International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 12, Issue 1 [January. 2023] PP: 09-19

Identification of Factors Affecting Traffic Accident Rate Involving Vulnerable Categories of Road Users

Irina Kravchenya
Road Transport and Traffic Management Dept., Belarusian State University of Transport, Gomel, Republic of Belarus
Corresponding Author: Irina Kravchenya

ABSTRACT:
The paper presents the results of statistical analysis of accidents involving vulnerable categories of road users (pedestrians, cyclists and animal-drawn transport drivers) in the Gomel region (Republic of Belarus). With their participation, a significant number of road accidents occur in the Republic of Belarus. Given the specifics of such categories of road users, the severity of the consequences of these accidents is usually high. Using the methods of variance analysis and analysis of conjugacy tables, the influence of various factors on accident rates with the participation of vulnerable categories of road users was analyzed. Based on the results of the study, the following conclusions were formulated. There is a growing trend in the proportion of dead and injured cyclists in the total number of dead and injured vulnerable categories of road users. The number of people dead and injured in road accidents is significantly affected by the following factors: hour of day, illumination, type of terrain, road ownership, category and type of road accident. Taking into account the dynamic patterns of accident rates and the identification of factors affecting road traffic accidents will increase the efficiency of measures to eliminate negative trends in the field of road safety and accident reduction. Measures are proposed to improve the traffic safety of vulnerable categories of road users, the introduction of which will significantly affect the accident situation and reduce the consequences of road traffic injuries.

KEYWORDS*: vulnerablecategories of road users, accident rate, variance analysis, analysis of conjugacy tables.*

Date of Submission: 24-12-2022 Date of acceptance: 04-01-2023

I. INTRODUCTION

The accident reduction problem is urgent and requires the improvement of road safety enhancement methods [2, 5].

As compared to developed countries, the road accident rate in the Republic of Belarus is characterized by a high fatality risk in road traffic accidents and vehicles dangerous to humans as well as a high severity of consequences, which is 3 to 15 times higher than similar indicators in countries with developed automobilization.

In 2006 in the Republic of Belarus country's Council of Ministers approved the Concept of Road Safety for the period up to 2015. An analysis of the accident rate for a period of time that has passed since the launch of the Concept, with the aim to summarize its actions, as well as the development of measures to improve road safety for the future, is of particular relevance [1].

On the territory of the Gomel region there is a set of measures to improve road safety "Good Road". One of the areas of work provided for in this document is the development of measures to improve road safety for vulnerable categories of road users [1].

An increase in the number of cars on urban roads leads to an increase in the number of road accidents involving vulnerable road users. A number of studies show that almost half of the 1.27 million people who die in road accidents every year in the world are pedestrians, cyclists and animal-drawn transport drivers [6]. Pedestrians, cyclists and animal-drawn transport drivers are the most vulnerable and unprotected on the road [6].

The paper sets out to estimate the dynamic patterns of accident rates in the Gomel region and to identify factors affecting road traffic accidents involving vulnerable road users. It will result in the increased efficiency of road accident reduction measures.

II. ANALYSIS OF THE DYNAMICS OF ACCIDENTS INVOLVING VULNERABLE CATEGORIES OF ROAD USERS

To assess the dynamics of accidents and to identify significant influencing factors, a large amount of information is required. The given objective is very ambitious and requires a large number of observations to draw serious conclusions.

As a source of information, we use the database of the State Traffic Inspection (Traffic Police) of the Department of Internal Affairs of the Gomel Oblast Executive Committee of the Gomel Region on road traffic accident victims over the last twelve years from 2009 to 2021. The number of people killed and injured in road traffic accidents involving vulnerable categories of road users is taken as the accident rate. Overall, there are about 5378 records available.

To assess the dynamic patterns in the number of vulnerable categories of road users killed and injured in road traffic accidents, we use the rate tendency and the rate trend. With regard to the performed analysis of road traffic accidents, the tendency shows the direction of movement of the analyzed indicator, i.e. how much the road traffic accident rate will change in one calendar year [1]:

$$t_Y = \frac{\sum_{i=1}^{n}(i-\bar{i})(Y_i-\bar{Y})}{\sum_{i=1}^{n}(i-\bar{i})^2}, \qquad (1)$$

where i is a period number;
n is the number of periods;
$\bar{i}$ is the mean;
$Y_i$is the value of the indicator corresponding to the i -th period;
$\bar{Y}$ is the mean value of the indicator.
The presence of a trend indicates the stability of the dynamic patterns of the indicator.
The results of calculating the tendency and determining the trend of changes in the number of road traffic fatalities and injuries involving vulnerable categories of road users in the Gomel region are shown in Table 1 and in Figure 1.

Table (1). – Analysis of accident rate statistics involving vulnerable categories of road users.

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	t_Y	trend
Pedestrians	deaths	76	60	57	56	52	43	43	40	34	23	26	30	22	-4,18	yes
	injuries	289	293	263	247	221	216	193	157	161	133	187	162	124	-13,66	yes
Cyclists	deaths	20	13	14	15	8	13	12	8	4	4	10	13	6	-0,8	no
	injuries	51	51	32	45	44	40	28	35	29	24	26	34	24	-2,05	no
Animal-drawntransportdrivers	deaths	1	1	2	2	0	2	0	0	0	0	0	1	0	-0,12	no
	injuries	7	9	7	6	3	7	4	6	2	0	3	0	0	-0,51	no
Total	deaths	97	74	73	73	60	58	55	48	38	27	36	44	28	-5,1	yes
	injuries	347	353	302	298	268	263	225	198	192	157	216	196	148	-16,2	yes

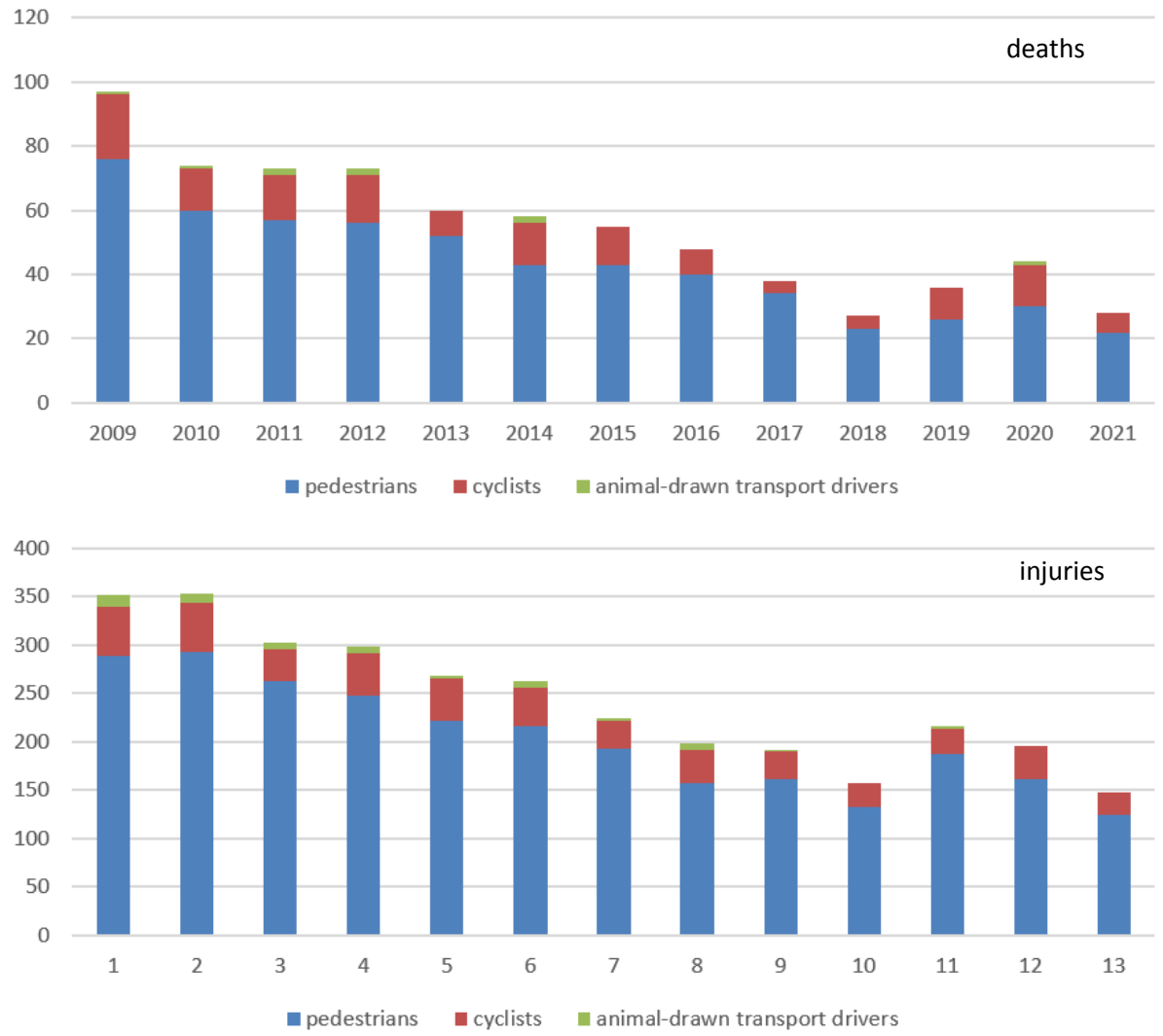


Fig. 1. Analysis of accident rate statistics involving vulnerable categories of road users

Over the researched period, there has been a steady decline in the number of deaths and injuries among vulnerable categories of road users. There is a general trend towards an increase in the number of pedestrians injured in road traffic accidents. They make up the majority of the killed and injured in road accidents with vulnerable categories of road users in the Gomel region.

Despite the increase in the number of dead and injured in recent years, in general, during the period under review, there is a tendency to reduce their number. In addition, this allows us to talk about the presence of a trend both in absolute values of indicators and in relative ones.

A negative point that requires attention is the trend of increasing the proportion of dead and injured cyclists, which, against the background of the trend of reducing their absolute values, indicates that the decline in the number of dead and injured cyclists is less rapid than other categories of vulnerable categories of road users.

The dynamic patterns of the social risk R_c (the number of deaths in road accidents per 100 thousand population) are presented in Table 2 and in Figure 2. Overtheresearchedperiod, therehasbeenastabledecreaseinthesocialriskfor vulnerable categories of road users.

Table (2). Dynamic patterns of the social risk in the Gomel region.

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	t_Y	trend
SocialriskK_c	Pedestrians	5,28	4,18	3,99	3,93	3,66	3,04	3,04	2,84	2,42	1,65	1,87	2,17	1,60	-0,29	yes
	Cyclists	1,39	0,91	0,98	1,05	0,56	0,92	0,85	0,57	0,28	0,29	0,72	0,94	0,44	-0,05	no
	Animal-drawntransportdrivers	0,07	0,07	0,14	0,14	0,00	0,14	0,00	0,00	0,00	0,00	0,00	0,07	0,00	-0,01	no
	Total	6,73	5,16	5,11	5,13	4,23	4,09	3,89	3,40	2,71	1,93	2,59	3,19	2,04	-0,35	yes

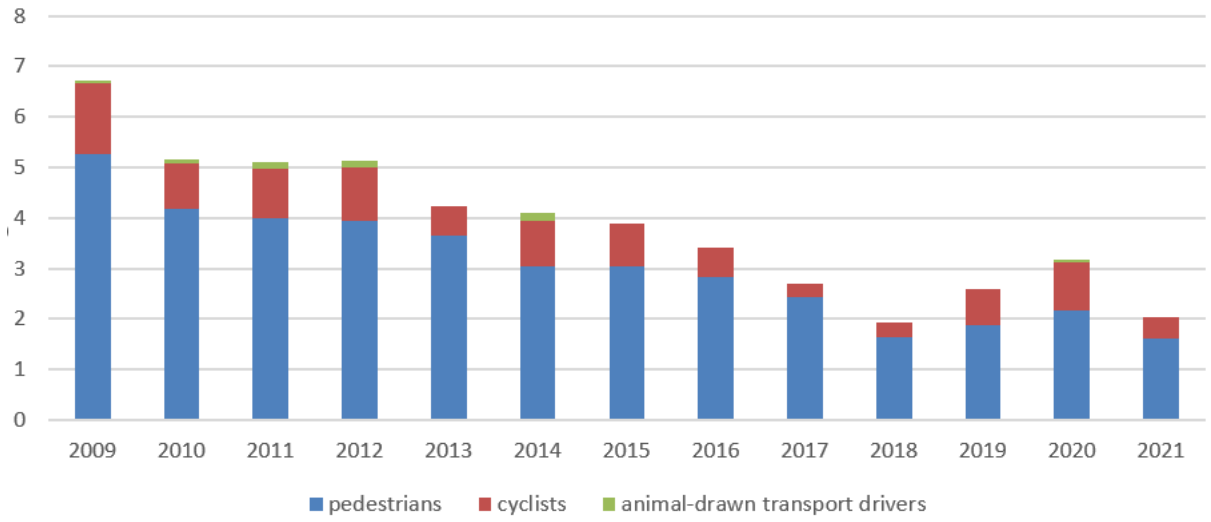


Fig. 2. Dynamic patterns of the social risk

An analysis of the number of deaths by regions of the Gomel region (Figure 3) showed that about two-thirds of all deaths belong to five or six regions.

An analysis of the number of deaths the most unfavorable regions are the city of Gomel,Svetlogorsky,Rechitsky,Zhlobinsky,Gomelsky and Buda-Koshelevsky districts.

Values of the social risk by regions of the Gomel region shown in figure 4.

An analysis of values of the social risk the most unfavorable regions are Buda-Koshelevsky, Chechersky, Svetlogorsky,Braginsky,Zhitkovichskyand Kormyanskydistricts.

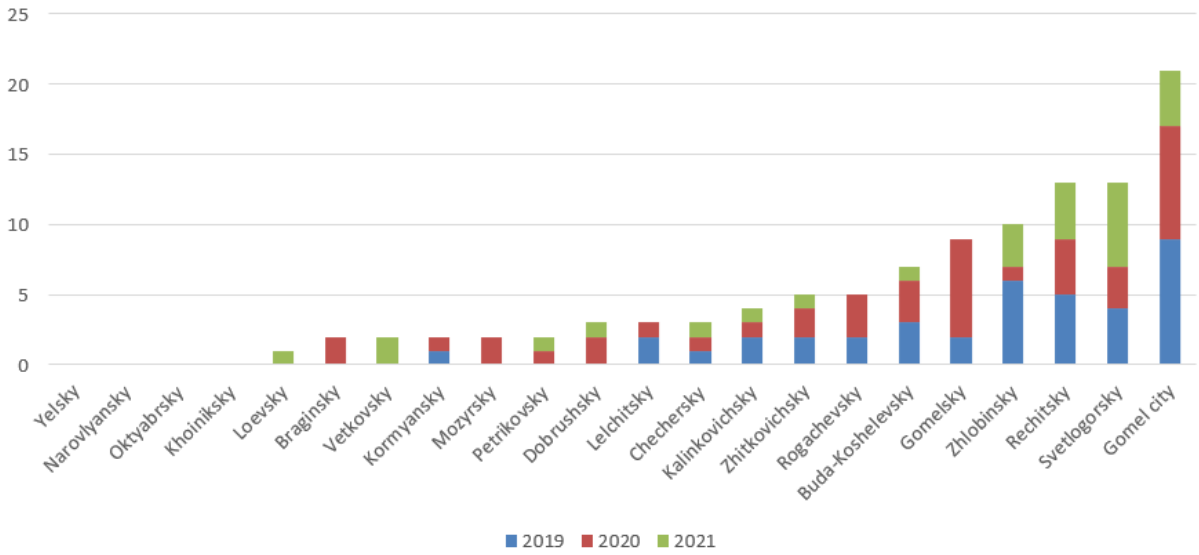


Fig. 3. The number of deaths by regions of the Gomel region

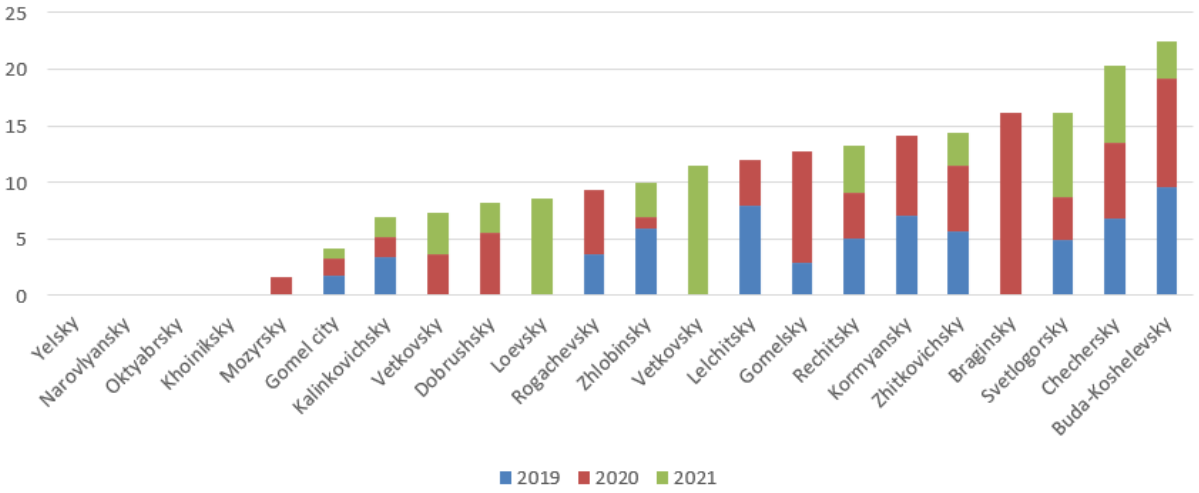


Fig. 4. Values of the social risk by regions of the Gomel region

Table 3 shows the regression analysis results of the number of victims in road accidents involving vulnerable categories of road users in the Gomel region in Statistica [7], the statistical data analysis program. The relationships shown in the table are statistically significant at the significance level of 0.05 and above [4].

Table (3). Statistical analysis results of road traffic deaths and injuries involving vulnerable road users.

	Relationship	Correlationcoefficient*r*	Determinationcoefficient R^2	Fisher'scriterion *F*	*p*-level
Deaths	y=10347,77-5,11x	-0,92	85,45	58,74	0,000017
Injuries	y=33265,1-16.39x	-0.92	85.51	59,01	0,000017
Socialrisk	y=707.047-0.39x	-0.92	85.12	57,21	0,000019

The change in the number of deaths and injuries caused to vulnerable road users in road traffic accidents and social risk is shown in Figures 5 – 7.

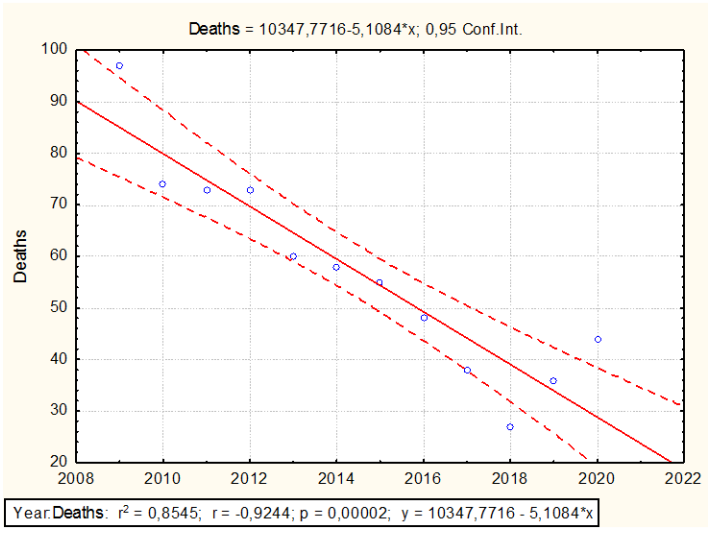


Figure 5. – Changes in the number of road traffic fatalities among vulnerable road users

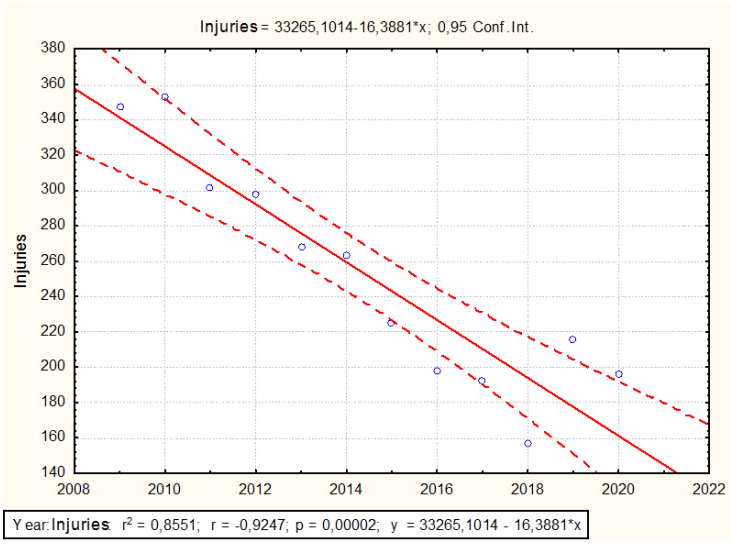


Figure 6. – Changes in the number of road traffic injuries among vulnerable road users

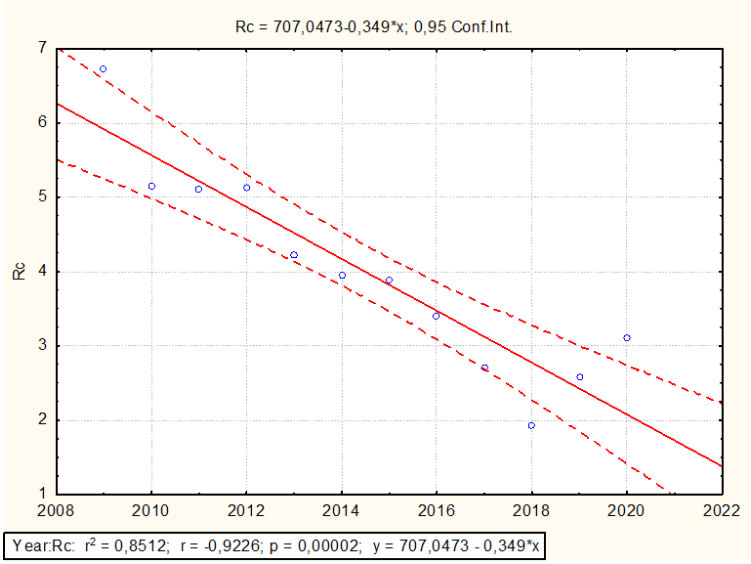


Figure 7. – Changes in the number of social riskamong vulnerable road users

Figure 5 shows that there was an increase in the number of deaths in 2019 and 2020. The increase in the number of injured was observed only in 2019. The dynamics of changes in the number of dead and injured is well described by linear regression. At the same time, the average annual number of dead is 5.1 people, and the number of injured is 16.39 people.

III. FACTORS AFFECTING THE NUMBER OF DEATHS AND INJURIES IN ROAD ACCIDENTS INVOLVING VULNERABLE CATEGORIES OF ROAD USERS AND THEIR SIGNIFICANCE

To assess the significance of the impact of various factors on the number of deaths and injuries in road accidents with vulnerable categories of road users, a variance analysisin Statistica was used [7].

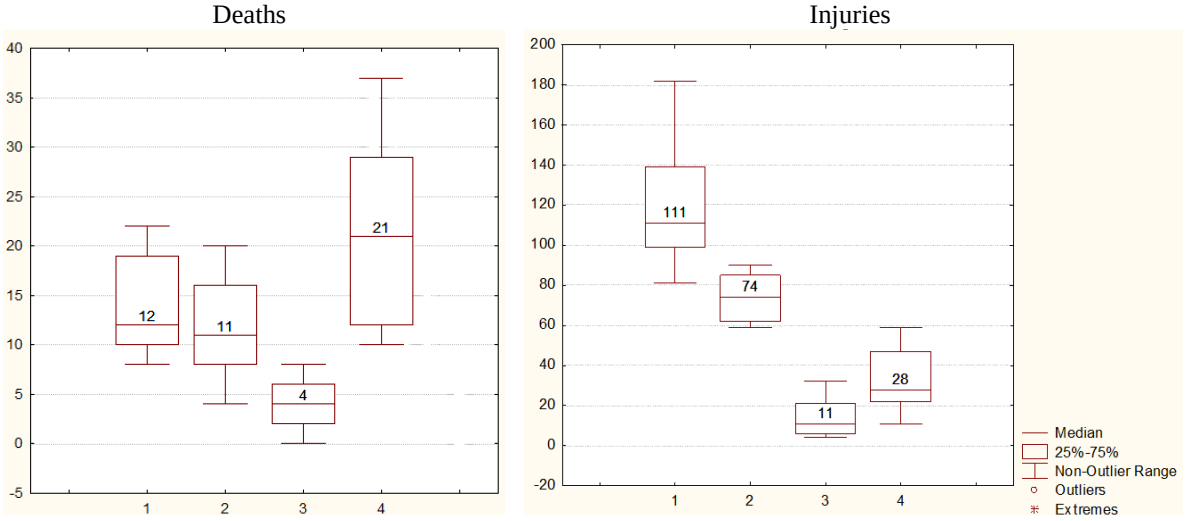
The most significant factors, both for the number of dead and the number of injured, are the hour of day, illumination level, type of terrain, and road ownership.

For the factors that significantly affect the accident rate, a variance analysis was performed. The purpose of variance analysis is to check the significance of the difference between the averages in different groups by comparing the variances of these groups [7]. Dividing the total variance into several sources (related to different effects in the plan) allows to compare the variance caused by the difference between groups with the variance caused by intra-group variability. The hypothesis being tested is that there is no difference between the groups. If the null hypothesis is true, the estimate of the variance associated with intra-group variability should be close to the estimate of the intergroup variance. If false– it is significant to deviate. In general, variance analysis can be divided into several types: one-dimensional (one dependent variable) and multidimensional (several dependent variables); one-factor (one grouping variable) and multifactorial (several grouping variables) with possible interaction between factors; with simple measurements (the dependent variable is measured only once) and repeated (the dependent variable is measured several times).

Figures 8-10 show box-and-whiskers diagrams of the number of vulnerable categories of road users dead and injured in road accidents by illumination level, type of terrain, and road ownership.

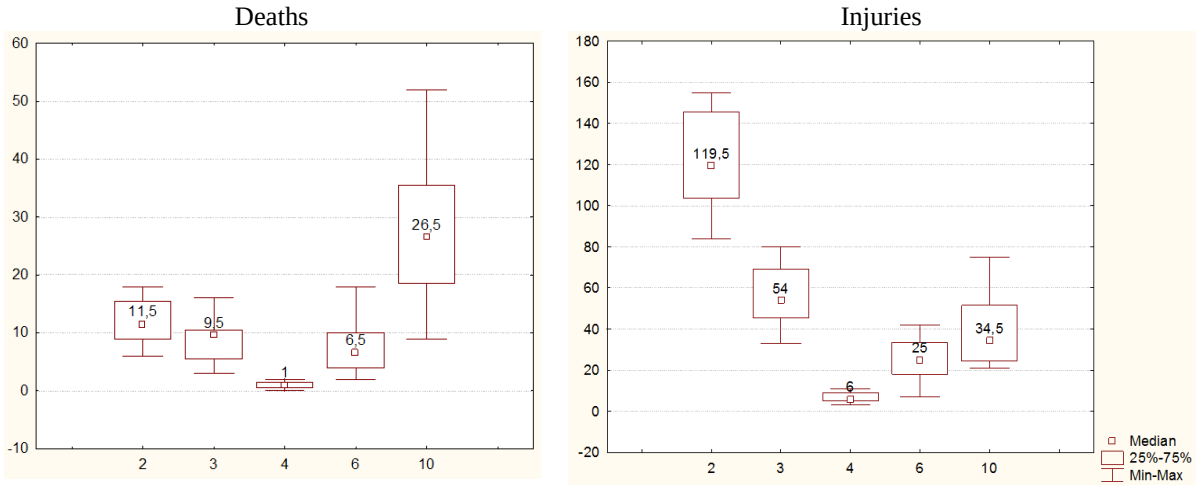
The analysis of Figures 8-10 show:

1. The greatest number of deaths (approximately 21 people annually) occurs at night on road sections where there is no artificial lighting. The highest number of injuries (approximately 111 people annually) occurs during daylight hours (Figure 8).
2. The highest number of deaths (approximately 27 people annually) occurs in districts. The largest number of injuries (approximately 120 people annually) falls on the city of Gomel (Figure 9).
3. The greatest number of deaths (approximately 21 people annually) falls on the roads maintained by the Gomelobldorstroy enterprise. The highest number of injuries (approximately 98 people annually) occur on roads maintained by the GCRCRT enterprise (Figure 10).



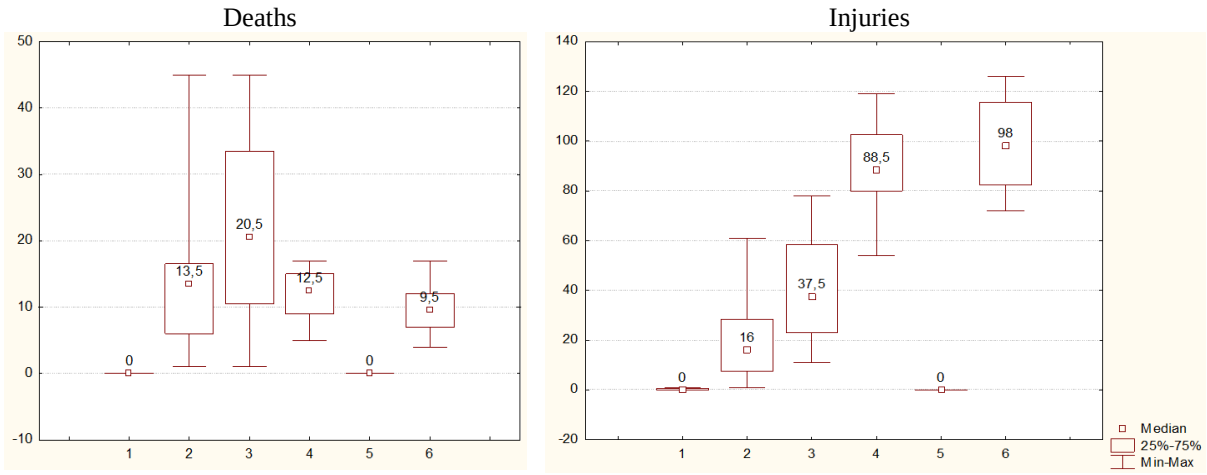
(1 – daylight hours; 2 – night time, outdoor lighting is on;
3 – night time, outdoor lighting is not turned on or faulty; 4 – night time, there is no outdoor lighting)

Fig. 8. – Box-and-whiskers diagrams of the number of dead and injured in road accidents by illumination level



(2 – cities of regional subordination, 3 – cities of district subordination,
4 – urban-type settlements, 6 – rural localities, 10 – districts)

Fig.9. – Box-and-whiskers diagrams of the number of dead and injured in road accidents by type of terrain



(1 – Belavtostrada enterprise, 2 – Gomelavtodor enterprise, 3 – Gomelobldorstroy enterprise,
4 – departmental road, 5 – private road, 6 – GCRCRT enterprise)

Fig. 10. – Box-and-whiskers diagrams of the number of dead and injured in road accidents by road ownership

Figure 11 shows categorized diagrams of the number of vulnerable categories of road users dead and injured in road accidents by time of day.

The highest number of deaths occurs from 18 to 23 o'clock. The greatest number of injured vulnerable categories of road users at 7 o'clock and from 17 to 21 o'clock. Figure 14 shows that about two-thirds of the dead and injured belong to one-third of the day. The most emergency is the evening period, which is stretched, unlike the morning period. This is due to the fact that "home – work" trips are made during the morning rush hour. However, in the evening, few people go straight home from work. Thus, the need to reduce the use of personal cars, as well as stretch rush hours by shifting the start or end of work shifts and lunch breaks.

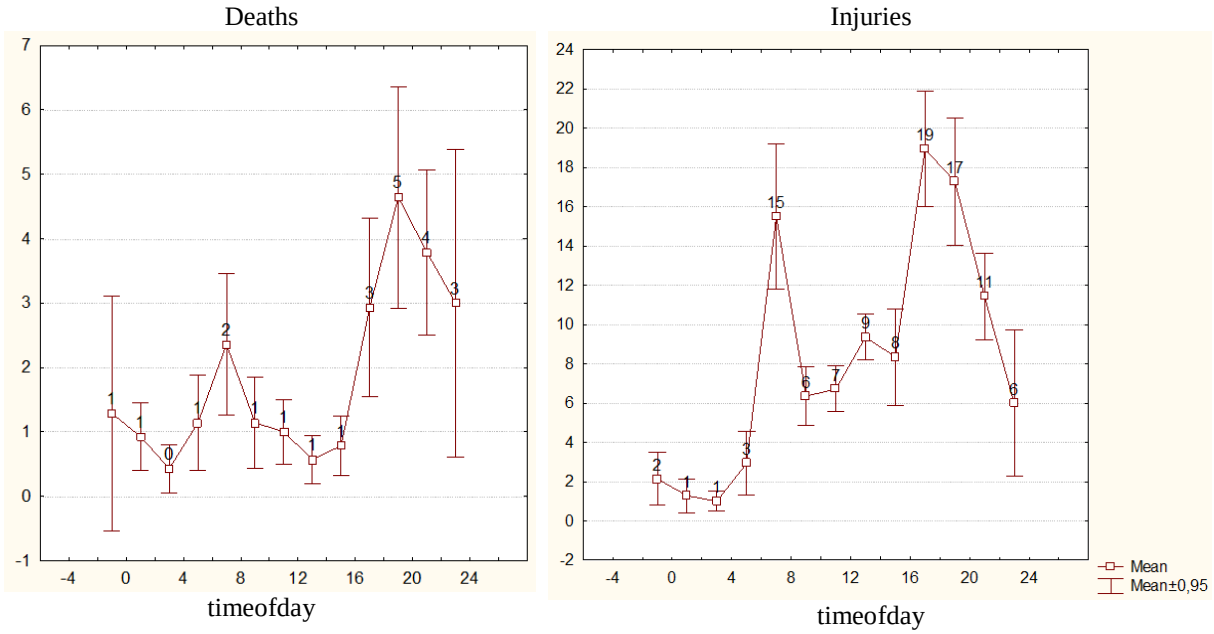


Fig. 11. Categorized diagrams of the number of dead and injured in road accidents by time of day

According to the criteria "Kruskal-Wallis test" and "F test, p (ANOVA)", it was found that the differences in the number of dead and injured in the considered groups of each factor are significant.

For all pairs of factors that significantly affect accident rates (see Figures 8-11), contingency tables has created in Statistica [7]. The construction of conjugacy tables is based on the concept of cross-tabulation. Cross-tabulation is the process of combining two (or several) frequency tables so that each cell in the constructed table is represented by a single combination of values or levels of tabulated variables. Thus, cross-tabulation allows to combine the frequency of occurrence of observations at different levels of the factors under consideration. By examining these frequencies, it is possible to determine the relationships between tabulated variables. The use of conjugacy tables is determined by the fact that categorical (nominal) variables or variables with a relatively small number of values are tabulated. Each cell of the conjugacy table contains a single combination of the values of two tabulated variables. The numbers in each cell, at the intersection of a certain row and a certain column, show how many observations correspond to these levels of factors.

Conjugacy tables for a pair of factors "Road ownership – Illumination level" and "Illumination level – Weather conditions" of injuries among vulnerable categories of road users are shown in Figure 12.

	1	2	3	4	Total
2	2,74306	1,18056	0,625000	3,47222	8,0208
3	6,18056	2,36111	1,076389	7,01389	16,6319
4	19,47917	11,45833	2,638889	2,32639	35,9028
6	22,43056	14,51389	1,770833	0,72917	39,4444
Total	50,83333	29,51389	6,111111	13,54167	100,0000

	1	2	4	Total
1	36,67517	13,27014	2,734233	52,6795
2	9,87969	14,69194	4,411229	28,9829
3	2,04156	2,84360	0,838498	5,7237
4	6,01531	5,50492	1,093693	12,6139
Total	54,61174	36,31061	9,077652	100,0000

Fig. 12. – Conjugacy tables for a pair of factors "Road ownership – Illumination level", "Illumination level – Weather conditions" of injuries among vulnerable categories of road users

Conjugacy tables for a pair of factors "Time of day – Illumination level" and "Time of day–Type of terrain" of injuries among vulnerable categories of road users are shown in Figure 13.

	1	2	3	4	Total
7	6,09851	3,59656	0,938233	0,89914	11,5324
17	11,64973	7,93589	1,485536	3,16654	24,2377
18	8,60047	8,48319	2,150117	5,08210	24,3159
19	5,86396	7,93589	2,189210	4,61298	20,6020
20	4,30023	7,42768	2,306489	5,27756	19,3120
Total	36,51290	35,37920	9,069586	19,03831	100,0000

	2	3	6	10	Total
7	6,77626	2,92702	0,76183	1,20289	11,6680
17	12,83079	5,45309	2,52606	3,40818	24,2181
18	11,62791	4,97193	3,16760	4,49078	24,2582
19	9,02165	4,73136	3,08741	3,88933	20,7298
20	8,05934	3,72895	2,44587	4,89174	19,1259
Total	48,31596	21,81235	11,98877	17,88292	100,0000

Fig. 13. – Conjugacy tables for a pair of factors "Time of day – Illumination level", "Time of day– Type of terrain" of injuries among vulnerable categories of road users

Conjugacy tables for a pair of factors "Type of terrain – Road ownership" and "Road condition –Weather conditions" of injuries among vulnerable categories of road users are shown in Figure 14.

	2	3	4	6	Total
2	0,142857	0,21429	9,53571	40,17857	50,0714
3	1,357143	1,10714	20,46429	0,25000	23,1786
6	1,464286	5,00000	4,07143	0,03571	10,5714
10	5,142857	10,39286	0,53571	0,10714	16,1786
Total	8,107143	16,71429	34,60714	40,57143	100,0000

	1	2	4	Total
1	52,11913	15,08209	0,420008	67,6212
2	3,62734	19,74036	9,011073	32,3788
Total	55,74647	34,82245	9,431081	100,0000

Fig. 14. – Conjugacy tables for a pair of factors"Type of terrain – Road ownership", "Road condition – Weather conditions" of injuries among vulnerable categories of road users

From the analysis of the conjugacy tables, the following conclusions were drawn:
– 45.75% of those killed in road accidents died at night on unlit sections of roads. 46.86% of all those killed died in the type of locality "Districts". 36.3% of all the dead died in the type of locality "Districts" at night on unlit sections of roads.
– 50.61% of the injured in road accidents are observed in the daytime. 50.07% of all wounded were injured in the city of Gomel. 28.6% of all wounded were injured in Gomel during daylight hours.
– Almost a third of people died on regional roads serviced by the Gomelobldorstroy enterprise.
– More than 40% of the wounded are in the city of Gomel on the roads serviced by GCRCRT enterprise.
– Almost a quarter of the dead died at night on unlit sections of roads serviced by Gomelobldorstroy enterprise.
– Almost a quarter of the wounded were injured during daylight hours on the roads serviced by the GCRCRT enterprise.

IV. CONCLUSIONS

Based on the results of the study, the following conclusions can be formulated:
1. There is a growing trend in the proportion of dead and injured cyclists in the total number of dead and injured vulnerable road users.
2. An analysis of the number of deaths the most unfavorable regions are the city of Gomel, Svetlogorsky, Rechitsky, Zhlobinsky, Gomelsky and Buda-Koshelevsky districts. An analysis of values of the social risk the most unfavorable regions are Buda-Koshelevsky, Chechersky, Svetlogorsky,Braginsky, Zhitkovichsky and Kormyanskydistricts.
3. The number of people dead and injured in road accidents is significantly affected by the following factors: hour of day, illumination, type of terrain, road ownership, category and type of road accident. This makes it necessary to:
– develop measures to reduce the use of private vehicles;
– carrying out a topographical analysis of the Gomel region with the development of measures, including the arrangement of artificial lighting and traffic light regulation at pedestrian crossings.
4. It is necessary to conduct a survey of a sufficient number of pedestrian crossings, followed by an analysis of the impact of various factors on the accident rate.
Taking into account the dynamic patterns of accident rates and the identification of factors affecting road traffic accidents will increase the efficiency of measures to eliminate negative trends in the field of road safety and accident reduction.
The analysis of the accident rate has shown that there is a general tendency to reduce the number of vulnerable categories of road users killed in road accidents and social risk. At the same time, the level of social risk in our country is large enough in comparison with the countries of Europe. You can also note that in the Gomel region it is observed the lowest rate of improvement in the accident rate with vulnerable categories of road users, which confirms the relevance of the work to improve road safety in the region.
An analysis of the dynamics of change in the accident rate with vulnerable categories of road users leads to the following conclusions:
1. Although there is a tendency to reduce the number of vulnerable categories of road users killed and injured in road accidents in the Gomel region, in 2009–2021 we failed to achieve sustainability of the dynamics to reduce these figures.
2. Despite the stable dynamics of decrease in a collision of vehicles and pedestrians, as a consequence of the number of pedestrians killed in road accidents, this category of road users is the largest share of fatalities in road accidents. Also it should be noted that there is a small rate of decline in fatalities of cyclists in road accidents.
Experience in the implementation of measures to improve road safety allow to make a conclusion about the appropriateness of targeted planning of activities in this field, and also has made it possible to formulate the basic stages of development the programs to improve road safety. An analysis of the theoretical foundations of the development of measures to improve road safety showed a variety of measures which implementation would

reduce the accident rate with vulnerable categories of road users. The work allowed to allocate for the implementation of a number of priority measures aimed at increasing road safety:

– statistical studies of the causes and risk factors contributing to road accidents and increasing the severity of their consequences;

– develop and continuously update information materials for information campaigns aimed at vulnerable categories of road users;

– continuous identification of concentration places of accidents with vulnerable categories of road users and implementation of measures to reduce the number and severity of accidents;

– quality of roads in the winter period;

– equipment of ground pedestrian crossings with safety islands;

– use of speed deterrent measures in hazardous areas.

REFERENCES

[1]. Azemsha, S.A. andStarovoitovA.N. [2017]"Application of scientific methods in improving road safety"Monograph : 191 p.

[2]. Fanny, M., Ilkka, N. and Satu, I. [2019]"Accident risk of road and weather conditions on different road types" Accident Analysis & Prevention, Vol. 122: pp. 116-125.

[3]. Kravchenya, I. M.,Lebid, I. andLuzhanska, N. [2020] "Winter Road Maintenance Efficiency Improvement by the Rational Use of Deicing Agents" Modern Engineering and Innovative Technologies, Vol. 15,Issue3: pp. 65-70. doi: 10.30890/2567-5273.2021-15-03-039.

[4]. Kravchenya, I. N., Luzhanska, N. and Lebid, I. [2021]"Evaluation of Accident Rate Dynamics Involving Vulnerable Road Users in the Gomel Region"Vol. 8,Issue1: pp. 134-139. doi: 10.30888/2663-5712.2021-08-01-09.

[5]. Nikolaoua, P.,Folla K., Dimitriou, L. and Yannis G. [2021] "European Countries' Road Safety Evaluation by TakingIntoAccount Multiple Classes of Fatalities" Transportation Research Procedia, Vol. 52: pp. 284-291.

[6]. "Pedestrians, cyclists among main road traffic crash victims" World health organization. URLhttps://www.who.int/news/item/11-12-2010-pedestrians-cyclists-among-main-road-traffic-crash-victims (access date: 20.09.2021).

[7]. Statistica 13.3. Computer program. Serial number JRR709H998119TE-A.