SIMULATION OF REGIONAL MORTALITY RATE IN ROAD ACCIDENTS IDENTIFIES THE RELATIONSHIP OF THE VEHICLES WHICH HAVE ARRIVED FROM OTHER REGIONS

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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 the vehicles which have arrived from other regions, the rating of sobriety and the number of people killed in road accidents in the Russian Federation regions.*

Keywords: *accident rates, statistical analysis, road traffic accidents.*

Practically in any field of activity mathematical representation of an object of management is the cornerstone of decision making process. The mathematical models, methods and algorithms intended for the description of road and transport accident rate at the regional and federal levels are developed taking into account the factors characterizing the "Voditel (driver)-Avtomobil (vehicle)-Doroga (road)-Sreda (human environment)" complex. At the same time one of the determining factors is the number of the vehicles (V) registered in the territory of the subject of the Russian Federation [1]. At the same time, participation in traffic of the vehicles, arrived from other regions, can bring a certain error in calculations.

Until recently rather precisely territorial accessory of the vehicles could be determined by a code of the state registration sign of the vehicles. Now according to point 24 of Rules of registration of automotive-vehicles and trail cars to them in State Inspection for Road Traffic Safety of the Ministry of Internal Affairs of the Russian Federation (The order of the Ministry of Internal Affairs of Russia of November 24, 2008 No. 1001 "About an order of registration of vehicles") "Vehicles are registered behind physical persons to the address specified in the passport of the citizen of the Russian Federation or in the articles of incorporation at the place of residence of owners granted by bodies of registration accounting. Registration of vehicles behind the physical persons which don't have registration at the place of residence is made to the address specified in the articles of incorporation in the place of stay of owners granted by bodies of registration accounting". Also, according to the item 25 "According to Statements of Owners the Unregistered Vehicles Belonging on the Property Right to the Physical Persons Having Registration at the Place of Residence Can Be Registered in the Place of Stay of Specified Persons for Stay".

That is, there is no accurate differentiation of accessory of the vehicles moving on roads on "local" and "third-party" now. Therefore accounting of the vehicles, arrived from other regions, can be only estimative.

Two approaches for receipt of this assessment were considered:

On the basis of the statistical data on the vehicles registered as in the territorial subject of the federation (according to the State traffic inspectorate) [9, 3], and in other subject, taking part in road accident with death (tab. 1). It is necessary that a share "third-party" the vehicles from regional to equally corresponding relation of participants of the specified road accidents;

On the basis of the assumption that the attitude of number of vehicles from another town towards the number of the vehicles registered in the region to equally corresponding relation of quantity of administrative offenses in the field of traffic (tab. 2).

The carried-out calculations showed that the second approach doesn't lead to improvement of results of modeling (the possible reason – concentration of photovideo fixing devices on certain highways that doesn't allow to assess a situation in a road net in general).

Table 1. *Death toll in the road accidents with participation of the vehicles, registered in other regions, and also other countries (given 2015)*

	Has died		
	Third-party	All	The relation of the dead with participation third-party to the "local" vehicles
Altai Krai	80	313	0,343348
Amur region	39	152	0,345133
Arkhangelsk region	36	136	0,36
Astrakhan region	44	137	0,473118
Belgorod region	54	207	0,352941
Bryansk region	112	244	0,848485
Vladimir region	213	389	1,210227
Volgograd region	132	345	0,619718
Vologda region	48	138	0,533333
Voronezh region	198	543	0,573913
Jewish Autonomous Region	22	42	1,1
Zabaykalsky Krai	61	213	0,401316
Ivanovo region	44	127	0,53012
Irkutsk region	115	479	0,315934
Kabardino-Balkar Republic	54	168	0,473684
Kaliningrad region	8	168	0,05
Kaluga region	148	268	1,233333
Kamchatka Krai	10	56	0,217391
Karachay-Cherkess Republic	36	129	0,387097
Kemerovo region	106	435	0,322188
Kirov region	65	192	0,511811
Kostroma region	28	86	0,482759
Krasnodar Krai	430	1 132	0,612536
Krasnoyarsk Krai	148	567	0,353222
Kurgan region	92	198	0,867925
Kursk region	98	244	0,671233
Leningrad region	193	611	0,461722
Lipetsk region	60	212	0,394737
Magadan region	2	30	0,071429
Moscow	142	673	0,26742
Moscow region	432	1 389	0,451411
Murmansk region	11	56	0,244444
Nenets Autonomous Okrug	5	5	
Nizhny Novgorod region	174	522	0,5
Novgorod region	84	169	0,988235
Novosibirsk region	137	360	0,61435
Omsk region	68	259	0,356021

Orenburg region	64	353	0,221453
Oryol region	70	147	0,909091
Penza region	116	233	0,991453
Perm Krai	120	421	0,398671
Primorsky Krai	52	302	0,208
Pskov region	83	181	0,846939
Republic of Adygea	74	131	1,298246
Altai Republic	24	58	0,705882
Republic of Bashkortostan	204	604	0,51
Republic of Buryatia	34	163	0,263566
Republic of Dagestan	130	496	0,355191
Republic of Ingushetia	32	71	0,820513
Republic of Kalmykia	68	93	2,72
Republic of Karelia	33	93	0,55
Komi Republic	38	125	0,436782
Republic of Mari El	26	101	0,346667
Republic of Mordovia	46	153	0,429907
Republic of Sakha (Yakutia)	22	119	0,226804
Republic of North Ossetia	55	119	0,859375
Republic of Tatarstan	158	492	0,473054
Republic of Tyva	32	120	0,363636
Republic of Khakassia	40	116	0,526316
Rostov region	238	676	0,543379
Ryazan region	149	292	1,041958
Samara region	122	430	0,396104
St. Petersburg	82	354	0,301471
Saratov region	115	362	0,465587
Sakhalin region	10	108	0,102041
Sverdlovsk region	116	522	0,285714
Smolensk region	74	183	0,678899
Stavropol Krai	149	480	0,450151
Tambov region	92	202	0,836364
Tver region	136	273	0,992701
Tomsk region	23	108	0,270588
Tula region	174	366	0,90625
Tyumen region	116	228	1,035714
Udmurt Republic	80	209	0,620155
Ulyanovsk region	82	196	0,719298
Khabarovsk Krai	61	196	0,451852
Khanty-Mansi Autonomous Okrug	93	244	0,615894
Chelyabinsk region	175	538	0,482094
Chuvash Republic	71	208	0,518248
Chukotka Autonomous Okrug	1	5	0,25
Yamalo-Nenets Autonomous Area	27	58	0,870968
Yaroslavl region	108	233	0,864

Table 2. *Share of administrative offenses of drivers third-party the vehicles from regional*

	In total	With photovideo fixing application
Arkhangelsk region	0,152894	0,134247
Krasnodar Krai	0.3272	0.4268
Leningrad region	2,810225	4,390677
Moscow	0,385191	0,382078
Moscow region	1,333935	1,585219
Nizhny Novgorod region	0.3883	0.42
Novosibirsk region	0.2165	0.2
Komi Republic	0,13973	0,148748
Rostov region	0.2622	0.239
Sverdlovsk region	0.185	0.141
St. Petersburg	0,183735	0,155982
Tver region	2,349561	2,943396

Lower for the characteristic of a social and economic, climatic condition of regions, and also the taken corrective actions on participants of traffic, the indicators applied at the previous stages of work [1] (tab. 3) are used.

At the same time, it should be noted that results of a research have shown that orientation only to official statistical data doesn't provide the results allowing to find an explanation of a number of the facts, in particular, connected with a role of alcoholic intoxication in road and transport accident rate.

The new indicator - the rating of sobriety of regions which is result of the research executed within the Federal project "Sober Russia" and CEC "Rating" [6], and characterizing both extent of alcoholization of regions, and effectiveness of the antialcoholic legislation is included in the list of indicators (tab. 2). In rating are considered: volumes of sale of beer and vodka, the number of the dead from an alcoholic poisoning, number of the people having alcoholism and alcoholic psychoses the crimes committed by drunk faces, operability of the antialcoholic legislation in regions of the country.

Selection of indicators from the list (tab. 3) for modeling is made on the basis of values of coefficients of rank correlation of a death toll in road accident and the indicators presented in table 3. Critical value of coefficient of correlation of Spirmen is equal 0,217 for significance value 0,95 at selection of data on 82 regions.

Table 3. *Values of coefficients of rank correlation of a death toll in road accident and various indicators*

Indicator	Values of coefficients of rank correlation
Environment (x_9)	0,461005
Average annual temperature (x_{10})	0,284819
Density of highways (x_{11})	0,410618
Investment potential (x_1)	0,839408
Level of economic development (x_2)	0,541247
Investment risk (x_3)	-0,66002
Population (H)	0,92962
Number of vehicles (T)	0,919595
Total assessment of quality of life (rating point) (x_4)	0,609813
Demographic situation (x_5)	0,006449
Level of the income (x_6)	0,220676
Amount of precipitation (rainfall amount)	0,064556
Number of the registered administrative offenses (in the sphere of road-safety) (x_7)	0,854019
Number of the registered administrative offenses with use of means of automatic photovideo fixing (x_8)	0,755385
Beer sale (liters per capita) (x_{12})	0,2113
Rating of sobriety of regions (x_{13})	-0,52144

At a large number of indicators and their correlation interrelation the statistical analysis becomes complicated therefore there is a need of the description of the studied phenomenon (object) more integrated indicators, so-called main components [7].

For the list of economic indicators (investment potential, level of economic development, investment risk, total assessment of quality of life, a demographic situation, level of the income) the main components have an appearance [8]:

$$y_1 = 0.42 \cdot x_1 + 0.47 \cdot x_2 - 0.41 \cdot x_3 + 0.487 \cdot x_4 + 0.147 \cdot x_5 + 0.42 \cdot x_6$$

$$y_2 = -0.188 \cdot x_1 + 0.023 \cdot x_2 - 0.462 \cdot x_3 + 0.12 \cdot x_4 - 0.847 \cdot x_5 - 0.135 \cdot x_6$$

$$y_3 = -0.6 \cdot x_1 + 0.315 \cdot x_2 + 0.19 \cdot x_3 - 0.183 \cdot x_4 - 0.1 \cdot x_5 + 0.676 \cdot x_6$$

$$y_4 = -0.54 \cdot x_1 + 0.01 \cdot x_2 - 0.59 \cdot x_3 - 0.022 \cdot x_4 + 0.57 \cdot x_5 - 0.168 \cdot x_6$$

$$y_5 = 0.097 \cdot x_1 + 0.47 \cdot x_2 - 0.377 \cdot x_3 - 0.368 \cdot x_4 + 0.248 \cdot x_5 + 0.654 \cdot x_6$$

$$y_6 = -0.128 \cdot x_1 + 0.427 \cdot x_2 - 0.267 \cdot x_3 - 0.578 \cdot x_4 + 0.5 \cdot x_5 + 0.376 \cdot x_6 .$$

Relative shares of the total dispersion caused by one, two... the main components, 0.6, 0.78, 0.9, 0.955, 0.98, 1.0 are respectively equal. Below the 4th components as the exception two a component doesn't affect the accuracy of calculations are used.

For the indicators characterizing law-enforcement practice of the State traffic inspectorate, the main components following:

$$y_7 = x_7$$

$$y_8 = 0.97 \cdot x_7 + 0.24 \cdot x_8$$

The regression equation with the main components has an appearance (without the vehicles, arrived from other regions).

$$y' = 0{,}766928 y_0 + 1{,}744578 y_1 + 2{,}210101 y_2 - 2{,}765713 y_3 + 2{,}243566 y_4 - 1{,}054771 y_7 +$$

$$0{,}937212 y_8 + 4{,}074471 x_9 + 9{,}524224 x_{10} - 0{,}267582 x_{11} + 22{,}937101, \qquad (1)$$

$$y_0 = 0.389305 \cdot H^{0.642368} \cdot T^{0.321184} .$$

The coefficient of determination is equal 0,9037, coefficient of rank correlation - 0.908642.

The accounting of the vehicles, arrived from other regions (according to these tab. 1) leads to the specified model assessment of number of the dead in road accident with use main a component, given above:

$$y' = 0{,}987437\, y_0' + 1{,}254723 y_1 + 4{,}947724 y_2 - 1{,}066012 y_3 + 7{,}560156 y_4 - 0{,}942654 y_7$$

$$+ 0{,}838684 y_8 - 19{,}046045 x_9 + 12{,}376387 x_{10} - 0{,}224517 x_{11} + 0{,}378907 x_{13} - 6{,}284509, \qquad (2)$$

$$y_0' = 0.282832 \cdot H^{0.648705} \cdot T^{0.324352}.$$

The coefficient of rank correlation is equal 0,916773, determination coefficient - 0,916338. It should be noted rather small value of the free member in the equation that can testify to completeness of set of indicators for the description of process.

The average deviation of calculated and actual values decreases by 12.4% (in comparison with the results corresponding to a formula 1).

The relevant actual and settlement data are submitted in the drawing.

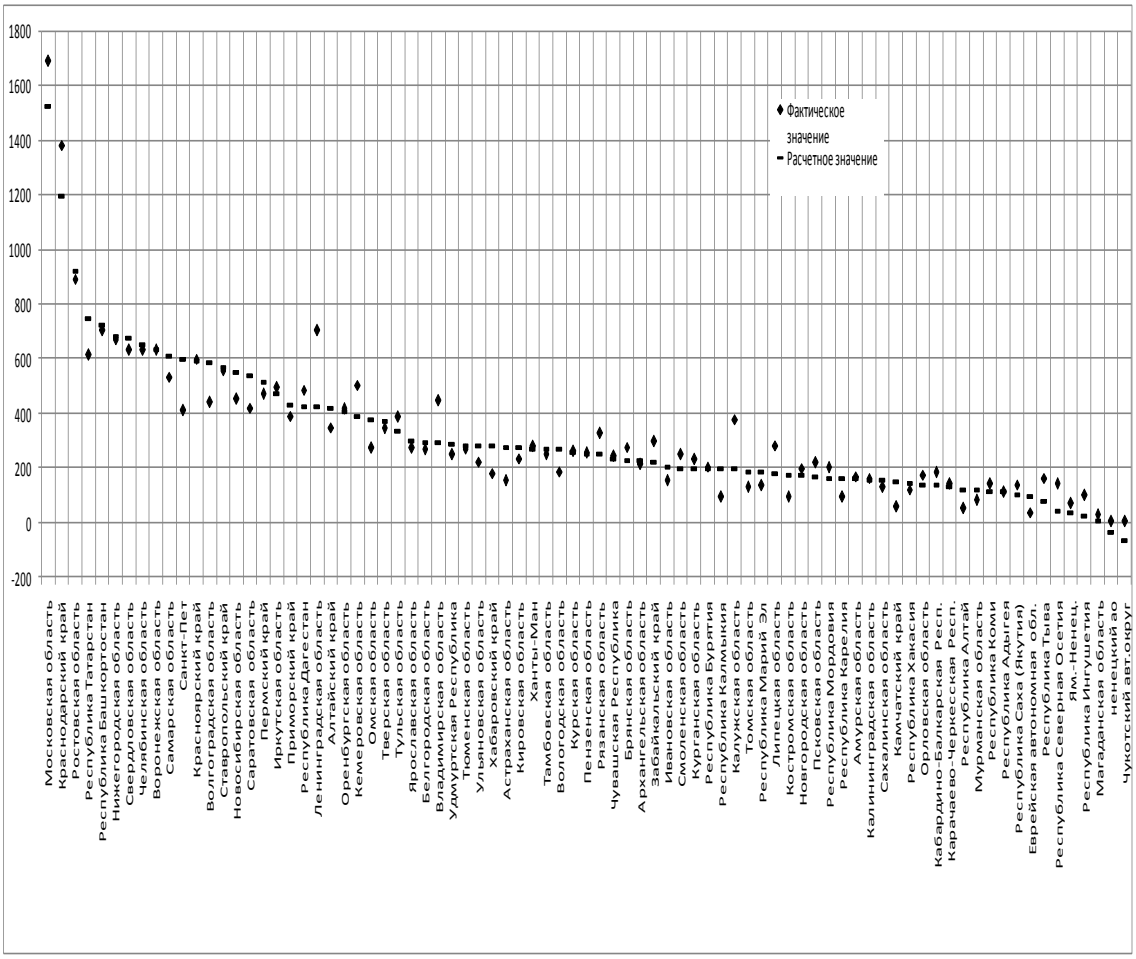

Fig. *Calculated and actual values of a death toll in road accidents (2014)*

The analysis has shown that the major factors connected with a death toll in road accident are (percent from a total settlement death toll):

Population and the number of vehicles (in total provide about 95 %);

Social and economic condition of the region (in total about 15 %);

Environment (-22 %);

Average annual temperature (about 11 %);

Density of highways (-16 %);

Punishments for administrative offenses in the field of traffic (nearly -6 %, at the same time the insignificant role of automatic photovideo fixing of violations of traffic regulations is noted);

Rating of sobriety of regions (23 %).

Lists of regions with rather high weight contribution of rating of sobriety to accident rate, and also with a high share of the dead because of drivers in state of intoxication are presented in table 4 (from total of the dead). Comparison of these two lists to some extent can serve as check of the received results.

Table 4. *Regions with rather high weight contribution of rating sobriety (I) in a formula (2), and also with a high share of the dead because of drivers in state of intoxication (II)*

(I)	(II)
Amur region	Altai Republic
Bryansk region	Sakhalin region
Jewish Autonomous Region	**Zabaykalsky Krai**
Zabaykalsky Krai	Udmurt Republic
Ivanovo region	**Magadan region**
Kaliningrad region	**Republic of Adygea**
Kamchatka Krai	Altai Krai
Karachay-Cherkess Republic	Kaluga region
Kurgan region	**Komi Republic**
Lipetsk region	Republic of Mordovia
Magadan region	**Chuvash Republic**
Murmansk region	Tambov region
Novgorod region	**Jewish Autonomous Region**
Oryol region	Vladimir region
Pskov region	**Republic of Tyva**
Republic of Adygea	**Republic of Mari El**
Altai Republic	Arkhangelsk region
Republic of Karelia	**Kurgan region**
Komi Republic	Penza region
Republic of Mari El	**Yamalo-Nenets Autonomous Area**
Republic of Sakha (Yakutia)	**Kamchatka Krai**
Republic of North Ossetia	Vologda region
Republic of Tyva	**Republic of Karelia**
Republic of Khakassia	Krasnoyarsk Krai
Chuvash Republic	**Ivanovo region**
Yamalo-Nenets Autonomous Area	**Amur region**

Follows from results of comparison that from 26 regions, the worst on each indicator, 14 enter both lists (tab. 4) that rather not bad characterizes results of modeling. Incomplete coincidence can be partly explained with feature of work of the State traffic inspectorate in different regions on identification of drivers in state of intoxication.

It should be noted that the rating of sobriety of regions offered in work [6] and which is well correlating with the number of the dead in road accident has allowed for the first time it is model to estimate influence of alcoholic intoxication on accident rate.

Results of calculations have shown that the offered approach to assessment of number of the CU, participating in traffic, allows to increase the accuracy of modeling of number of the dead in road accident. The average deviation of calculated and actual values decreases by 12.4%. The presented results find a logical explanation and can be used for assessment of a condition of road and transport accident rate.

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