, availability of software and destination documents, degree of development of the control system, level of infant mortality as an integral indicator of the results of the social sphere).

Specific contribution of each component in the aggregate potential or integral risk is assessed on the basis of results of the annual survey conducted among experts of the Russian and foreign investment, consulting companies and enterprises [RIA Rejting (2013)].

Information sources for compilation of the rating are the ministries and departments, regional administrations, as well as a number of organizations with relevant data needed.

3. Methodology

The research methodology consisted of collection and analysis of statistical information necessary to carry out the correlation analysis, the formation on its basis of a set of indicators that influence the process in question, the establishment of regression models; calculating the parameters of the models, their interpretation, generation of proposals on the basis of models created to improve road safety.

The said identity of processes in various fields, characterized by the loss of life, allows us to consider the possibility of modeling these processes on the basis of a common approach.

The results of the correlation analysis presented in Table 1 were the basis for the generated list of indicators (Table 1) for building regression models.

Table 1. Correlation coefficient of the loss of life for various reasons and regions of indicators (2011; significance levels - 0.95)

Indicators	Road accidents, y_1	Loss of life for all reasons, y_2	Suicides, y_3	Accidental alcohol poisoning, y_4	Murders, y_5	Fire-related deaths, y_6	Number of observations (regions); limit value
Quality of life, x_1	-0.38729	0.4672	0.264931	0.163461	0.298566	0.435122	81; 0.219
Natural conditions, x_2	0.29213	0.44789	0.064451	0.167872	0.00255	0.314286	81; 0.219
Average yearly temperature, x_3	0.262	0.20242	-0.22739	-0.16722	-0.21008	-0.02202	81; 0.219
Motorways density, x_4	0.52391	0.25383	-0.09929	0.064953	-0.15147	0.068212	77; 0.221
Beer sale, x_5	0.419334	0.50838	0.582989	0.424354	0.492043	0.578678	77; 0.221
Investment potential, x_6	0.876797	0.8877	0.68365	0.475529	0.73	0.80355	77; 0.221
Investment risk index, x_7	-0.64661	-0.67982	-0.39097	-0.40646	-0.30749	-0.59198	77; 0.221

Weconsideredvariousoptionsfortheapproximationofthedead, butthebestaccuracycharacteristicswasprovidedbythefollowingdependence: $y = a \cdot H^{\alpha} T^{\beta} + \sum_{i=1}^{7} a_i \cdot x_i + a_0$,

where, α, β, a_0, a_i $(i = 1,\ldots,7)$ are parameters;

y – number of fatalities;

H – population size;

T – number of vehicles.

For various reasons of deaths we obtained estimates of their numbers. Table 2 shows the values of the Spearman's correlation coefficient and the coefficient of correlation of actual and estimated data, corresponding to the following design ratios. Information about the specific "contribution" (%) in modulus of each of the terms (excluding the term containing the population) in the formulas are given in Table 3.

4. Models

The model numbers of evaluation of the dead for various reasons are as follows.

1. Suicides

$$y_3 = 0.7191 \cdot H^{0.9016} - 784.8778 \cdot x_1 + 2.59155 \cdot x_5 - 29.145 \cdot x_3 - 170.8092 \cdot x_6 - 69.4306 \cdot x_7 + 500.9344$$

Approximately (we excluded an insignificant factor x_7)

$$y_3 = 0.7191 \cdot H^{0.9016} - 784.8778 \cdot x_1 + 2.59155 \cdot x_5 - 29.145 \cdot x_3 - 170.8092 \cdot x_6 + 500.9344$$

Graphic illustration of resultsis given in.Fig.1. App.

2. Fires

$$y_6 = 0.041445 \cdot H^{1.0442} - 54.62477 \cdot x_1 + 0.99378 \cdot x_5 - 10.5712 \cdot x_2 + 3.0472 \cdot x_6 - 224.497 \cdot x_7 + 132.232645$$

Approximately (we excluded an insignificant factor x_6)

$$y_6 = 0.041445 \cdot H^{1.0442} - 54.62477 \cdot x_1 + 0.99378 \cdot x_5 - 10.5712 \cdot x_2 - 224.497 \cdot x_7 + 132.232645$$

Graphic illustration of resultsis given in Fig. 2. App.

3. Murders

$$y_5 = 0.275466 \cdot H^{0.826378} - 10.2055 \cdot x_1 + 2.14173 \cdot x_5 + 99.67 \cdot x_6 + 664.309 \cdot x_7 - 323.977$$

Approximately (we excluded an insignificant factor x_1)

$$y_5 = 0.275466 \cdot H^{0.826378} + 2.14173 \cdot x_5 + 99.67 \cdot x_6 + 664.309 \cdot x_7 - 323.977$$

Graphic illustration of resultsis given in Fig. 3. App.

4. Road accidents

$$y_1 = 0.23239 \cdot H^{0.656292} T^{0.328146} - 521.3929 \cdot x_1 + 2.602 \cdot x_2 + 0.99324 \cdot x_3 + 0.16237 \cdot x_4 -$$
$$- 6.73521 \cdot 10^{-2} x_5 + 106.6 \cdot x_6 - 159.038 \cdot x_7 + 376.751$$

Specific contribution of the first term (with the population and transport) is about 60% of the sum of the absolute values of the remaining terms.

We may approximately put down the following (we excluded insignificant factors x_2, x_3, x_5)

$$y_1 = 0.23239 \cdot H^{0.656292} T^{0.328146} - 521.3929 \cdot x_1 + 0.16237 \cdot x_4 + 106.6 \cdot x_6 - 159.038 \cdot x_7 + 376.751$$

Graphic illustration of resultsis given in Fig. 4. App.

It should be noted that the dependence of the number of fatalities in road accidents on the population and number of vehicles is a relatively stable value. Processing a large data array of regions from 2008 to 2014 leads to the following formula (the remaining terms of the formula are not considered)

$$y_1 = 0.389 \cdot H^{0.642368} T^{0.321184},$$

thatisvirtuallyidenticaltotheresultsobtainedintheprocessingoftheannualdataarrayofregions.

Table 2. Values of Spearman's correlation coefficient and the coefficient of correlation of actual and estimated data corresponding to given design ratios

	Road accidents	Murders	Suicides	Fire-related deaths
Spearman's correlation coefficient	0.939414	0.794852	0.860577	0.887671
Coefficient of correlation	0.971981	0.846325	0.853603	0.920574

Table 3. Specific "contribution" (%) in modulus of each of the terms in the given formulas(disregarding the term containing the population)

	Road accidents	Murders	Suicides	Fire-related deaths
Quality of life	65	1.6	53.2	18.2
Natural conditions	2			19.4
Average yearly temperature	1		12.1	
Motorways density	4			
Beer sale	1	30.8	15.8	29.8
Investment potential	19	23.3	16.9	1.5
Investment risk index	8	44.3	2	31.1

The relationship between the fatalities in the road accidents and the number of deaths for individual causes of death has the following form:

y_1=0.006998 y_2-0.110728 y_3-0.183453y_4+0.220933 y_5+1.226096y_6+25.873936

Spearman'scorrelationcoefficientof actual and calculated values is 0.911771, and the coefficient of correlation is 0.917557.

Graphic illustration of resultsis given in Fig. 5. App.

The relationship between the fatalities of the road accidents and the most tangible indicators (number of deaths from all causes and fire-related deaths) has the following form (see Figure 6, App.):

y_1=0.007776y_2+0.907351y_6+18.379761

Spearman'scorrelationcoefficientis 0.909218, the coefficient of correlation is 0.911.

Summing up the results of the calculation by region according to the formula, we obtain the estimate of the number of killed in road accidents in Russia, equal to 24,826, which practically corresponds to the actual data of the Russian road police – 23,114 people[State Automobile Inspectorate (2016)]. Figure 1 shows the corresponding estimated and actual data for Russia in the last 7 years.

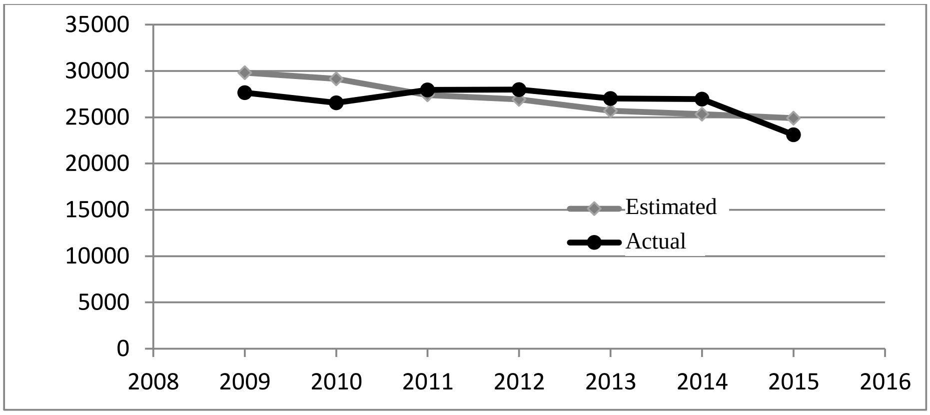

Fig. 1. Estimated and Actual Values of Road Accidents Fatalities in Russia.

On the basis of statistical data for the years 2008-2014 we also conducted a correlation analysis of the number of fatalities in road accidents caused by intoxicated drivers and data about regions. Relevant results are shown in Table 4.

Table 4. Results of Spearman's rank correlation analysis of the number of road accident fatalities caused by intoxicated driversand data about regions.

Indicator	Quality of life	Natural conditions	Temperature	Motorways density	Beer sale per capita	Investment potential	Investment risk
Value	0.241	0.187571	-0.10372	0.042498	**0.440692**	**0.587335**	**-0.40361**

The most significant interrelation between the number of road deaths per capita under review and the volume of sales of beer, investment potential and investment risk index is noted.

Table 5 summarizes data on the factors that best determine (within the framework of the model approach under consideration) the nature of the processes associated with loss of life.

Table 5. The most important factors for different processes related to loss of life.

	Road accidents	Suicides	Murders	Fire-related deaths
Quality of life	+	+		+
Natural conditions				+
Average yearly temperature		+		
Motorways density				
Beer sale		+	+	+
Investment potential	+	+	+	
Investment risk index	+		+	+

5. Conclusions

It can be noted that the hypothesis about the relationship of the processes considered is confirmed by the simulation results, and their quality is high enough in the event of road accidents. In the rest of the cases it is necessary to identify additional factors affecting the processes. But these results have a logical explanation and can be used to assess the status of road traffic accidents, the determination of measures aimed at reducing mortality due to traffic accidents and reduce the severity of their consequences.

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APPENDIX

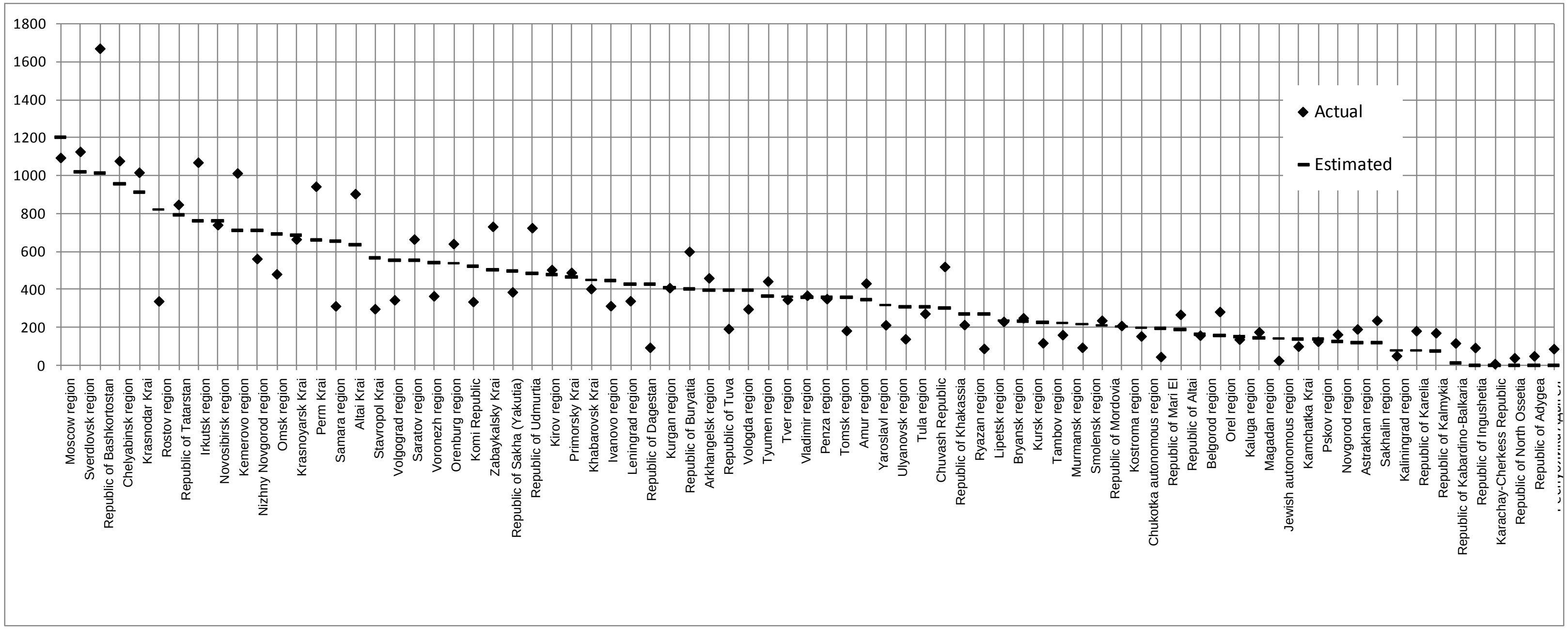

Fig. 1. Calculated and Actual Values of the Number of Suicides in the Russian Federation in 2011

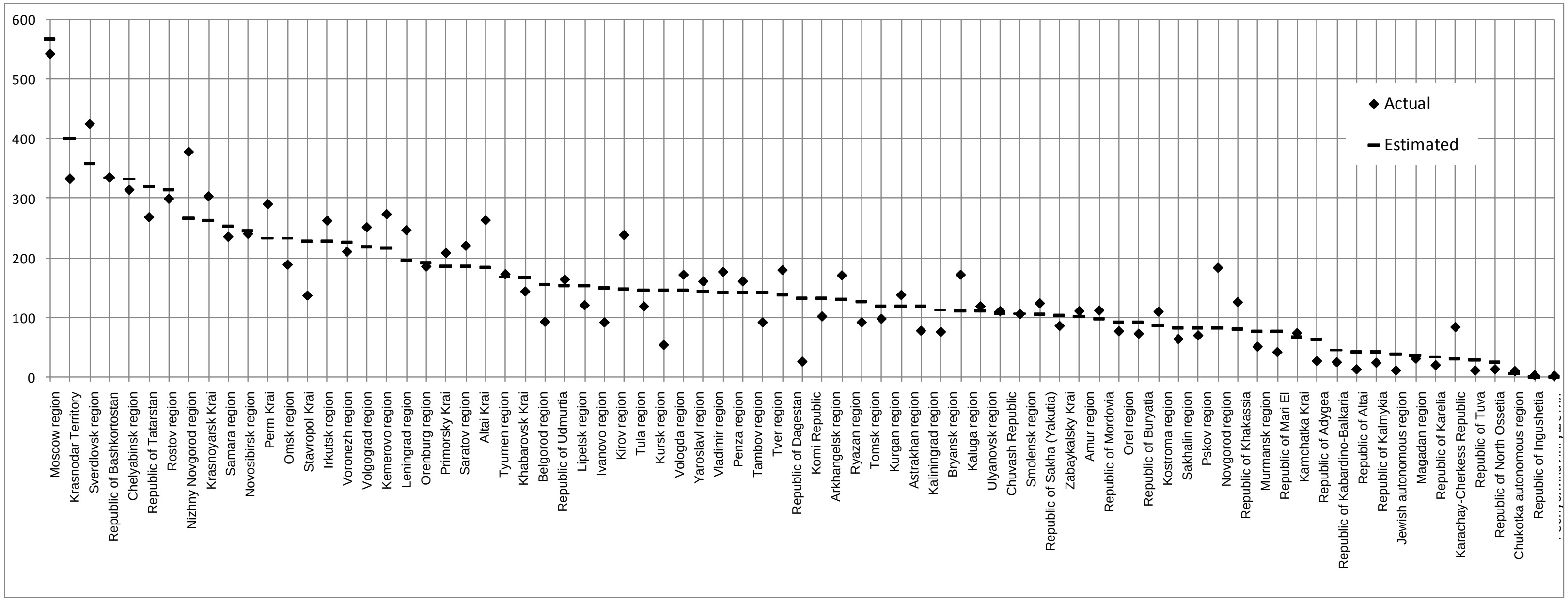

Fig. 2. Estimated and Actual Values of the Number of People Killed in Fires in the Russian Federation in 2011

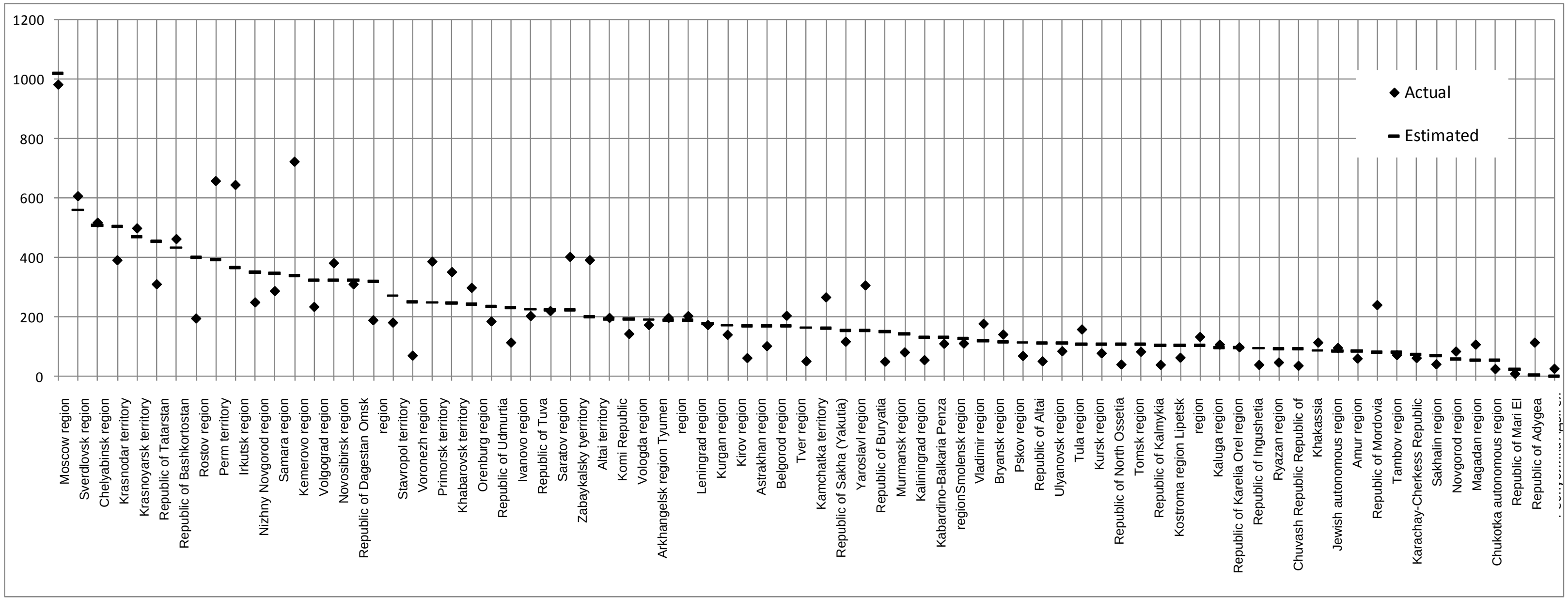

Fig. 3. Calculated and Actual Values of the Number of Murders in the Russian Federation in 2011

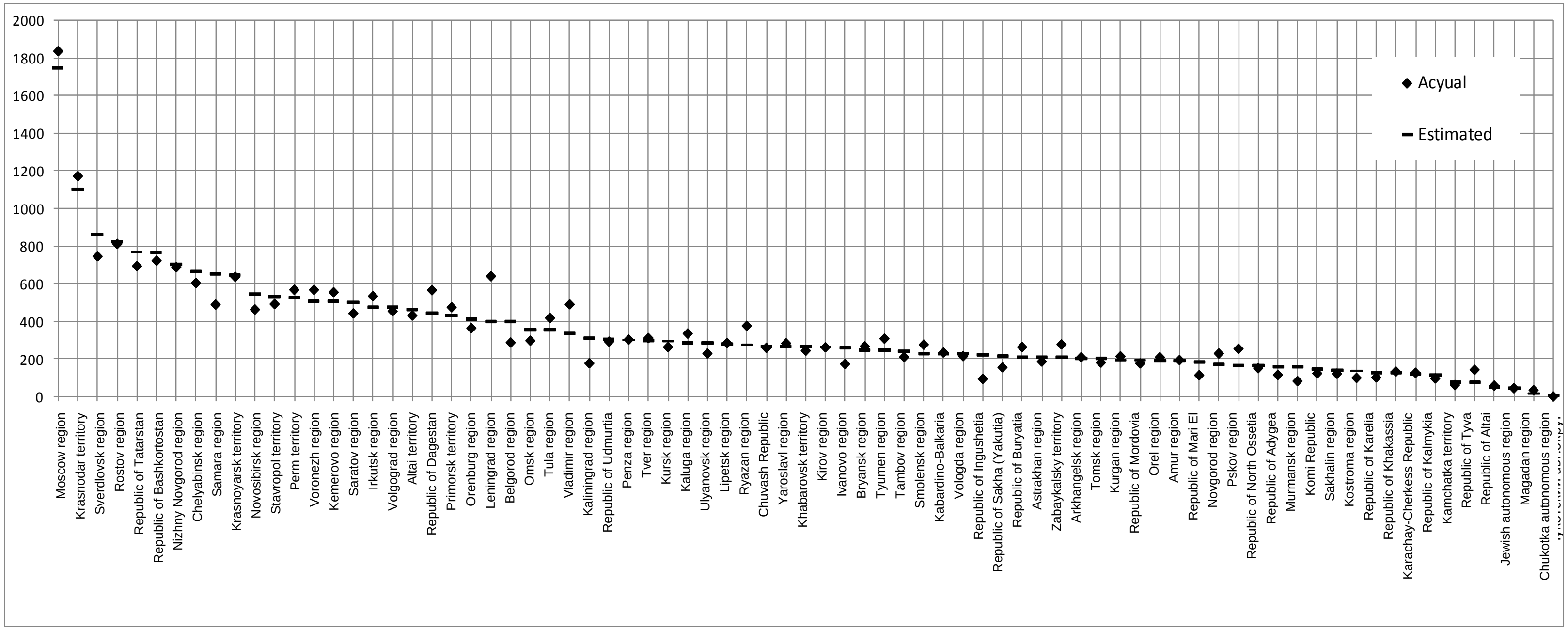

Fig. 4. Calculated and Actual Values of the Number of People Killed in Road Accidents in the Russian Federation in2011

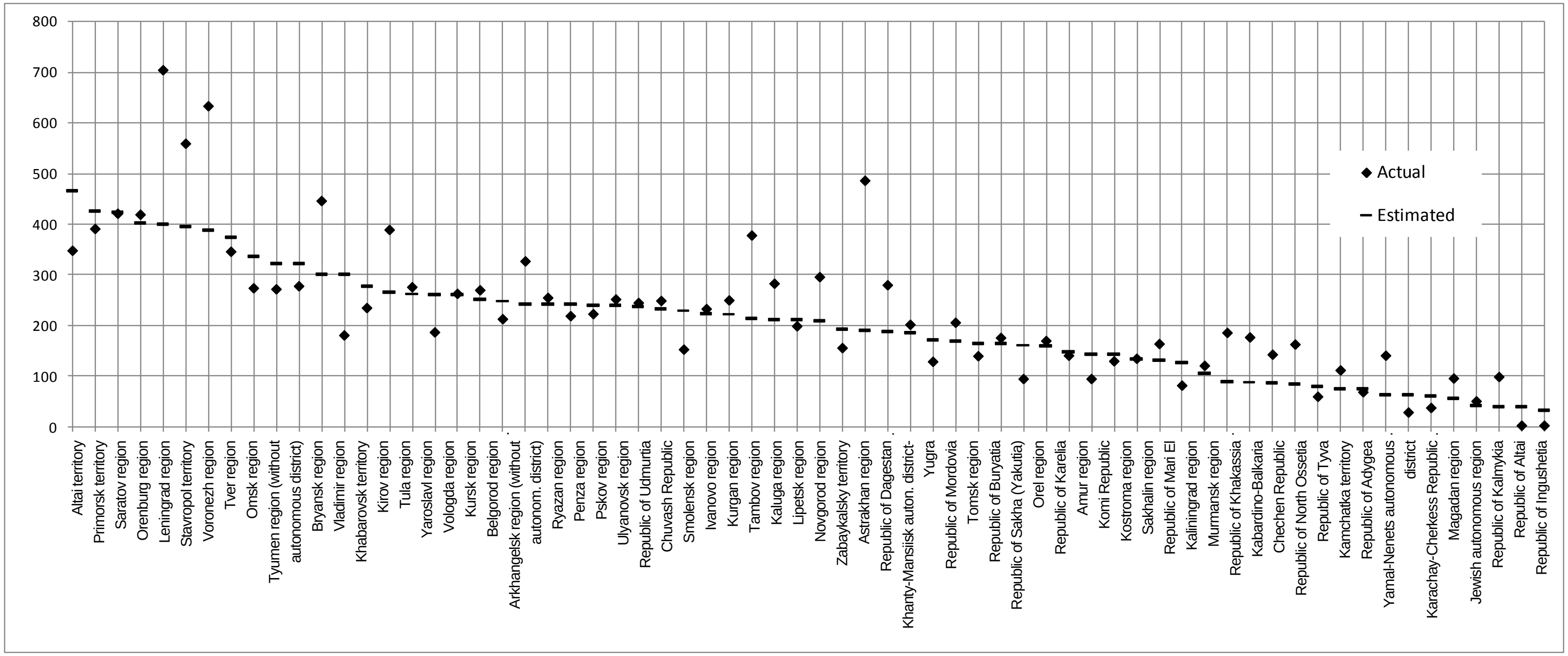

Fig. 5. Calculated (Based on Indicators of the Individual Causes of Death) and Actual Values of the Number of People Killed in Road Accidents in the Russian Federation in 2014

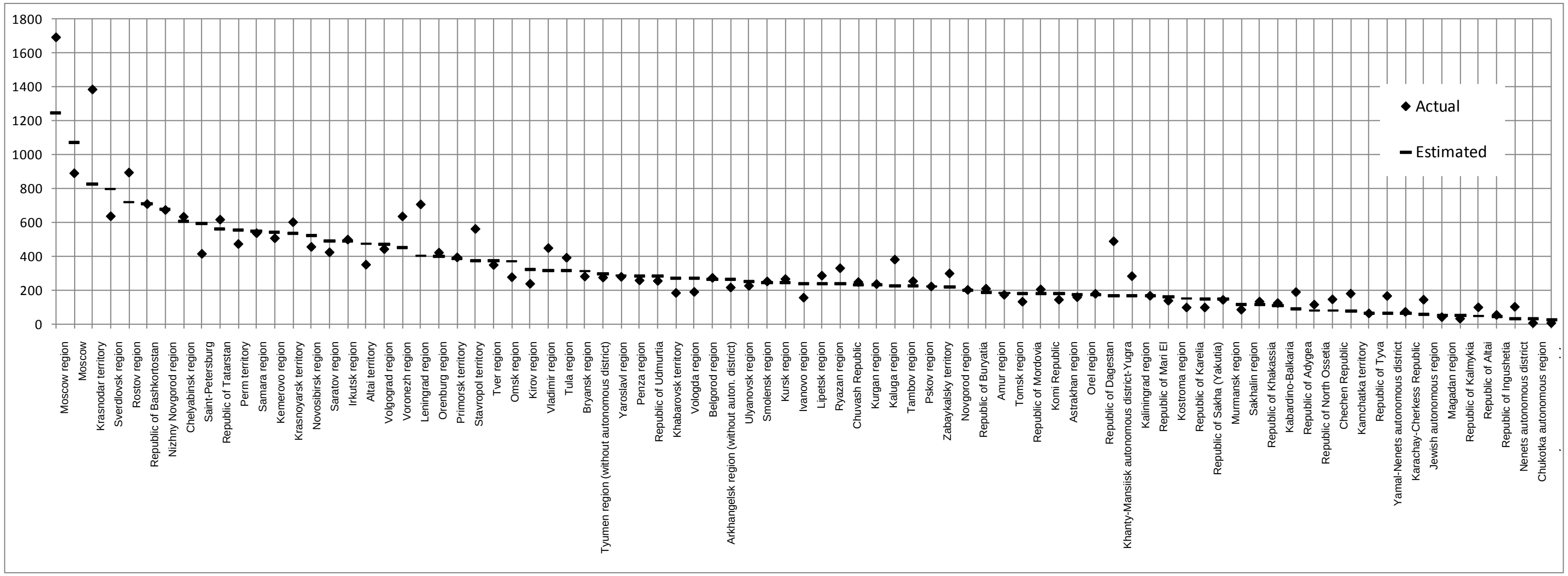

Fig. 6. Calculated (Based on the Indicators of Major Causes of Death) and Actual Values of the Number of People Killed in Road Accidents in the Russian Federation in 2014