Research of the world trend of risks accident rate

Cite as: AIP Conference Proceedings **2439**, 020020 (2021); https://doi.org/10.1063/5.0068455
Published Online: 12 October 2021

Nataliia Semchenko, Oleksii Stepanov, Olha Kholodova, et al.

Research of the World Trend of Risks Accident Rate

Nataliia Semchenko[a)], Oleksii Stepanov, Olha Kholodova, Maryna Buhaiova

Department of Traffic Management and Road Safety, Kharkov National Automobile and Highway University, 25 Yaroslava Mudrogo Street, Kharkiv, 61002, Ukraine

[a)] Corresponding author: nat-semchenko@ukr.net

Abstract. In the research indicators of social risk (number of deaths per 100,000 inhabitants) and transport risks (number of deaths per 10,000 cars) are accepted as assessment criteria for accidents in the world. Based on statistics of accidents and the motorization level in countries with developed transport infrastructure, proper medical care and friendly, safe behavior of road users developed regression models of social and transport risks, the motorization level of which exceeds 200 cars / 1000 inhabitants, which distinguishes them from models of R. Smeed, which are based on statistical data of the thirties of the last century, data of the time when there were no well-known now and widely used systems of active, passive and post-accident safety of cars and roads, modern methods of traffic organization, high-tech means of onboard communication and control of traffic modes, intelligent transport systems, technologies, and drugs of emergency medical care and the like. It is determined that at the current level of traffic organization and ensuring its safety, minimal social and transport risks occur at the motorization level of 600 - 700 cars per 1000 inhabitants.

INTRODUCTION

The World Health Organization (WHO) report for 2018 [1] noted that deaths from road accidents [2-5] continued to rise, amounting to 1,35 million deaths per year. It is emphasized that today injuries as a result of road accidents are the main cause of death of children and young people aged 5-29 years and one of the three leading causes of death of persons aged 5 to 44 years. Studies of various aspects of road safety in different countries [1, 6-11] have shown that the world has long and steadily formed a global problem of uneven road accidents in the world. First of all, the inverse dependence of the emergency risk on the material well-being of countries is clearly visible. The risk of death as a result of an accident in low-income countries is three times higher than in high-income countries. The highest death rates are in Africa (26.6 cases per 100,000 people) and the lowest in Europe (9.3 cases per 100,000 people).

One of the dominant factors influencing the state of road safety is the motorization level. At different times, researchers have assessed the relationship between the growth of accidents and the increase of the motorization level [12].

A variety of indicators can be used to assess the level of road accidents. Among them, the most commonly used for comparative studies are two indicators: Human Risk and Transport Risk [13-18].

The indicator of social risk proposed by R. Smeed [19] is the dependence of the deaths in road ratio accidents per 100,000 of the population from the motorization level. The value of this indicator is periodically published in the reports of the World Health Organization (WHO). This paper uses data from the WHO report in 2018 [1].

Transport risk is the ratio of the number of dead to 100,000 registered vehicles in the country. It should be noted that the methods of determining the number of deaths in different countries and WHO differ. According to the WHO method, the victims are citizens injured in road accidents who died within 30 days after the accident. In Ukraine, for example, these are those who died at the scene of an accident. Considering these differences and the fact that the emergence of the COVID-19 pandemic in the world is making its own changes in the current transport mobility, our research is based on 2018 data obtained from the WHO report and calculated according to the WHO methodology [1].

Transport, Ecology - Sustainable Development EKO Varna 2021
AIP Conf. Proc. 2439, 020020-1–020020-11; https://doi.org/10.1063/5.0068455
Published by AIP Publishing. 978-0-7354-4140-8/$30.00

SOCIAL RISKS ANALYSIS

A Professor from Great Britain R. Smeed in 1949 analyzed the statistics of road deaths in 20 countries around the world, the 1930s, which had a large fleet and proposed a model that links social risks with the motorization level A in the country [9, 16, 19-22].

Smeed's formula for social risks - deaths in road accidents per 100,000 population

$$RH = \alpha \cdot A^{1/3} \quad (1)$$

where $\alpha = 3$, was calculated for 20 empirical points.

Figure 1 shows the trend, plotted according to Smeed's model, on the real values of social risks in countries with a significant car park. At the end of the 1930s, the number of cars per 1000 inhabitants in some countries exceeded 200, the value of which in Ukraine was reached only 80 years later - in 2016.

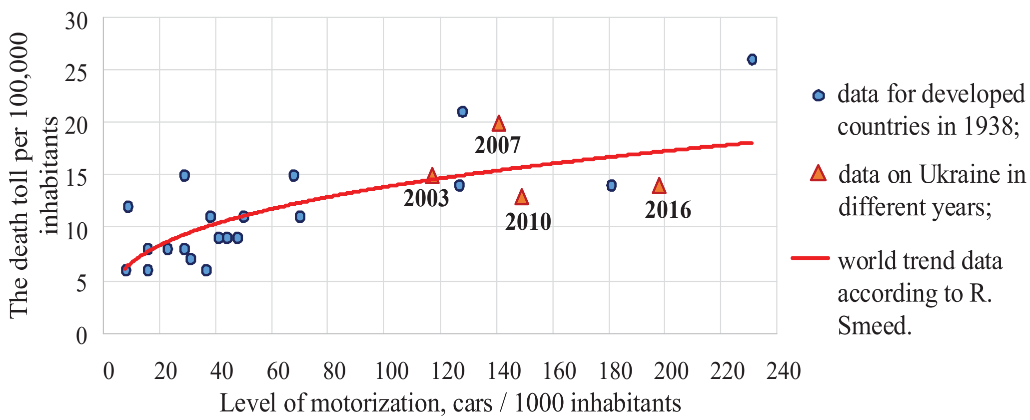

FIGURE 1. The original social risks curve of R. Smeed

The value of the parameter $\alpha = 3$ means the acceptance of the following hypothesis: at high levels of motorization, social risks asymptotically approach the mark of 30 deaths per 100,000 inhabitants.

The world's leading countries have taken the predictive Smeed's model very seriously and, united around a common security problem, have begun to take drastic measures to reduce the potential danger of motorization.

The main ones are:

- improving driver training;
- education of road users in the principles of mutual respect, responsibility, friendliness, which ensures the safety of transport behavior;
- development of active, passive, and post-accident vehicle safety systems;
- introduction of regular technical inspections of cars;
- accounting for road safety requirements in the process of urban planning, stratification of the road network;
- development of road engineering infrastructure (signs, markings, enclosure, signs, etc.), aimed at improving traffic safety;
- state supervision over the observance of traffic rules with the use of modern technical means;
- improving the organization of medical care for road accident victims and the development of special sections of traumatology, specified of road accidents.

The implementation of these and several other measures has allowed not only to stabilize, but also significantly reduce social risks with increasing levels of motorization.

Data on the number of deaths in road traffic accidents per 100,000 inhabitants in various regions are shown in tables 1-6.

TABLE 1. Accident rates by country in the European region.

Country	Population	Number of vehicles	Number of cars per 1000 inhabitants	The death toll according to the WHO	The death toll per 100,000 inhabitants	The death toll per 10,000 cars
Austria	8712137	7421647	578	452	5,2	0,61
Belarus	9480042	4192291	362	841	8,9	2,01
Belgium	11358370	7330718	559	657	5,8	0,90
Bosnia and Herzegovina	3516016	978229	214	552	15,7	5,64
Bulgaria	7131494	4031748	393	730	10,2	1,81
Greece	11183716	9489299	586	1026	9,2	1,08
Croatia	4213265	1996056	380	340	8,1	1,70
Czech Republic	10610947	7325787	485	630	5,9	0,86
Cyprus	1170125	650805	532	60	5,1	0,92
Denmark	5711870	3131673	480	227	4	0,72
Estonia	1312442	885040	476	80	6,1	0,90
Finland	5503132	5217850	612	261	4,7	0,50
France	64720688	42363000	578	3585	5,5	0,85
Germany	81914672	56622000	572	3327	4,1	0,59
Great Britain	65778572	38388214	519	2019	3,1	0,53
Hungary	9753281	4022798	345	756	7,8	1,88
Ireland	4726078	2573961	513	194	4,1	0,75
Italy	59429936	52581575	679	3333	5,6	0,63
Latvia	1970530	803628	319	184	9,3	2,29
Lithuania	2908249	1391568	560	234	8	1,68
Netherlands	16987330	10757655	528	648	3,8	0,60
Norway	5254694	3969612	584	143	2,7	0,36
Poland	38224408	27409106	567	3698	9,7	1,35
Portugal	10371627	6590094	548	768	7,4	1,17
Romania	19778084	7014661	305	2044	10,3	2,91
Russia	143964512	54014259	324	25969	18	4,81
Serbia	8820083	2282401	291	649	7,4	2,84
Slovakia	5444218	2606412	546	330	6,1	1,27
Slovenia	2077862	1468439	537	134	6,4	0,91
Spain	46347576	32986384	593	1922	4,1	0,58
Sweden	9837533	6102914	520	278	2,8	0,46
Switzerland	8401739	5980515	543	223	2,7	0,37
Ukraine	44438624	14433709	202	6089	13,7	4,22

TABLE 2. Accident rates by country in the region of Asia and the Ocean.

Country	Population	Number of vehicles	Number of cars per 1000 inhabitants	The death toll according to the WHO	The death toll per 100,000 inhabitants	The death toll per 10,000 cars
Australia	24125848	18326236	740	1351	5,6	0,7
Japan	127748512	81602046	591	5224	4,1	0,6
Kazakhstan	17987736	4383120	250	3158	17,6	7,2
Malaysia	31187264	27613120	361	7374	23,6	2,7
New Zealand	4660833	3656300	774	364	7,8	1,0
Russia	143964512	54014259	324	25969	18	4,8
South Korea	50791920	25680967	459	4990	9,8	1,9
Thailand	68863512	37338139	206	22491	32,7	6,0

TABLE 3. Accident rates by country in the region of North and Central America and the Caribbean.

Country	Population	Number of vehicles	Number of cars per 1000 inhabitants	The death toll according to the WHO	The death toll per 100,000 inhabitants	The death toll per 10,000 cars
Canada	36289824	23923806	662	2118	5,8	0,9
Costa Rica	4857274	1991398	287	812	16,7	4,1
El Salvador	6344722	1008080	94	1411	22,2	14,0
Guatemala	16582469	3250194	69	2752	16,6	8,5
Honduras	9112867	1694504	95	1525	16,7	9,0
Jamaica	2881355	541316	179	391	13,6	7,2
Mexico	127540424	40205671	275	16725	13,1	4,2
Panama	4034119	1288573	132	575	14,3	4,5
USA	322179616	281312446	910	39888	12,4	1,4

TABLE 4. Accident rates by country in the region of South America.

Country	Population	Number of vehicles	Number of cars per 1000 inhabitants	The death toll according to the WHO	The death toll per 100,000 inhabitants	The death toll per 10,000 cars
Argentina	43847432	21633584	314	6119	14	2,8
Bolivia	10887882	1711005	70	1687	15,5	9,9
Brazil	207652864	93867016	249	41007	19,7	4,4
Chile	17909754	4960945	230	2245	12,5	4,5
Colombia	48653420	13477996	148	8987	18,5	6,7
Ecuador	16385068	1925368	109	3490	21,3	18,1
Peru	31773841	5604789	73	4286	13,5	7,6
Venezuela	31568180	7999760	147	10640	18,5	13,3
Uruguay	3444006	2342026	200	460	13,4	2,0

TABLE 5. Accident rates for the countries of the African region.

Country	Population	Number of vehicles	Number of cars per 1000 inhabitants	The death toll according to the WHO	The death toll per 100,000 inhabitants	The death toll per 10,000 cars
Botswana	2250260	653274	133	535	23,8	8,2
Libya	6293253	3553497	290	1645	28,1	4,6
Morocco	35276784	3791469	68	6917	19,6	18,2
Namibia	2479713	371281	106	754	30,4	20,3
Nigeria	185982632	11733425	61	39802	21,4	33,9
Seychelles	1262132	507676	176	173	13,7	3,4
Tunisia	11403248	2015601	125	2595	22,8	12,9
Zimbabwe	16150362	1198584	114	5601	34,7	46,7

TABLE 6. Accident rates by country in the Middle East.

Country	Population	Number of vehicles	Number of cars per 1000 inhabitants	The death toll according to the WHO	The death toll per 100,000 inhabitants	The death toll per 10,000 cars
Azerbaijan	9725376	1330551	112	845	8,7	6,4
Iran	80277424	30377065	256	16426	20,5	5,4
Jordan	9455802	1502420	166	2306	24,4	15,3
Lebanon	6006668	1866407	434	1090	18,1	5,8
Qatar	2569804	1330487	532	239	9,3	1,8
Oman	4424762	1370913	215	713	16,1	5,2
Saudi Arabia	32275688	6895794	336	9311	28,8	13,5
Syria	18430452	2396544	73	4890	26,5	20,4
Turkey	79512424	21090422	253	9782	12,3	4,6
United Arab Emirates	9269612	3391125	313	1678	18,1	4,9

Figure 2 shows the number of fatalities in road accidents per 100,000 inhabitants in the countries of the European region, grouped by motorization level.

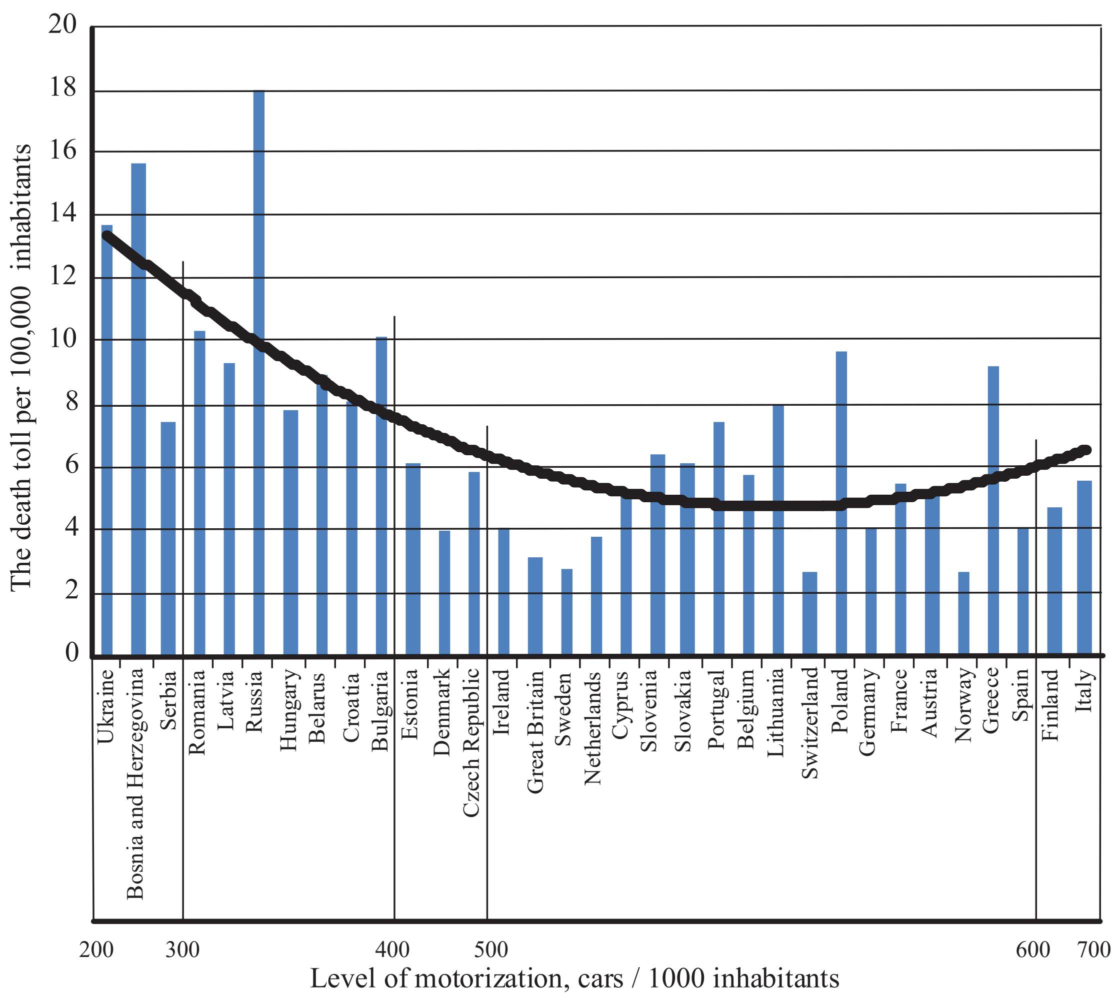

FIGURE 2. Social risks in the countries of the European region

It is noteworthy that among European countries, the motorization level of which exceeds 200 cars/ 1000 inhabitants, only Bosnia and Herzegovina and Russia have worse social risk indicators than Ukraine.

Social (and later transport) risks in Ukraine are well coordinated with Smeed's law. It should be noted, however, that he built his models on the basis of statistics of the 1930s, data from the time when there were no well-known now and widely used systems of active, passive, and post-accident safety of cars and roads, modern methods of traffic organization, high-tech means of onboard communication and control of traffic modes, intelligent transport systems, technologies and drugs of emergency medical care and the like.

As the analysis of the dependence $RH = f(A)$ in Fig. 1 and Fig. 2 shows, at the motorization level of 200 cars / 1000 inhabitants, the current state of social risk in the countries of the European region corresponds to the model of R. Smeed. But with increasing this indicator, social risks decrease. Their minimum values are observed at the motorization level in 500 - 600 cars per 1000 inhabitants. With its further growth, social risks increase. From this, we can conclude that with the current state of transport infrastructure and traffic organization optimal for the European region, in terms of traffic safety, is the motorization level in 500 - 600 cars per 1000 inhabitants.

From Fig. 2 we can conclude that a fairly adequate choice as an approximate model of the dependence of the social risks RH on the motorization level A in the European region is a second-degree polynomial.

Based on the data in Table 1, it was found through regression analysis that the dependence $RH = f(A)$ for countries in the European region, the motorization level of which exceeds 200 cars / 1000 inhabitants, is described by equation

$$RH = 6,6 \cdot 10^{-5} \cdot A^2 - 0,078 \cdot A + 28,33 \tag{2}$$

with the level of proximity of the statistical relationship R=0,76 (R^2=0,574), $A_{\min}$= 591 cars / 1000 inhabitants, $RH_{\min}$ = 5,3 death toll per 100,000 inhabitants.

Similar dependencies are obtained for the countries of Asia and Oceania, as well as the countries of North and Central America and the Caribbean.

The dependence of social risks on the motorization level for countries in Asia and Oceania, the motorization level of which also exceeds 200 cars / 1000 inhabitants, is well described by the polynomial model

$$RH = 1,05 \cdot 10^{-4} \cdot A^2 - 0,1427 \cdot A + 54,11 \tag{3}$$

with the level of proximity of the statistical relationship R=0,9 (R^2=0,812), $A_{\min}$= 680 cars / 1000 inhabitants, $RH_{\min}$ = 5,6 death toll per 100,000 inhabitants.

Dependence of social risks on the motorization level for the countries of North and Central America and the Caribbean, is described by a polynomial model

$$RH = 3 \cdot 10^{-5} \cdot A^2 - 0,0397 \cdot A + 21,3 \tag{4}$$

with the level of proximity of the statistical relationship R=0,78 (R^2=0,61), $A_{\min}$= 662 cars / 1000 inhabitants, $RH_{\min}$ = 8,2 death toll per 100,000 inhabitants.

The regression correlation coefficients and the determination coefficients of models (2) - (4) show that the parameters are quite closely related.

As in this region only in four countries, the number of cars per 1000 inhabitants exceeds 200, the modeling took into account countries with a lower motorization level.

The regression dependences for the regions discussed above are reproduced in Fig. 3. As follows from Fig. 2 and Fig. 3, all curves have a minimum at the motorization level in 500-700 cars / 1000 inhabitants.

Data on the number of fatalities in road accidents per 100,000 inhabitants in the countries of the Middle East, Africa, and South America, grouped by level of motorization are given in tables 4-6. In these countries, the field of dispersion of social risks does not depend on the motorization level (Fig. 4) and is not subject to modeling. The death toll per 100,000 inhabitants in the countries of these regions is extremely high and ranges from 10 to 35 people.

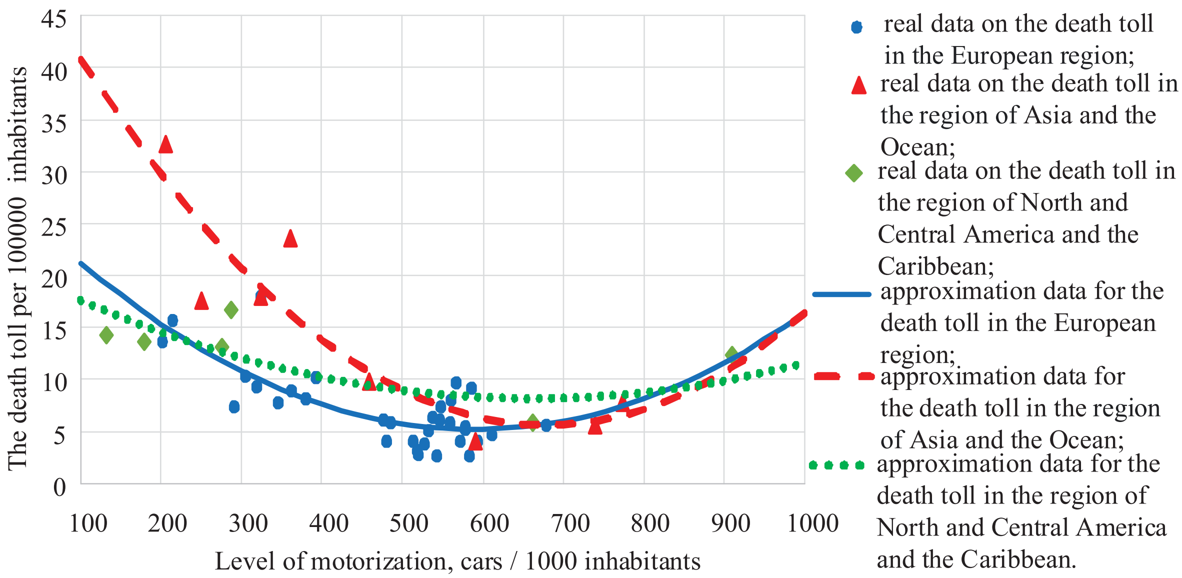

FIGURE 3. Dependence of social risks on the motorization level in the regions of the world

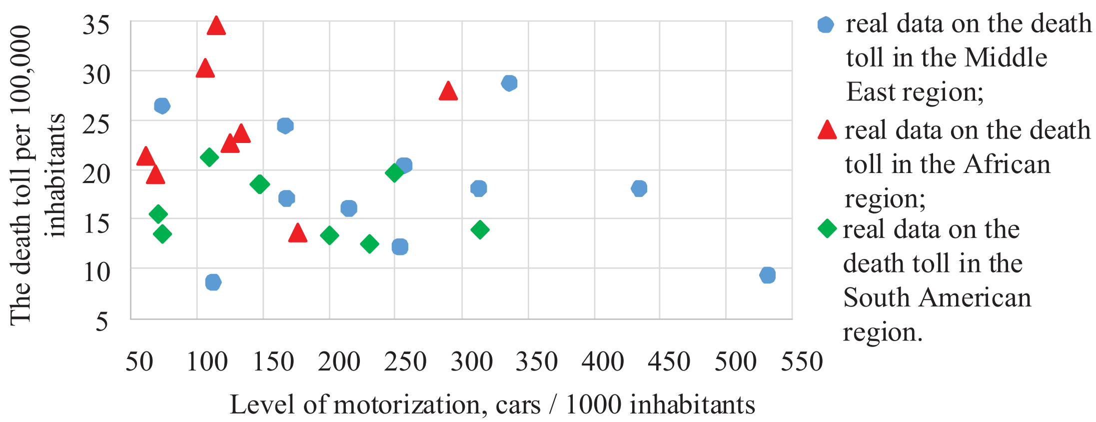

FIGURE 4. Distribution of values of social risk of countries from the motorization level

In today's world, traffic safety is based on a number of fundamental concepts, rules, and practices that are formed, according to John Adams [23], during the "transport self-education of the nation." According to him, citizens, public organizations, authorities, business structures, expert community, in short, all individuals and institutions facing the real problems of adapting society to the appearance of a huge mass of cars on the roads and streets [22, 23]. It is this process of adapting the collective transport behavior of the nation to the growing motorization that explains the fundamental difference between the existing dependence of social risks on the motorization level from the law of R. Smeed.

In regions of the world, where the dependence of social risks on the motorization level is observed, there are minimal social risks at the values of motorization of 600 - 700 cars per 1000 inhabitants (Fig. 3). This confirms the preliminary conclusion that there is an optimal motorization level, at which the current level of traffic organization can provide the least social risks.

TRANSPORT RISKS ANALYSIS

The most common is also the indicator of transport risks RT, which is determined by the number of deaths per 10,000 cars [9, 16, 17, 22].

Simultaneously with the development of a model of social risk, Professor R. Smeed proposed a simple, but as further experience has shown, an extremely successful model that links transport risks with the motorization level in the country. He concluded that the death rate in road accidents per unit of the car fleet decreases as the population motorization increases hyperbolically.

Smeed's formula for transport risks is as follows

$$RT = \alpha \cdot A^{-2/3} \qquad (5)$$

where α is the dimensional constant associated with the choice of a specific base of the transport risk indicator.

Figure 5 shows the original dependence transport risks, plotted according to Smeed's model, on real values in the world in 1938 and the value of this indicator for Ukraine in 2008, 2011, and 2016, which is generally in line with the trend identified by Smeed, but for Ukraine significantly higher than in most of the world's leading automotive countries today.

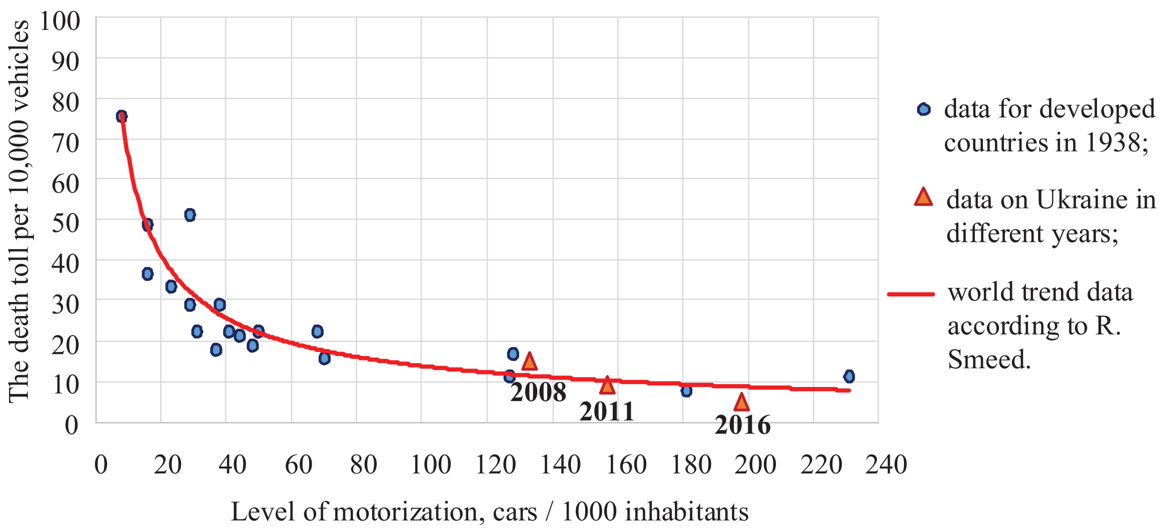

FIGURE 5. The original transport risks curve of R. Smeed

Data on the number of fatalities in road accidents per 10,000 cars in the countries are given in tables 1-6.

Figure 6 shows the number of fatalities in road accidents per 10,000 cars in the countries of the European region, grouped by motorization level.

Based on the data in Table 1, it was found through regression analysis that the dependence $RH = f(A)$. The analysis shows that a sufficiently adequate choice as an approximating model, in this case, is polynomial. The dependence $RT = f(A)$ for countries in the European region, the motorization level of which exceeds 200 cars / 1000 inhabitants, is described by equation

$$RT = 2,84 \cdot 10^{-5} \cdot A^2 - 0,0336 \cdot A + 10,63 \qquad (6)$$

with the level of proximity of the statistical relationship R=0,908 (R^2=0,824), A_{min}= 592 cars / 1000 inhabitants, RT_{min} = 0,7 death toll per 10,000 cars.

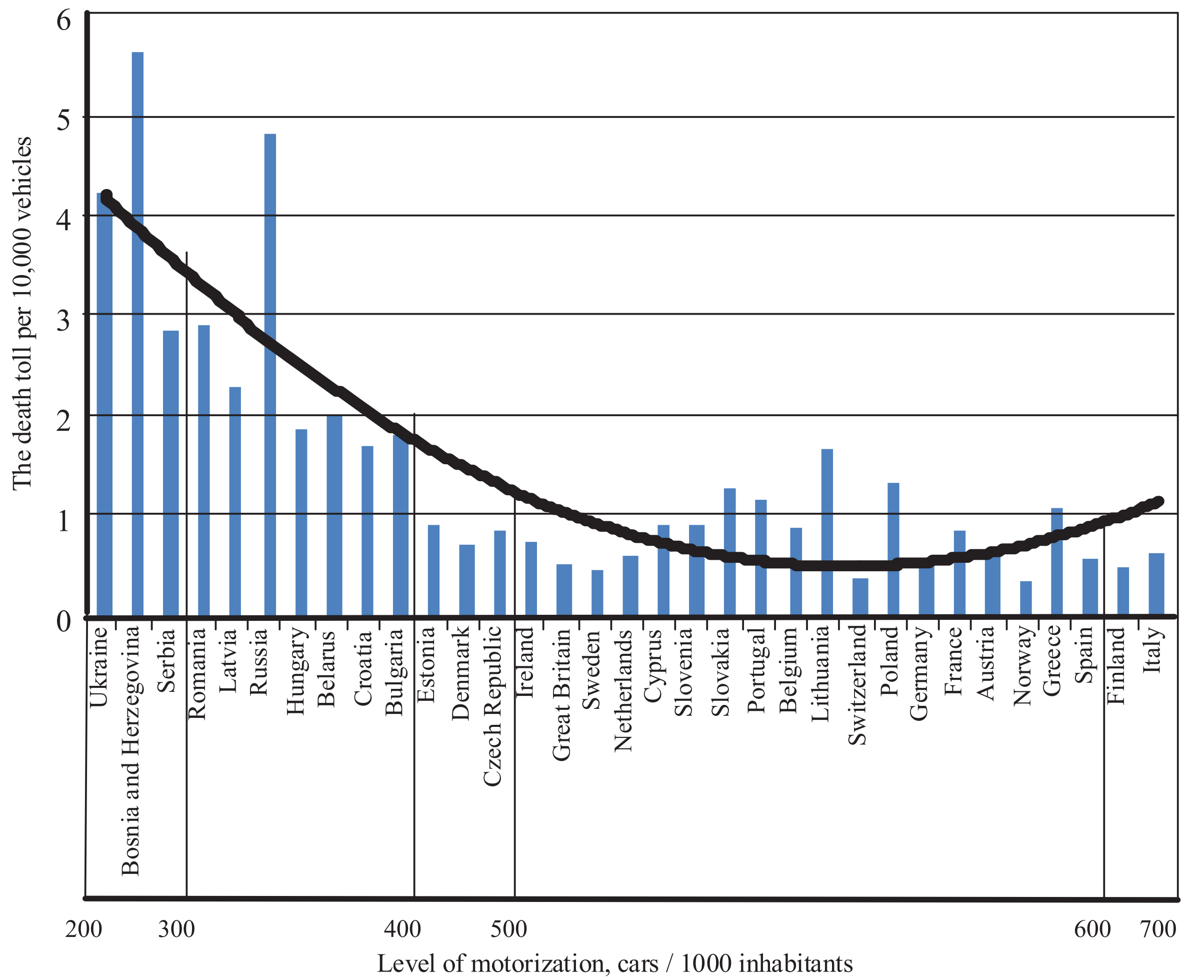

FIGURE 6. Transport risks in the countries of the European region

Similar dependencies of transport risk are observed in Asia and Oceania, as well as in North and Central America and the Caribbean.

The dependence of transport risks on the motorization level for countries in Asia and Oceania, the motorization level of which also exceeds 200 cars / 1000 inhabitants, is well described by the polynomial model

$$RT = 2{,}98 \cdot 10^{-5} \cdot A^2 - 0{,}0401 \cdot A + 14{,}06 \quad (7)$$

with the level of proximity of the statistical relationship R=0,958 (R^2=0,917), A_{min}= 673 cars / 1000 inhabitants, RT_{min} = 0,6 death toll per 10,000 cars.

Dependence of transport risks on the motorization level for the countries of North and Central America and the Caribbean, is described by a polynomial model

$$RT = 2{,}8 \cdot 10^{-5} \cdot A^2 - 0{,}036 \cdot A + 12{,}33 \quad (8)$$

with the level of proximity of the statistical relationship R=0,845 (R^2=0,714), A_{min}= 643 cars / 1000 inhabitants, RT_{min} = 0,8 death toll per 10,000 cars.

The regression correlation coefficients and the determination coefficients of models (6) - (8) show that the parameters are quite closely related.

Dependencies of transport risks on the motorization level for Europe, Asia and Oceania, North and Central America, and the Caribbean are presented in Fig. 7.

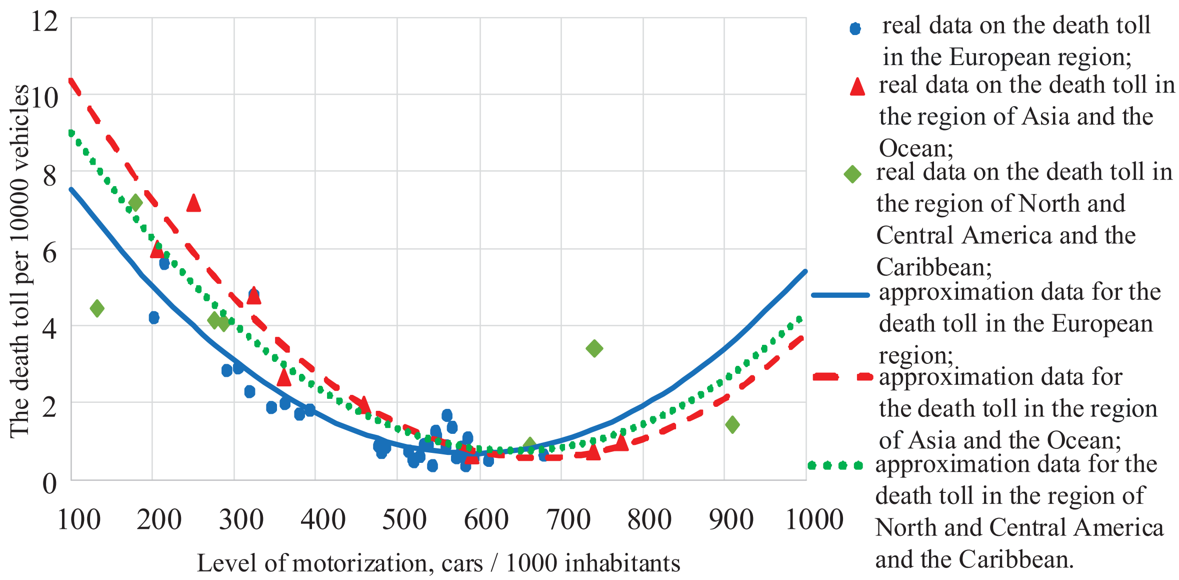

FIGURE 7. Dependence of transport risks on the motorization level in the regions of the world

As in the case of social risk analysis, in the Middle East, Africa, and South America, the field of transport risk dispersion (Fig. 8) is very large, the closeness of the statistical relationship with the motorization level is very small, and not subject to mathematical modeling. The death toll per 10,000 cars in the countries of these regions is extremely high and ranges from 18 people in Ecuador (South America) to 45 people in Zimbabwe (Africa). However, in these regions, it should be noted the reduction of transport risks with increasing levels of motorization.

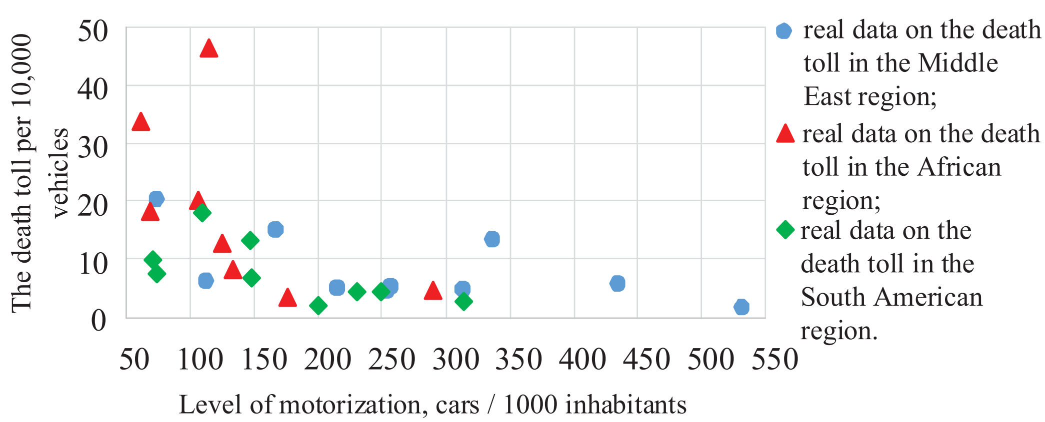

FIGURE 8. Distribution of transport risk values of countries from the motorization level

In the regions of the world where the dependence of transport risks on the motorization level is monitored, as in the case of social risks, minimal risks are observed also with motorization values of 600 - 700 cars per 1000 inhabitants (Fig. 7).

Thus, at the current level of traffic organization, the maximum safety of its participants is observed at the motorization level of 600 - 700 cars per 1000 inhabitants.

CONCLUSION

Social risk indicators (number of deaths per 100,000 inhabitants) and transport risks (number of deaths per 10,000 cars) are the most widespread as assessment criteria for accidents in the countries of the world.

In countries with developed transport infrastructure, proper medical care, and friendly, safe behavior of road users, both social and transport risks with increasing levels of motorization decrease to a certain value, and then begin to increase.

At the current level of organization of road traffic and ensuring its safety, minimal social and transport risks occur at the level of motorization of 600 - 700 cars per 1000 inhabitants.

REFERENCES

1. Global status report on road safety 2018, available at https://www.who.int/publications/i/item/9789241565684
2. A. A. Bykov, *Risk Analysis Problems* **4**, 2, 178-191 (2007).
3. L. J. Blincoe , T. R. Miller , E. Zaloshnja and B. A. Lawrence, *The Economic and Societal Impact of Motor Vehicle Crashes* (National Highway Traffic Safety Administration, Washington DC, 2010), p. 304.
4. B. B. Prokhorov and D.I.Shmakov, *Problems of forecasting* **3**, 125-135 (2002).
5. L. Chang , W. Chen, *Journal of Safety Research* **36**, 4, 365-375 (2005).
6. Global Plan for the Decade of Action for Road Safety 2011-2020, available at https://www.who.int/roadsafety/decade_of_action/plan/en/
7. M. J. Koornstra, Sadhana **32**, 365-395 (2007).
8. B. B. Prokhorov and D.I.Shmakov, *Problems of forecasting* **4,** 139, 139-147 (2013).
9. R. J. Smeed, Traffic Engineering and Control **10**, 364-371 (1968).
10. M. M. Chong , A. Abraham and M. Paprzycki, *Informatica* **29**, 5, 89-98 (2005).
11. J. Abellan , G. Lopez and J.de Ona, *Expert Systems with Applications* **40**, 15, 6047-6054 (2013).
12. Yu. I. Molev and M. G. Cherevastov, *Problems and innovations in the field of mechanization and technologies in the construction and road industries* **1**, 2(2), 33-36 (2016).
13. E. van Beeck, G. J. J. Borsboom and J. P. Mackenbach, *International Journal of Epidemiology* **29**, 503-509 (2000), doi: 10.1093/intjepid/29.3.503.
14. D. W. Reinfurt , J. R. Stewart and N. L. Weaver, *Accident Analysis and Prevention* **23**, 453-462 (1991).
15. A. C. Wagenaar, Accident Analysis and Prevention **16**, 191-205 (1984).
16. B. A.Kramarenko, *Truck* **6**, 47-48 (2019).
17. M. Ya. Blinkin and A. V. Sarychev, Institutional quality and transport risks. Part 1,available at http://www.polit.ru/analytics/2007/05/03/transport.html.
18. A. R. Abdulzyanov, *News of higher educational institutions. Volga region. Social Sciences* **2**, 46, 123-134 (2018), doi: 10.21685/2072-3016-2018-2-15.
19. R. J. Smeed *J. of the Royal Stat. Society* **112,** 1, 1-34 (1949).
20. Ranking of countries by level of motorization, available at https://nonews.co/directory/lists/countries/vehicles-capita.
21. N. O. Semchenko, *Municipal economy of cities. Series: Engineering science and architecture* **6**, 159, 161-168 (2020), doi: 10.33042/2522-1809-2020-6-159-161-168.
22. M. Ya. Blinkin and E. M. Reshetova *Road Safety: Background, International Experience, Basic Institutions* (House of the Higher School of Economics, Moscow, 2013), p. 240.
23. J. G. U. Adams, *J. Traf. Eng. and Control* **28,** 2, 70-73 (1987).