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Statistical and Structural-Entropic Analysis of Main Trends of Road Traffic Accident Rate: Comparison of India and Russia

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Abstract

India and Russia are quite different countries in such aspects as location, climate, population density, economics specifics, etc. At the same time India and Russia are influential and significant for world community countries. Indian economy is the third-largest by gross domestic product with regard to purchasing power parity, Russian economy is the sixth-largest by the same parameter. Economies of both countries are fast-growing. This fact contributes to fast growth of vehicle parks of these countries. In the period from 2000 to 2019 Indian vehicle park has grown from 48.9 mln. units to 297.2 mln. units (+ 407 % growth), Russian vehicle park has grown from 24.5 mln. units to 61.7 mln. units (+ 151 % growth). One of the negative aspects of active automobilization is accompanying road accident rate. Governments of both countries pay serious attention to this negative consequence. What are the trends of road accident rate and current results in road safety sphere in compared countries? What samenesses and differences has structure of road accident rate formation in India and Russia? This article gives answers to these answers.

Analysis, held by authors, is not just statistical analysis of road accident rate aspects but it is an attempt to research the process by analyzing its structural peculiarities. Entropic analysis as quantitative evaluation of chaos of process of formation of deaths as result of road accidents can solve this problem.

Results of the research-comparison are establishment of country-specific law of R. Smeed; identification of medium-term regularities of change in time of three main characteristics of road accident rate – Human Risk *HR*, Transport Risk *TR* and Severity of road accidents S_{RA} (according to the data of 2010…2019); identification of medium-term regularities of change in time of orderliness (evaluative characteristic - relative entropy *Hn*) of road safety provision systems (according to the data of 2010…2019).

One the basis of received regularities analysis of road accident rate specifics in India and Russia was held. Specific for compared countries recommendations for improvement of road safety provision systems were formulated.

Keywords: India, Russia, Road safety, Road traffic accident rate, Statistical analysis, Structural-entropic analysis, Human Risk, Transport Risk, Severity of road accident, Relative entropy, Analysis of perfection of road safety provision orderliness.

Abbreviations: *HR* - Human Risk; *TR* - Transport Risk; S_{RA}, - Severity of Road Accidents; *RTA* - Road Traffic Accident; *A* – Automobilization; *H* – Entropy; *Hn* - Relative Entropy; *GDP* - Gross Domestic Product; *PPP* - Purchasing power parity; *WHO* - World Health Organization; *BRICS* - Brazil, Russia, India, China, South Africa.

I. INTRODUCTION

Comparison of different countries is always constructive and enables to solve range of problems. It is especially useful to compare class-comparable countries. India and Russia are both participants of BRICS and they can be compared with each other. BRICS countries cover 26 % of planet total surface. In 2019 they accounted for 42 % of the world's human population. These five countries have combined gross domestic product (GDP) with regard to purchasing power parity (PPP) of 33.3 % (24.2% as for current exchange rates) of the world's GDP [1]. Despite class similarity India and Russia are quite different countries (fig. 1-2).

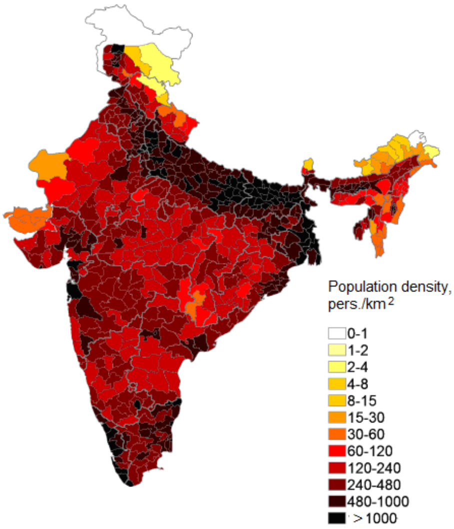

Fig. 1. Population density in India

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Fig. 2. Population density in Russia

India distinguishes by enormous human potential, highest population density and space deficit. While Russia has the biggest territory in the world, serious disproportions of density in different regions and 9 times smaller size of population than in India.

Traffic accident rate is a downside of economic growth and increase of quality of life. The problem of imbalance between car benefits and car harm appeared for the first time in 1896 when the first fatal traffic accident happened [2]. Since that time for 125 years humanity has tried to develop automobilization benefits, transform they to new forms and transfer them to new level. At the same time, it is necessary to minimize automobilization negative effects, one of which is traffic accident rate.

This article presents comparative analysis of traffic accident rate formation processes in India and Russia. The main attention was paid to temporal aspect of changing of traffic accident rate trends. The research used not only simple regression models [3] but also deeper analysis based on evaluation of structural-entropic orderliness [4] of process of development in time of transport systems of India and Russia.

II. LITERATURE REVIEW

Comparative analysis used results of evaluation of road safety in different countries, recorded in WHO Global status report on road safety of 2013 [5], 2015 [6], 2018 [7]. Despite its clarity statistics of WHO Global status report on road safety doesn't allow to fully evaluate qualitative peculiarities of road accident rate.

There are few works devoted to comparison of road traffic safety management in India and in other countries.

Article [8] is one of this works. It presents comparative statistics between BRICS countries and USA which considers such aspects as approaches to road safety provision and achievements of countries in this sphere.

Article [9] considers issues of objectivity of statistics of road accident rate in India. Authors claim that «Only 17.2 % and 2.3 % of RTIs requiring treatment as inpatient and outpatient, respectively, were reported to the police in a population-based study. Only one-quarter of RTIs presented to emergency departments were reported to the police. 22 % of fatal RTIs in a population-based study were not reported to the police».

Determining objectivity of statistics in Russia is quite problematic. T. Fattakhov in [10] states: «In Russia several departments collect statistics about road accidents. For this reason problems with access to information and synchronization between different sources exist».

It is interesting to analyze difference and dynamics in structure of victims of road accidents in India and Russia.

Article [11] considers distribution of road accidents victims by categories. Indian statistics of 2002 [11] shows that deaths in road accidents divides into 12 % of drivers and passengers of motorized four wheelers, 42 % of pedestrians, 14 % of bicyclists, 27 % of motorcyclists. Such division shows vulnerability of citizens that can't afford car. However, in last 15 years situation in India changed. Data of WHO Global status report on road safety-2018 [7] shows that share of drivers and passengers of motorized four wheelers among dead people in road accidents in 2016 stayed the same as in 2002 (18 %), when share of dead pedestrians and bicyclists significantly decreased (10 % and 2 % respectively). At the same time share of dead motorcyclists increased up to 40 %.

Russia has quite high stability of road accident victim's structure. 27…29 % of dead people are pedestrians and 57…60 % - drivers and passengers of motorized four wheelers [12]. The structure is stable for 2000…2019.

Another interesting research in sphere of road safety in India is presented in next papers [13-26].

Summary and main conclusions of works in road safety sphere, including above mentioned, are presented in [27].

III. PURPOSE AND PROBLEMS OF COMPARATIVE RESEARCH

The purpose of this work is to establish regularities of road safety provision systems of India and Russia, to compare these regularities and to identify sameness and difference of transport system aspects of such different countries as India and Russia.

Problems:

1. Establishment of long-term regularity of regression connection between Transport Risk *TR* and Automobilization *A* for road safety provision systems of India and Russia.
2. Establishment of medium-term regularities of change in time of three major characteristics of traffic accident rate – Human Risk *HR*, Transport Risk *TR* and Severity of traffic accidents S_{RA} – for road safety provision systems of India and Russia (according to the data of 2010…2019).
3. Establishment of medium-term regularities of change in time of orderliness of road safety provision systems (according to the data of 2010…2019).
4. Analysis of samenesses and differences in found regularities for road safety provision systems of India and Russia.
5. Synthesis of recommendations for improvement of road safety provision systems specific for India and Russia.

IV. METHOD

The fourth and the fifth problems are general in relation to first three and they can be characterized as philosophical, based on the ideas of Hegel dialectic.

For the solution of the first problem (search of the long-term regularities $TR = f(A)$) we used regression analysis and construction of analogues of classic law of R. Smeed [28] for the data of 1970…2019 in India [29] and Russia [12]. Values of Transport Risk *TR* and Automobilization *A* were defined with use of the classic approaches, presented in R. Smeed work [28, 30, 31].

In particular, Transport Risk *TR* is defined as (1):

$$TR_i = N_{Di} / [(N_{Vhi} / 10000)], \quad (1)$$

where N_{Di} - number of dead people in traffic accidents in year i;
N_{Vhi} - size of vehicle fleet of the country in year i;
10000 - coefficient of casting TR to specific dimension;
i - year index.

Automobilization A_i is defined as number of vehicles per 1000 citizens (according to the first of January of year *i*) (2):

$$A_i = [N_{Vhi} / P_i] \cdot 1000, \quad (2)$$

where N_{Vhi} - number of vehicles in the country in year i;
Pi - size of population of country in year i;
1000 - coefficient of casting A;
i - year index.

For the solution of the second problem we used two methods: estimated method of finding values of Human Risk *HR* (3), Transport risk *TR* (1) and Severity of traffic accidents S_{RA} (4) and method of construction and subsequent qualitative analysis of time series (2010…2019) of required values.

Human Risk HR_i is defined as (3):

$$HR_i = N_{Di} / [(P_i / 100000)], \quad (3)$$

where N_{Di} - number of dead people in traffic accidents in year i;
P_i - median size of population of country in year i;
100000 - coefficient of casting HR to specific dimension;
i - year index.

Severity of traffic accidents S_{RAi} is defined as (4):

$$S_{RAi} = N_{Di} / N_{Vi}, \quad (4)$$

where N_{Di} - number of dead people in traffic accidents in year i;
N_{Vi} - number of victims (sum of dead people and injured people) in traffic accidents in year i;
i - year index.

For the solution of the third problem it is necessary to identify relative information entropy *Hn* for the road safety provision systems [32] of compared countries during the period of 2010…2019 and perform qualitative analysis [33] of time series (2010…2019) of *Hn* values [33, 34].

The method of finding relative information entropy for the road safety provision systems is considered in detail in works [35-38]. Let us give a brief reminder that principal approach to definition of relative information entropy *Hn* was developed by C. E. Shannon in works [39, 40]. It is defined by formula (5):

$$H = -\Sigma(\omega_i \cdot ln\omega_i) \quad (5)$$

where *n* - number of parts of process of informational transformation;
w_i - weight coefficients, meeting the normalization condition $\Sigma\omega_i = 1$;
i - year index.

V. INITIAL DATA

Tables 1 and 2 presents necessary for analysis data that defines the state of road safety in India and Russia.

Tables 3 and 4 presents calculated values of major specific road safety characteristics – Human Risk HR, Transport Risk *TR* and Severity of road accidents S_{RA} – and also Automobilization *A* for India and Russia.

VI. RESULTS

VI.I Long-term regularity of regression connection between Transport Risk *TR* and automobilization *A* (identification of regional geography specifics of R. Smeed law)

In 1949 English scientist R. Smeed, one of classics of transport science, published article [28], in which he suggested power function $TR = \alpha \cdot A^{-\beta}$ that connects Transport risk *TR* and automobilization level *A*.

Classical law of R. Smeed [28, 30, 31] applied to data (1970…2019) on Transport Risk *TR* and automobilization *A* in compared countries (India and Russia) appears as follows (fig. 3).

In case of Russia (fig. 3b) power function not correctly enough describes process of change of Transport Risk *TR* in time. Therefore, in Russian case function *TR = f(A)* should be piecewise non-linear [41]. Until the automobilization level reaches 80 vehicles per 1000 citizens, Russian data satisfies power model $TR = 280 \cdot A^{-0,5}$ (fig. 4a).

After that point (fig. 4b) data satisfies different exponential model $TR = 59,6 \cdot exp(-0,0076 \cdot A)$.

M. Y. Blinkin wrote about this peculiarity of Russian case of R. Smeed law in his work [30]. Why Russian model differs from classical, proposed by R. Smeed in 1949?

Possible explanations are presented below:

1. Originality of model for Russia depends on specifics of uneven settlement of population in the country territory, low population density on major part of country area and low level of transport system development (roads density and low load level) [42].
2. Transformation of power model into exponential can be explained by the shift of economic-social formation (from socialism to capitalism). This shift had an impact on

qualitative change of lifestyle of Russians. Value of human life and intention to save it increased [43].

3. Level of TR is quite high for automobilization level A = 80 vehicles per 1000 people. This value of *A* was registered in 1990. In this period of time Russia had unique structure of vehicle park ownership. Trucks and buses were state property. Passenger cars were the property of people with quite low morality standards, prone to violation of traffic code [44]. Drivers of passenger cars and their behavior on the roads contributed to growth of traffic accident rate in those years (1988…1996).

VI.II Medium-term regularity of change in time of three main characteristics of traffic accident rate – Human Risk HR, Transport Risk TR and Severity of road accidents (according to the data 2010…2019)

Values of *TR*, *HR* и S_{RA} are calculated by formulas (1), (3) and (4). Fig. 5 shows time series (2010…2018) of these indicators.

Table 1. Dynamics in time (1970…2018) of characteristics of the road safety state in India [29]

Year	Population, thous. people	Country's vehicle fleet, thous. units	Annual number of road accidents, units/year	Annual number of victims in road accidents, person/year	Annual number of deaths in road accidents, person/year
1970	539000	1401	114999	85000	15000
1980	673000	4521	153000	133000	24000
1990	835000	19152	283000	198000	54000
2000	1014825	48857	391000	478000	79000
2010	1176742	127746	500000	663000	135000
2011	1210193	141866	498000	653000	142000
2012	1208116	159491	490000	647000	138000
2013	1223581	181508	486000	632000	138000
2014	1238887	190704	489000	633000	140000
2015	1254019	210023	501000	646000	146000
2016	1268961	230031	481000	646000	151000
2017	1283601	253311	465000	619000	148000
2018	1298043	272988	467000	620000	151000
2019	1312241	297190	449000	622000	151000

Table 2. Dynamics in time (1970…2018) of characteristics of the road safety state in Russia [12]

Year	Population, thous. people	Country's vehicle fleet, thous. units	Annual number of road accidents, units/year	Annual number of victims in road accidents, person/year	Annual number of deaths in road accidents, person/year
1970	130079.2	2881	≈ 120000	≈ 140000	≈ 20000
1980	138126.6	7180	≈ 150000	≈ 167615	27615
1990	147665.1	11861	≈ 170000	≈ 250366	35366
2000	146890.1	24476	≈ 157596	≈ 208995	29594
2010	141956.0	41648.965	199083	276762	26544
2011	142912.56	43325.312	199868	279801	27953
2012	143030.13	45471.096	203597	286609	27991
2013	143347.13	47881.786	204068	285462	27025
2014	146301.86	52175.879	199720	278748	26963
2015	146307.66	56469.971	184000	254311	23114
2016	146832.29	58025.620	173694	241448	20308
2017	146899.00	59790.545	169432	234462	19088
2018	146828.17	60578.772	168099	232907	18214
2019	146780.72	61739.156	164358	227858	16981

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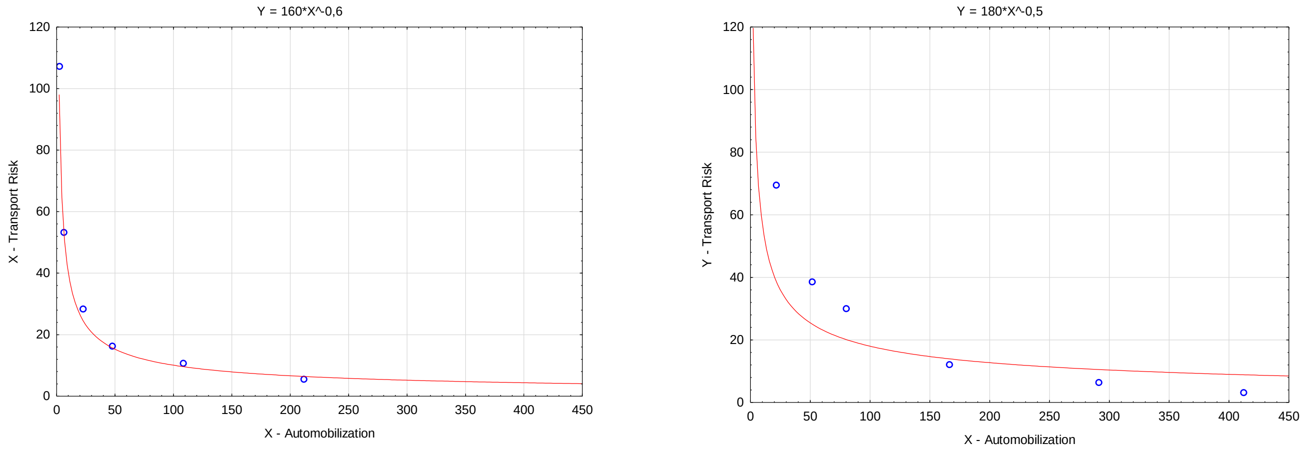
Table 3. Dynamics in time (1970…2018) of major specific characteristics of road safety in India

Year	Human Risk *HR*, dead in road accidents/ 100 thous. peoples	Transport Risk *TR*, dead in road accidents/ 10 thous. vehicles	Severity of road accident S_{RA}, %	Automobilization *A*, vehicles/1000 pers.
1970	2.8	107.1	17.65	2.6
1980	3.6	53.1	18.05	6.7
1990	6.5	28.2	27.27	22.9
2000	7.8	16.2	16.53	48.1
2010	11.5	10.6	20.36	108.6
2011	11.7	10.0	21.75	117.2
2012	11.4	8.7	21.33	132.0
2013	11.3	7.6	21.84	148.3
2014	11.3	7.3	22.12	153.9
2015	11.6	7.0	22.60	167.5
2016	11.9	6.6	23.37	181.3
2017	11.5	5.8	23.91	197.3
2018	11.6	5.5	24.35	211.9
2019	11.5	5.4	24.27	226.5

Table 4. Dynamics in time (1970…2018) of major specific characteristics of road safety in Russia

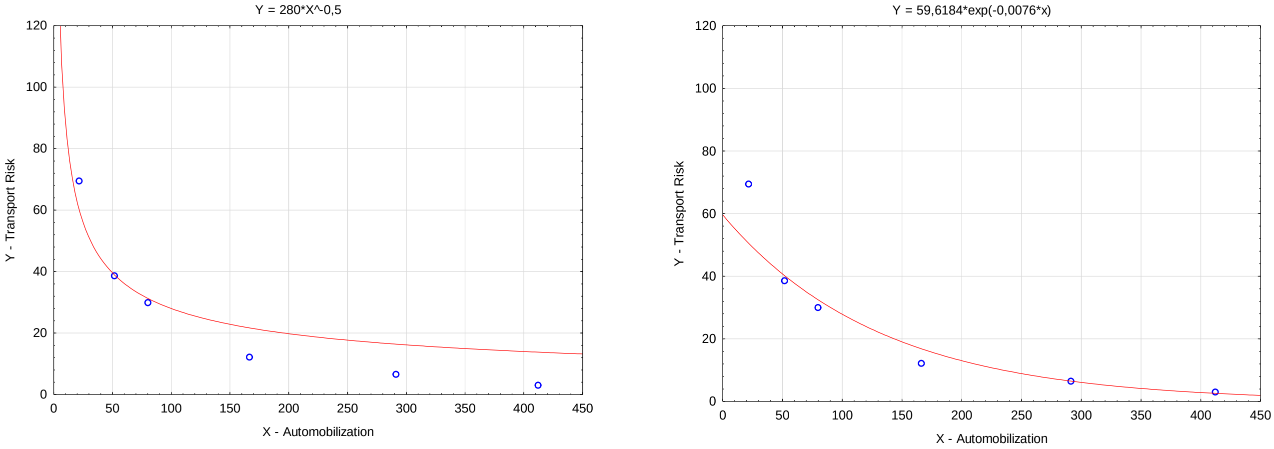
Year	Human Risk *HR*, dead in road accidents / 100 thous. peoples	Transport Risk *TR*, dead in road accidents / 10 thous. vehicles	Severity of road accident S_{RA}, %	Automobilization *A*, vehicles/1000 pers.
1970	15.4	69.4	14.29	22.1
1980	20.0	38.5	16.48	52.0
1990	23.9	29.8	14.13	80.3
2000	20.2	12.1	14.16	166.6
2010	18.7	6.4	9.59	293.4
2011	19.6	6.5	9.99	303.2
2012	19.6	6.2	9.77	317.9
2013	18.9	5.6	9.47	334.0
2014	18.4	5.2	9.67	356.6
2015	15.8	4.1	9.09	386.0
2016	13.8	3.5	8.41	395.2
2017	13.0	3.2	8.14	407.0
2018	12.9	3.0	7.82	412.6
2019	11.6	2.7	7.45	420.6



A). India $TR = 160 \cdot A^{-0,6}$ (R^2 = 0,863)

B). Russia $TR = 180 \cdot A^{-0,5}$ (R^2 = 0,511)

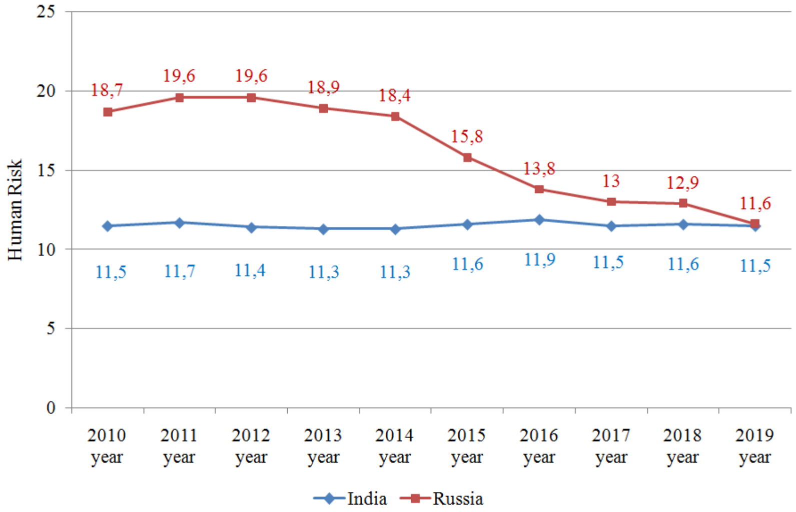
Fig. 3. Models of general view $TR = \alpha \cdot A^{-\beta}$



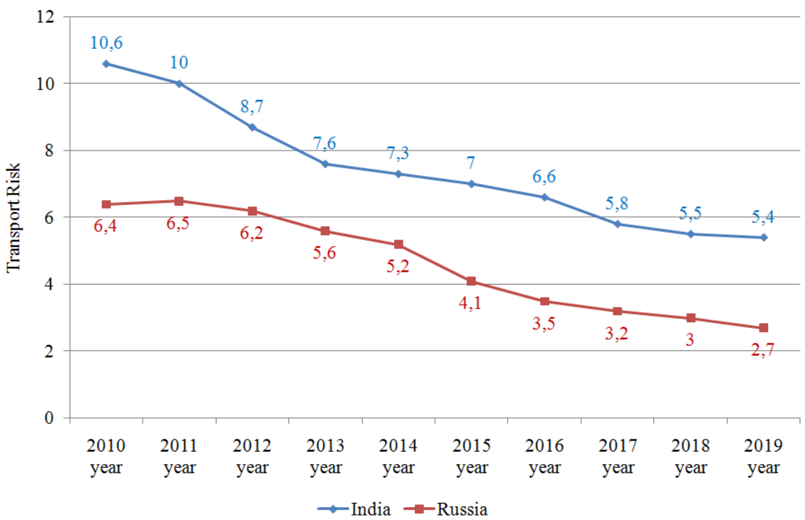
A). Case for Russia when A = [0; 80]
$TR = 280 \cdot A^{-0,5}$

B). Case for Russia when A =]80; 420[
$TR = 59.6 \cdot exp(-0.0076 \cdot A)$

Fig. 4. Corrected models $TR = f(A)$ for Russia



A). Human Risk *HR*



B). Transport Risk *TR*

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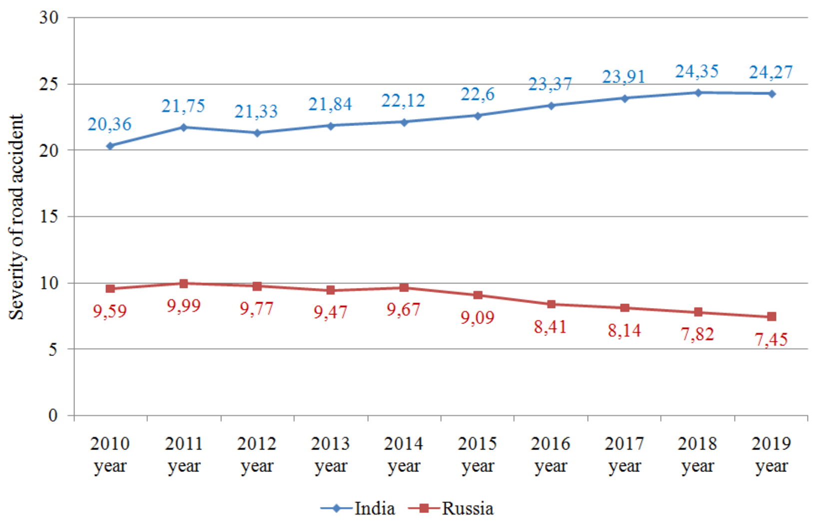

C). Severity of Road Accidents S_{RA}

Fig. 5. Time series (2010…2018) of RTA rate indicators

VI.II.I Explanation of originality of research of trends of change in time of three main characteristics of traffic accident rate in India and Russia

Let us consider peculiarities of trends shown in fig. 5. Value of Human Risk *HR* in India is much smaller than in Russia. The reason of this is a big size of population in India in comparison to Russia.

Values of Transport risk *TR* and Severity of road accidents S_{RA} are bigger in India than in Russia. Cybernetic cause-effect chain of road accident rate formation (fig. 6) shows blocks of information transformation in order of their reason [35, 36, 37, 38].

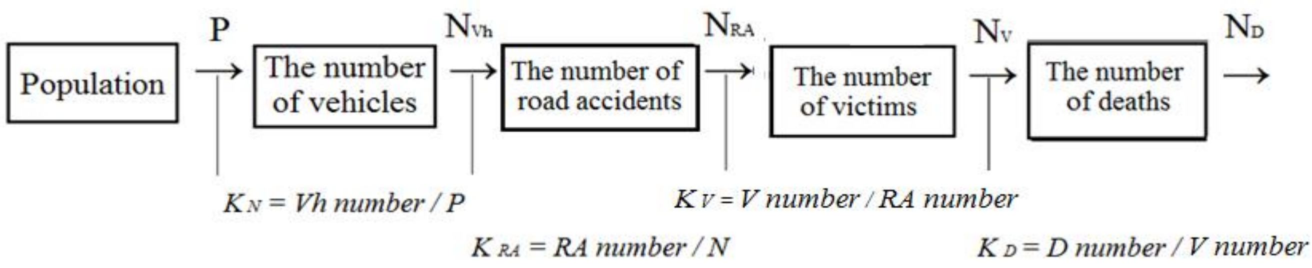

Fig. 6. The cause-effect chain of road traffic accident rate formation [35, 36, 37, 38]

Human Risk *HR* is determined by relation of block 5 (the number of deaths) and block 1 (population); Transport risk *TR* is determined by relation of block 5 (the number of deaths) and block 2 (the number of vehicles); Severity of road accidents S_{RA} is determined as relation of block 5 (the number of deaths) and block 4 (the number of victims).

India (table 5), in comparison to Russia (table 6), has relatively low transformation coefficient K_N between block 2 (the number of vehicles) and block 1 (population).

This coefficient K_N determines automobilization level (in 2019 its value in India was 226.5 vehicles per 1000 people, in Russia – 420.6 vehicles per 1000 people).

At the same time India (table 5), in comparison to Russia (table 6), has relatively high transformation coefficient K_D between block 5 (the number of deaths) and block 4 (the number of victims).

These facts determine originality of traffic accident rate formation in compared countries. Therefore, traffic accident rate formation process should be considered from a perspective of analysis of orderliness of road safety provision. Such analysis requires entropic analysis - calculation of relative information entropy *Hn* of road safety provision systems of compared countries and consideration of general trend of *Hn* during the medium-term period.

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Table 5. Values of transformation coefficients between blocks of the cause-effect chain of road traffic accident rate formation (2010…2018) in India

Year	K_N	K_{RA}	K_V	K_D
2010	0.1086	0.0039	1.3260	0.2036
2011	0.1172	0.0035	1.3112	0.2175
2012	0.1320	0.0031	1.3204	0.2133
2013	0.1483	0.0027	1.3004	0.2184
2014	0.1539	0.0026	1.2945	0.2212
2015	0.1675	0.0024	1.2894	0.2260
2016	0.1813	0.0021	1.3430	0.2337
2017	0.1973	0.0018	1.3312	0.2391
2018	0.2119	0.0017	1.3276	0.2435
2019	0.2265	0.0015	1.3853	0.2428

Table 6. Values of transformation coefficients between blocks of the cause-effect chain of road traffic accident rate formation (2010…2018) in Russia

Year	K_N	K_{RA}	K_V	K_D
2010	0.2934	0.0048	1.3902	0.0959
2011	0.3032	0.0046	1.3999	0.0999
2012	0.3179	0.0045	1.4077	0.0977
2013	0.3340	0.0043	1.3989	0.0947
2014	0.3566	0.0038	1.3957	0.0967
2015	0.3860	0.0033	1.3821	0.0909
2016	0.3952	0.0030	1.3901	0.0841
2017	0.4070	0.0028	1.3838	0.0814
2018	0.4126	0.0028	1.3855	0.0782
2019	0.4206	0.0027	1.3864	0.0745

VI.III Medium-term regularity of change in time of orderliness *Hn* of road safety provision systems (according to data of 2010…2018)

Law of R. Smeed [28, 31, 30] is not applicable to analysis of processes of change of global transport systems that took less than 10 years. Entropic analysis is more suitable instrument. It can evaluate level of system orderliness. Particularly relative entropy *Hn* evaluates level of chaos in country's road safety provision system.

Method of calculation of entropic characteristics for road safety provision systems was developed in 2017…2020 by A. Petrov and V. Kolesov and is presented in works [35-38]. In this work we omit description of methodic details and present only results of calculation of relative entropy *Hn* for road safety provision systems of compared countries (table 7). Data in graphical representation is presented in fig. 7.

Table 7. Relative entropy *Hn* for road safety provision systems of India and Russia

Year	Country's value of relative entropy *Hn* for the State road safety system	
	India	Russia
2010	0.763	0.759
2011	0.750	0.755
2012	0.743	0.764
2013	0.728	0.745
2014	0.723	0.734
2015	0.714	0.720
2016	0.710	0.718
2017	0.696	0.713
2018	0.687	0.712
2019	0.686	0.710
2010…2019	0.763…0.686	0.759…0.710
	- 10.1 %	- 6.5 %

Road safety provision systems orderliness, or negentropy, should be evaluated as *(1 – Hn)*. Since 2011 orderliness of state road safety provision system in India is higher than in Russia. Furthermore, relative entropy *Hn* of Indian state road safety provision system decreases faster than in Russia. It is fair statement with condition of objectivity of official statistics that was used for calculation of relative entropy *Hn* of road safety provision systems of compared countries.

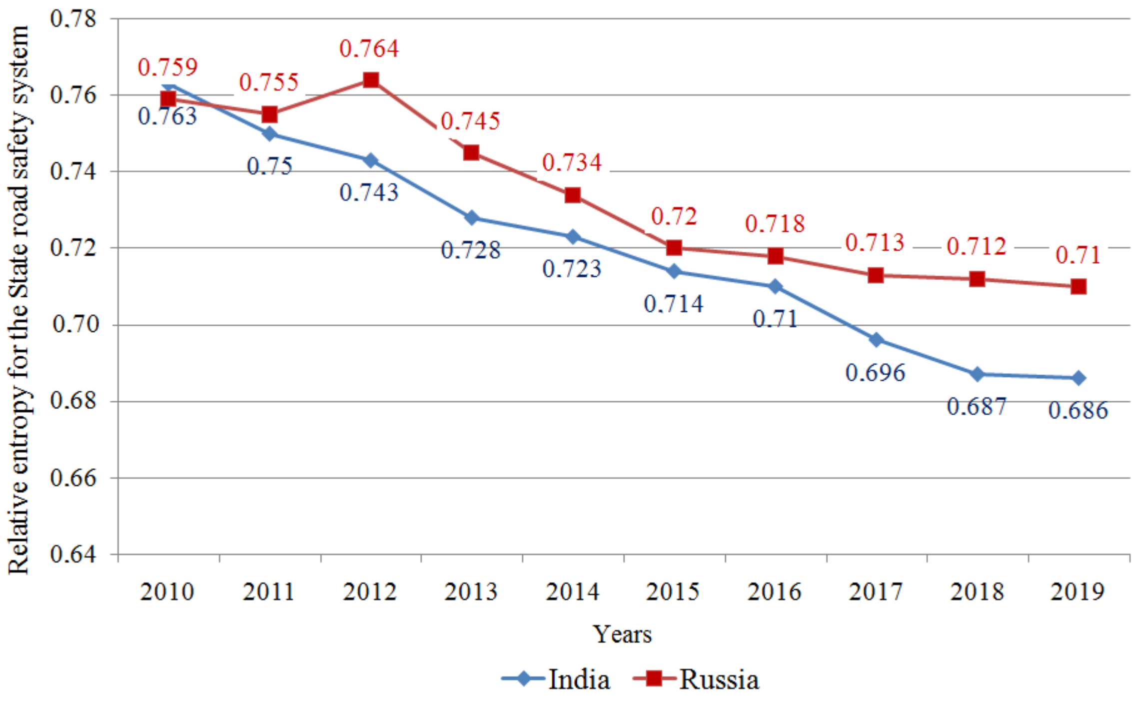

Fig. 7. Medium-term (2010…2018) dynamics of change of Relative entropy for road safety provision systems of India and Russia

VI.III.I Qualitative analysis of orderliness of structure perfection of road safety provision systems in compared countries

Data of table 7 and fig. 7 illustrates structural perfection of road safety provision systems of compared countries in dynamics. General conclusion – in recent years level of structural perfection of road safety provision system in India is higher than in Russia. According to the pace of change of relative entropy *Hn*, processes of orderliness improvement proceed more successful in India than in Russia.

To understand reason of success, we need to compare values of positive Q_i of different links of the cause-effect chain of road accident rate formation (fig. 6) and their significance in formation of result.

Positive *Q* is determined by formula (6) and formula (7):

$$Q = Q_N + Q_{RA} + Q_V + Q_D, \qquad (6)$$

$$Q = ln(1/K_N) + ln(1/K_{RA}) + ln(K_V) + ln(1/K_D). \qquad (7)$$

where $Q_N = ln(1/K_N)$ - positive share of link 1 «population – the number of vehicles»;

$Q_{RA} = ln(1/K_{RA})$ - positive share of link 2 «the number of vehicles – the number of road accidents»;

$Q_V = ln(K_V)$ - positive share of link 3 «the number of road accidents – the number of victims»;

$Q_D = ln(1/K_D)$ - positive share of link 4 «the number of victims – the number of deaths».

Tables 8 and 9 presents calculated values of positive Q_i of different links of researched process of formation of result in road safety provision sphere (for India and Russia).

Comparison of Q_i values of different links of the cause-effect chain of road traffic accident rate formation of tables 8 and 9 allows to make next conclusions.

- India has bigger relative positive of links 1 Q_N «population – the number of vehicles» and links 2 Q_{RA} «the number of vehicles – the number of road accidents».
- Russia has bigger relative positive of links 3 Q_V «the number of road accidents – the number of victims» and links 4 Q_D «the number of victims – the number of deaths».

This specific has an influence on formation of system orderliness result.

Table 8. Values of positive of different links of the cause-effect chain of RTA rate formation (2010…2019) in India

Year	Positive of different links of the cause-effect chain of RTA rate formation				
	Q_N	Q_{RA}	Q_V	Q_D	ΣQ
2010	2.2205	5.5432	0.2822	1.5915	9.6373
2011	2.1437	5.6520	0.2710	1.5258	9.5924
2012	2.0248	5.7853	0.2779	1.5451	9.6332
2013	1.9082	5.9228	0.2627	1.5216	9.6154
2014	1.8712	5.9661	0.2581	1.5088	9.6043
2015	1.7869	6.0384	0.2542	1.4872	9.5666
2016	1.7077	6.1701	0.2949	1.4535	9.6263
2017	1.6228	6.3003	0.2861	1.4309	9.6401
2018	1.5518	6.3782	0.2834	1.4124	9.6259
2019	1.4851	6.4951	0.3259	1.4157	9.7218
2010…2019	2.2205…1.4851	5.5432…6.4951	0.2822…0.3259	1.5915…1.4157	9.6373…9.7218
	- 33.1 %	+ 17.1 %	+ 15.5 %	- 11.0 %	+ 0,87 %

Table 9. Values of positive of different links of the cause-effect chain of RTA rate formation (2010…2019) in Russia

Year	Positive of different links of the cause-effect chain of RTA rate formation				
	Q_N	Q_{RA}	Q_V	Q_D	ΣQ
2010	1.2262	5.3433	0.3294	2.3444	9.2433
2011	1.1935	5.3788	0.3364	2.3036	9.2123
2012	1.1460	5.4087	0.3420	2.3262	9.2229
2013	1.0965	5.4580	0.3357	2.3573	9.2476
2014	1.0311	5.5655	0.3334	2.3358	9.2657
2015	0.9520	5.7265	0.3236	2.3981	9.4003
2016	0.9284	5.8113	0.3294	2.4756	9.5447
2017	0.8989	5.8662	0.3248	2.5082	9.5981
2018	0.8853	5.8871	0.3261	2.5484	9.6470
2019	0.8660	5.9286	0.3267	2.5966	9.7180
2010…2019	1.2262…0.8853	5.3433…5.9286	0.3294…0.3261	2.3444…2.5966	9.2433…9.7180
	- 27.8 %	+ 10.9 %	- 1.0 %	+ 10.7 %	+ 5.1 %

VII. DISCUSSION AND CONCLUSION

In this section we try to solve problems 4 and 5 of this research. We analyze sameness and difference of regularities of road safety provision systems of India and Russia and formulate specific for India and Russia recommendations on improvement of road safety provision systems.

As it was mentioned in first part of this article, India and Russia have quite different transport systems and philosophy of road safety provision. We will consider these differences in detail.

Firstly, vehicles parks significantly differ in compared countries. India has a big share of two-wheel and three-wheel vehicles. Drivers of these transport vehicles are weakly protected from road accident risk. In Russia such vehicles are unpopular. Scooters, motorcycles, bicycles are relatively cheap and more common in India than in Russia. Therefore, positive Q_N of link «Population – Vehicle park» of the cause-effect chain of road accident rate formation in India ($Q_{N\ 2019\ India}$ = 1.4851) is significantly bigger than in Russia ($Q_{N\ 2019\ Russia}$ = 0.8660). Risks of surviving of road accident victims evaluate by positive Q_D of link «Road accidents victims – Deaths in road accidents» of the cause-effect chain of road accident rate formation. And situation for this characteristic is opposite – Q_D in Russia ($Q_{D\ 2019\ Russia} = 2.5966$) is bigger than in India ($Q_{D\ 2019\ India} = 1.4157$). Values of second and third link of the cause-effect chain of road accident rate formation are approximately same for compared countries.

Structural-entropic analysis allows to analyze peculiarities of road accident rate formation process by different aspects of country lifestyle.

On the basis of results, specific for India and Russia recommendations on improvement of road safety provision systems were formed.

- Indian road safety provision system has weak link 4 «the number of victims – the number of deaths» of the cause-effect chain of road accident rate formation. Therefore, emergency medical care and medical insurance should be developed.
- Russian road safety provision system has weak link 1 - «population – the number of vehicles» of the cause-effect

chain of road accident rate formation. Despite higher level of automobilization in Russia than in India, this is weakness of Russian system.

This fact probably can be explained by data [45]. Gini coefficient represents society stratification by income inequality. According to the data [45] Gini coefficient in Russia in 2014 was 0.416, while in India in 2012 it was 0.367 for city population and 0.280 for countryside population.

The higher level of property stratification in Russia contributes to growth of aggression of wealthy citizens towards poor people. It also has an impact on transport behavior, tendency to violation of traffic code and growth of number of road accidents with rich people as participants. On the other hand, 13.5 % citizens of Russia are very poor people whose income is less than minimal cost of living [46]. They could follow the principle «We always have lived badly and there is no reason to start live well» and they don't appreciate own lives and lives of different people.

Simple statistical analysis of road safety can give deceptive results. It shows that road safety sphere in better in Russia than in India. But results of analysis by separate indicators (Human Risk *HR*, Transport Risk *TR*, Severity of road accidents S_{RA}) are not so unambiguous. Structural-entropic analysis, that considers road accident process and the cause-effect chain, also gives new representation of situation in road safety sphere. Chaos on Indian roads [47] appears to be specific form of road traffic orderliness. And level or road safety provision system orderliness *(1 – Hn)* is higher in India than in Russia.

FUTURE SCOPE

A special feature of structural-entropy analysis is the ability to dissect road accidents piecemeal, along the links of the entire chain. The authors believe that the approach to accident analysis is very progressive and allows solving a number of special tasks.

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