International Journal of Technology 12(7) 1427-1436 (2021)
Received September 2021 / Revised December 2021 / Accepted December 2021

International Journal of Technology

http://ijtech.eng.ui.ac.id

Determinants of Pedestrian–Vehicle Crash Severity: Case of Saint Petersburg, Russia

Maria Rodionova[1*], Angi Skhvediani[1], Tatiana Kudryavtseva[1]

[1]*Graduate School of Industrial Economics, Institute of Industrial Management, Economics and Trade, Peter the Great St.Petersburg Polytechnic University, St.Petersburg , Polytechnicheskaya, 29, 195251, Russia*

Abstract. This article investigates factors that explain pedestrian injury severity levels in Saint Petersburg, Russia during the 2015–2021 period. The research takes into account such factors as weather conditions, infrastructure factors, human factors, and lighting conditions to assess their influence on pedestrian injury severity in pedestrian–vehicle crashes. The most influential factors are lighting conditions, particularly the lack of lighting when it is dark, which are associated with a 14.9% increase in fatal accidents. The greatest impact on the increase of fatal accidents due to road infrastructure conditions relates to road barrier shortcomings (4.7%). Such infrastructure road conditions as restraint system for pedestrians and horizontal markings also have a significant effect on fatal outcomes, increasing them by 1.4% and 0.7%, respectively. The obtained results may serve as a basis for St. Petersburg authorities to develop new road safety policies.

Keywords: Infrastructure factors; Ordered probit; Pedestrian–vehicle crashes; Road accident; Severity modeling

1. Introduction

Currently, one of the main global objectives is to reduce road traffic deaths and injuries by 50% by 2030. A vast number of people are killed each year as a result of road traffic crashes. Millions more suffer non-fatal injuries, including lifelong disability. According to the World Health Organization (2018), the lives of approximately 1.35 million people are cut short every year because of a road traffic crash. Between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury. Road traffic injuries cause considerable economic losses for victims, for their families, and for nations. These losses are primarily in the form of treatment costs and reduced or lost productivity.

The paper considers data on road accidents in Saint Petersburg, Russia to determine the causes of crashes, which will enable preventive measures to be identified. According to the Road Safety Strategy of the Russian Federation for 2018–2024, the social risk—that is, the number of deaths due to road accidents per 100,000 people—should be reduced to four. The "Safe and high-quality roads" national strategy enshrines "the pursuit of zero mortality", and the government aim is for there to be no fatal accidents by 2030. To that end, the analysis of road crash data will facilitate the implementation of sufficient measures to improve the existing situation.

*Corresponding author's email: rodionovamary98@gmail.com, Tel.: +7 (812) 534-73-31
doi: 10.14716/ijtech.v12i7.5403

Here, we consider road safety improvement and the creation of recommendations to reduce severe consequences of road crashes. Possible conditions that affect the level of road safety have been mentioned in numerous studies (Chen et al., 2016; Chen et al., 2020; Ghandour et al., 2020). Some studies present an analysis of the influence of various factors, such as weather conditions, time of day, and the gender of those involved, on the frequency of accidents (Anastasopoulos et al., 2012). Other studies categorize accidents according to severity and give recommendations to reduce severity and fatalities (Ma et al., 2008; Barua et al., 2016; Dong et al., 2016; Zeng et al., 2017). Oftentimes, studies on the conditions that lead to road accidents only look at one type of accident (Nashad et al., 2016; Billah et al., 2021) or the frequency of the occurrence of accidents by type (Mothafer et al., 2016; Cheng et al., 2017; Wang et al., 2017). Some studies also explore factors related to the driver behavior (Wedagama and Wishart, 2018).

Every year, more studies on this topic appear for certain sections of roads and territories, and both the overall situation in the country and reducing the sample to cities are considered. The circumstances mentioned substantiate the relevance of the paper.

2. Data and methods

The study uses data from Karta DTP, a non-commercial project dedicated to the problem of road traffic accidents in Russia and to collecting data on those accidents. We consider the data that affect the severity level and frequency of vehicle–pedestrian accidents in Saint Petersburg. The data covers the 2015–2021 period and 13,888 observations. Vehicle–pedestrian accidents rank second by frequency in terms of the total number of accidents in St. Petersburg during the period under review. The overall number of accidents is 37,585 or 37% compared to vehicle collisions, which account for 40%. However, in vehicle–pedestrian accidents, fatalities and serious injuries occur in 5% and 39% of incidents, respectively; the corresponding rates for vehicle collisions are 2% and 33%, respectively. More details can be seen in Table 1 below. Usually, vehicle–pedestrian accidents have a higher rate of mortality and injury severity (Kim et al., 2017; Chen and Fan, 2019). In view of all the above, the necessity of examining vehicle–pedestrian accidents is confirmed.

Table 1 Rate of vehicle–pedestrian and vehicle collisions by injury severity

Severity level	Vehicle–pedestrian accidents		Vehicle collisions	
	Quantity	Share	Quantity	Share
Slight injury	7834	56%	9706	64.9%
Seriously injury	5363	39%	4908	32.8%
Fatal	691	5%	334	2.2%
Total	13888	100%	14948	100%

The study looks at different factors relating to road traffic accidents, such as infrastructure shortcomings, weather conditions, and information about those involved. These factors are considered independent variables in the regression analysis to investigate their impact on the severity level of vehicle–pedestrian accidents in Saint Petersburg. We selected these factors based on an analysis of the relevant research. Table 2 presents the variables for the ordered probit regression analysis.

Ordered probit regression analysis is used to analyze the model. The dependent variable in the examined model is severity level, categorized from lowest to highest (slight, severe, and fatal). A Stata tool was used in performing the analysis. Ordered probit regression is computed using the cumulative standard normal distribution.

Table 2 Independent variables in the model

Classification	Supporting Studies	Data	Coding/Value
Light	Chen et al. (2016); Chen et al. (2020); Islam and Mannering (2021)	Dark, road illumination	1=This condition 0= Day time, others
		Dark, road illumination off	1=This condition 0= Daytime, others
		Dark, road illumination is missing	1=This condition 0= Day time, others
Weather	Park et al. (2012); Chen et al. (2016)	Precipitation	1=This condition 0=Clear, others
Road infrastructure conditions	Chen et al. (2016); Chen et al. (2020)	Roadway horizontal markings are absent or hardly identifiable	1=This condition 0=Others
		Pedestrian restraint system at desired locations is absent	1=This condition 0=Others
		Road signs at desired locations are absent	1=This condition 0=Others
		Misapplication, low visibility of the road signs	1=This condition 0=Others
		Road barriers at desired locations are absent	1=This condition 0=Others
		Surface distress	1=This condition 0=Others
		Defective traffic light	1=This condition 0=Others
Human factors	Park et al. (2012); Onieva-García et al. (2016); Chen et al. (2016); Islam and Mannering (2021)	Participants count	Min value=1 Max value=26 Mean value=2.34
		Pedestrian gender	1=Female 0=Male
		Driver gender	1=Female 0=Male

The difficulty is that the sign of the coefficients explains only the direction of the effects on the dependent variable, with average values for all outputs of dependent variables. This is why we will also provide average marginal effects for each injury severity type.

3. Results and Discussion

3.1. Descriptive Statistics of Accident Factors in Vehicle–pedestrian Accidents

As mentioned, vehicle–pedestrian accidents pose a greater threat due to the greater number of severe injuries and fatalities. This can be explained by the fact that in a collision, the person in the vehicle is safer than the pedestrian, even though the number of vehicle collisions is greater than the number of vehicle–pedestrian collisions.

Therefore, we can highlight vehicle–pedestrian accidents as the most dangerous from the viewpoint of the severity of the consequences. Many studies examine the data relating to a certain type of accident and share the conclusion about the danger of pedestrian accidents (Kim and Ulfarsson 2019; Billah et al., 2021). The danger level is greater because nothing can protect the human body in a collision with a vehicle. In such collisions, the most severe traumas are suffered by the pedestrian(s). Studies of this type of accident confirm the high fatality rate (Petrescu and Petrescu, 2017; Billah et al., 2021).

To identify the patterns associated with such accidents, it is necessary to consider the conditions present during the vehicle–pedestrian collision that can have a significant effect on the accident outcome. The examined groups of factors in our dataset are road conditions relating to road infrastructure shortcomings, lighting conditions, and human factors, all taking “precipitation” conditions into account. The descriptive statistics are shown below

in Tables 3–6.

Table 3 Infrastructure factors by injury severity rate

Infrastructure factors	Slight	Severe	Fatal	Quantity	Share
Roadway horizontal markings are absent or barely identifiable	926	736	92	1754	31.30%
Pedestrian restraint system at desired locations is absent	678	576	86	1340	23.91%
Road signs at desired locations are absent	673	526	72	1271	22.68%
Misapplication, low visibility of road signs	413	295	34	742	13.24%
Road barriers at desired locations are absent	45	51	11	107	1.91%
Surface distress	35	25	8	68	1,21%
Defective traffic light	26	25	3	54	0.96%
Others				268	4.78%
Total				5604	100%

For the analyses, we observed seven variables that represent the most frequent road infrastructure conditions listed in Table 3. We then investigated whether there any trends in the data on infrastructure factors by severity level; see Figure 1 below. The figure shows that the distribution corresponds to the occurrence frequency of the infrastructure factors (percentage).

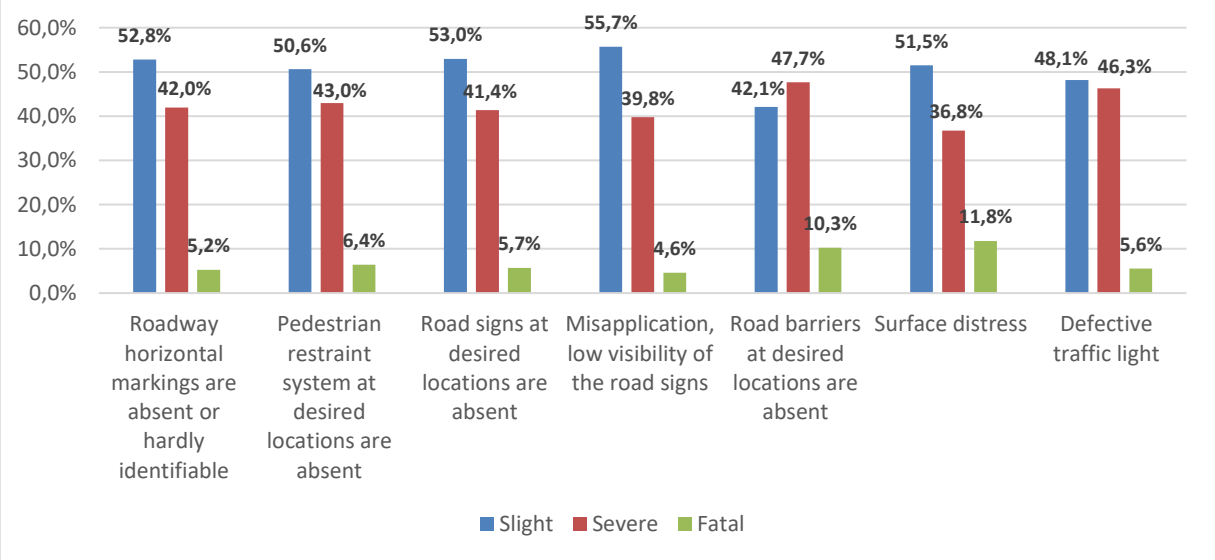


Figure 1 Infrastructure factors by severity level

Table 4 Lighting conditions by injury severity rate

Lighting conditions	Slight	Severe	Fatal	Quantity	Share
Daytime	4918	3188	310	8416	60.60%
Dark, road illumination	2672	2004	314	4990	35.93%
Twilight	183	87	24	294	2.12%
Dark, road illumination is missing	41	63	34	138	0.99%
Dark, road illumination off	20	21	9	50	0.36%
Total				13888	100%

Lighting conditions are considered separately (three variables) from infrastructure factors to obtain a more detailed indication of the effects on possible accident outcomes.

If we observe the time of day in terms of accident frequency by severity level, overall, 60% of accidents occur in the daytime and 40% occur at nighttime. But what is interesting

is that the number of fatal accidents is higher at night, as shown in Figure 4. Therefore, the time of day has a significant effect on the possibility of a fatal outcome.

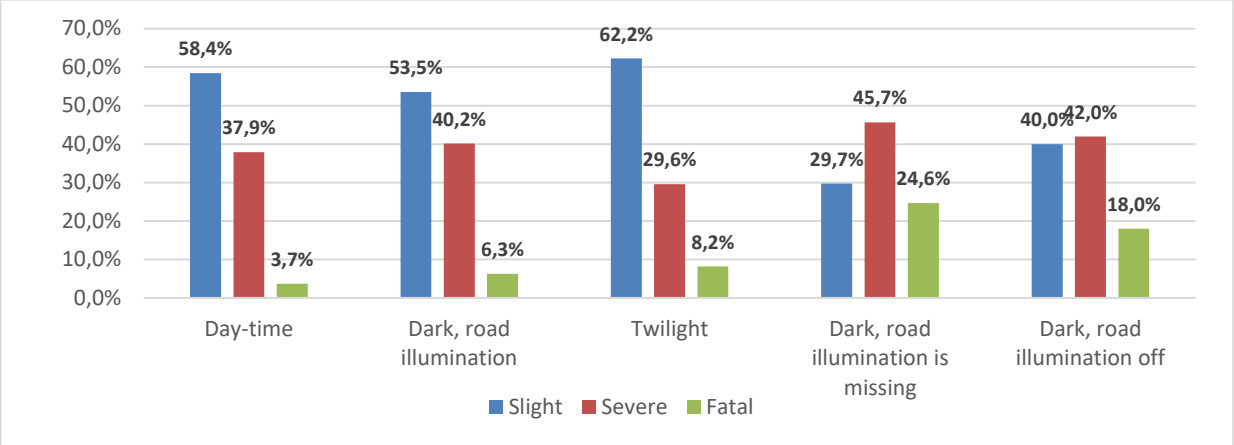


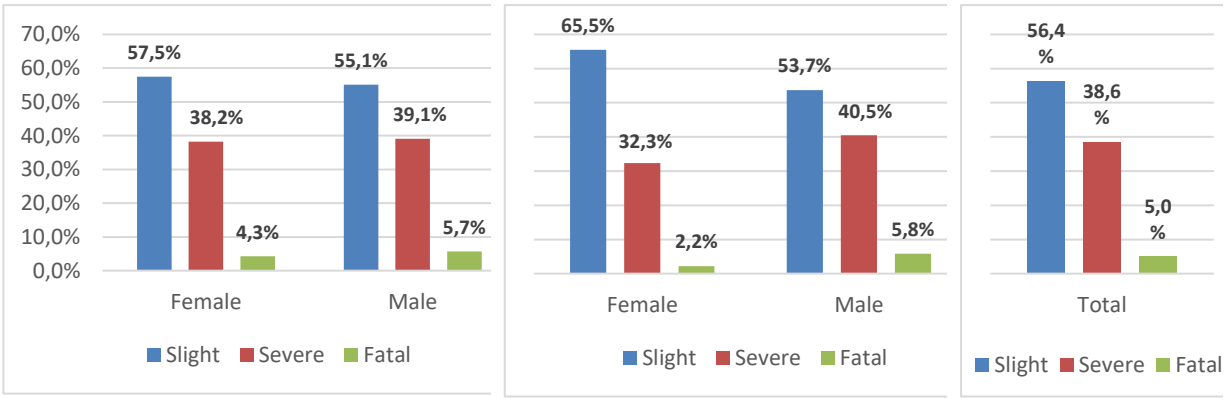
Figure 2 Lighting conditions by injury severity rate

We also analyze human factors, which reveals a difference in terms of the gender of pedestrians and drivers involved in accidents.

Table 5 Pedestrian gender by injury severity rate

Pedestrian gender	Slight	Severe	Fatal	Quantity	Share
Male	3576	2538	372	6486	47%
Female	4258	2825	319	7402	53%
Total				13888	100%

From Table 5, it can be concluded that female pedestrians are more frequently involved in accidents, but their injuries are less severe. However, the difference between genders is not high. As Figure 3a indicates, the difference in the proportion of different types of severity injuries between female and male pedestrians varies from 0.9% to 2.4%.



a **b** **c**

Figure 3 (a) Vehicle–pedestrian accidents by injury severity rate and pedestrian gender; (b) driver gender; (c) total amount of incidents

However, there is quite a significant difference in the drivers' injury severity rate. In particular, male drivers have a higher percentage of accidents with fatal or severe injuries. See Figure 3b and Table 6 for more details.

Table 6 Driver gender

Driver gender	Slight	Severe	Fatal	Quantity	Share
Male	5751	4335	620	10706	77%
Female	2083	1028	71	3182	23%
Total				13888	100%

As can be seen, male drivers are involved in more accidents than female drivers (77% vs. 23%). However, this may be because men drive vehicles more frequently than women. Of note is that female drivers are more likely to suffer slight injuries, while male drivers are more likely to suffer more severe injuries.

3.2. Regression Analyses

Ordered probit regression analysis was used to compute factor effects on changes in the predicted probability of severity level. The model consists of 14 regressors and one dependent variable. 13 regessors are dummy variables and one regressor – "hpc" – reflects number of participants, which aken part in the accident. Dependent variable is severity level of injuries.

In the analysis, we focused on the coefficients and their corresponding level of statistical significance. We also examined average marginal effects to enable predicting the probabilities of accident severity levels. The results are shown in Table 7.

Table 7 Results of regression analysis

Variable	Label	Coefficient	z-ratio	Marginal effects/Std. Err.		
				Slight (1)	Severe (2)	Fatal (3)
Light (reference: Daytime, other road conditions)						
Dark, road illumination	li	0.113***	5.23	-0.044*** (0.008)	0.032*** (0.006)	0.012*** (0.002)
Dark, road illumination off	lio	0.552***	3,42	-0.212*** (0.059)	0.128*** (0.025)	0.084** (0.034)
Dark, road illumination is missing	lim	0.826***	8,53	-0.307*** (0.031)	0.158*** (0.006)	0.149*** (0.026)
Weather (reference: clear, other weather)						
Precipitation	wp	0.152***	4,60	-0.059*** (0.013)	0.043*** (0.009)	0.017*** (0.004)
Road infrastructure conditions (reference: other conditions)						
Roadway horizontal markings are absent or barely identifiable	ihm	0.068**	2,19	-0.026** (0.012)	0.019** (0.009)	0.007** (0.003)
Pedestrian restraint system at desired locations is absent	iprs	0.131***	3,69	-0.051*** (0.014)	0.037*** (0.010)	0.014*** (0.004)
Road signs at desired locations are absent	irsa	0.027	0,75	-0.011 (0.014)	0.008 (0.010)	0.003 (0.004)
Misapplication, low visibility of the road signs	irsm	-0.039	-0,85	0.015 (0.018)	-0.011 (0.013)	-0.004 (0.004)
Road barriers at desired locations are absent	irba	0.354***	3,17	-0.138*** (0.043)	0.091*** (0.025)	0.047** (0.019)
Surface distress	isd	0.195	1,37	-0.076 (0.056)	0.053 (0.037)	0.023 (0.019)
Defective traffic light	itl	0.101	0,64	-0.039 (0.062)	0.028 (0.044)	0.011 (0.019)
Human factors						
Participant count	hpc	0.341***	4,98	-0.132*** (0.026)	0.098*** (0.020)	0.034*** (0.007)
Human factors (reference: male gender)						
Pedestrian gender	hpg	-0.060***	-2,91	0.023*** (0.008)	-0.017*** (0.006)	-0.006*** (0.002)
Driver gender	hdg	-0.300***	-12,01	0.115*** (0.009)	-0.089*** (0.008)	-0.026*** (0.002)

From the above table with the results of the regression analysis we can conclude following:

1) From lightning category of regressors all of them has significant impact on severity level: dark time, illumination is missing (lim) and dark time illumination on (li) and illumination is off (lio). "lim" regressor has the highest coefficients (1: -30.7%; 2: 15.8%; 3: 14.9%). The "lio" regressor has the following effects: 1: -21.2%; 2: 12.8%; 3: 8.4%. The "li" regressor estimates the smallest effect on severity level for response 1: -4.5%; 2: 3.2%; 3: 1.2%.
2) Precipitation (wp) decreases the probability of slight outcomes by 5.9% and increases the probability of severe and fatal outcomes by 4.3% and 1.7%, respectively.
3) In terms of infrastructure road conditions, the following factors have a significant effect on severity level: horizontal markings (ihm), pedestrian restraint systems (iprs), and road barriers (irba). The absence of road barriers has the greatest impact on severity level. It decreases the probability of slight accident outcomes by 13.8% and increases the probability of severe injuries and fatal outcome by 9.1% and 4.7%, respectively. The absence of a pedestrian restraint system causes a decrease in slight outcomes by 5.1%, while the probability of severe and fatal outcomes increases by 3.7% and 1.4%, respectively. The absence or hard identifiability of roadway horizontal markings has the least significant influence on severity level. This condition decreases the probability of slight outcomes by 2.6% and increases severe and fatal outcomes by 1.9% and 0.7%, respectively.
4) All observed human factors have a significant impact on all outcomes in terms of severity level in some way. The "hpc" variable that contains information about participant counts has the greatest impact. It has values from 1 to 26, and if the value increases by 1 unit the probability of a slight outcome decreases by 13.2%, whereas the probabilities of severe and fatal outcomes increase by 9.8% and 3.4%, respectively. In terms of driver gender, female drivers increase the probability of slight outcomes by 11.5%, while male drivers increase the probabilities of severe injuries and fatal outcomes by 8.9% and 2.6%, respectively. The same logic exists in examining pedestrian genders, but there is a smaller effect on severity level. Female pedestrians increase the probability of slight outcomes by 2.3%, while male pedestrians increase the probabilities of severe injuries and fatal outcomes by 1.7% and 0.6%, respectively.

3.3. Discussion of Obtained Results

The results of the research allow us to conclude the following.

Road infrastructure conditions—As is suggested by Zahra and Herlily (2018), road infrastructure factors have an effect on the risk of accidents. According to Calvo-Poyo et al. (2020), investing in road infrastructure improves traffic safety. Our study results indicate bottlenecks and gaps in St. Petersburg's road infrastructure. The most frequent shortcomings that cause accidents and severe outcomes are problems with road signs, roadway horizontal markings, and pedestrian restraint systems. According to the regression analysis, horizontal markings, pedestrian restraint systems, and road barriers have a significant impact on severity level. It is therefore suggested that investments in improving these things can reduce severe and fatal accident outcomes in the city.

Lighting conditions—As observed by Chen et al. (2016), the time of day impacts severity level and the accident frequency curve. Our study shows that more fatal accidents occur at nighttime and more non-fatal accidents occur in the daytime. This might be the result of more overall daytime traffic, whereas at night there are worse visibility conditions due to low lighting that cause more severe accident outcomes. The regression model shows that the lack of lighting when it is dark has the greatest impact on increasing the probability

of severe injuries and fatalities, increasing the risk by 15.8% and 14.9%, respectively. In addition, the other variables of lighting conditions when it is dark have a significant impact on severity level, decreasing slight outcomes and increasing severe and fatal outcomes.

Human factors—As found by Onieva-García et al. (2016), males had higher death rates than females in vehicle–pedestrian accidents. However, exposure rates were higher for females. Our analysis revealed the same finding, with a 2% difference in the number of fatal accidents with male pedestrians vs. female pedestrians, but the overall exposure was higher for females. The regression revealed a significant effect of all factors on accident outcomes, as was also found by Zuraida et al. (2017). The greatest impact in this category of factors estimated for participant count that increases severe and fatal outcomes by 9.8% and 3.4%, respectively. Regarding gender differences, male drivers and pedestrians are associated with the increase in severe and fatal accident outcomes, while female drivers and pedestrians are associated with the increase in slight outcomes.

Precipitation also significantly affects severity level, increasing severe and fatal outcomes by 4.3% and 1.7%, respectively, and decreasing slight outcomes by 5.9%. Similar findings were obtained by Chen et al. (2016), and Chen et al. (2020).

4. Conclusions

In this paper, we analyzed accident data in St. Petersburg for the period 2015–2021 consisting of 13,888 observations. We examined different road conditions, weather, severity level, and pedestrians and their exposure vis-à-vis the frequency of data occurrence. We identified an interesting trend, which is that some conditions that do not cause a greater number of accidents can be the cause of a greater number of fatal accidents. We obtained and analyzed some statistical data that can be used in further regression modelling. The main contribution of the paper is the provision of an ordered probit regression analysis to evaluate the impact of observed factors on the severity level of accident outcomes.

The study results allow us to conclude the following. The most severe accident outcomes in St. Petersburg are the result of vehicle–pedestrian accidents. These account for 13,888 incidents, 5% of which are fatal and about 40% of which result in serious injuries. This fact allowed us to examine this type of accident and the impact of road conditions at the moment of accident occurrence in more detail.

The main results of the research are: (1) The greatest impact on fatal and severe outcomes was caused by lighting factors, that is, the lack of lighting when it is dark (14.9% and 15.8%, respectively) and illumination when it is dark is off (8.4% and 12.8%, respectively); (2) Precipitation has a significant effect on severity level, causing a 4.3% and 1.7% increase in the probability of severe and fatal outcomes, respectively, and a 5.9% decrease in the probability of slight injuries; (3) Of the top seven road infrastructure shortcomings in St. Petersburg, only road barriers, pedestrian restraint systems, and horizontal markings have a significant effect on changing the severity of road accidents; (4) The more people involved in accidents, the greater the probability of more severe injuries; and (5) Female pedestrians and drivers increase the probability of slight outcomes compared to male pedestrians and drivers, who are associated with an increase in severe and fatal outcomes.

Acknowledgements

The research is funded by the Ministry of Science and Higher Education of the Russian Federation as part of World-class Research Center program: Advanced Digital Technologies (contract No. 075-15-2020-934 dated 17.11.2020).

References

Anastasopoulos, P.C., Shankar, V.N., Haddock, J.E., Mannering, F.L., 2012. A Multivariate Tobit Analysis of Highway Accident-Injury-Severity Rates. *Accident Analysis and Prevention*, Volume 45, pp. 110–119

Barua, S., El-Basyouny, K., Islam, M.T., 2016. Multivariate Random Parameters Collision Count Data Models with Spatial Heterogeneity. *Analytic Methods in Accident Research*, Volume 9, pp. 1–15

Billah, K., Sharif, H.O., Dessouky, S., 2021. Analysis of Pedestrian–Motor Vehicle Crashes in San Antonio. Texas. *Sustainability,* Volume 13(12), pp. 1–23

Calvo-Poyo, F., Navarro-Moreno, J., de Oña, J., 2020. Road Investment and Traffic Safety: An International Study. *Sustainability,* Volume 12(16), pp. 1–15

Chen, H., Zhao, Y., Ma, X., 2020. Critical factors Analysis of Severe Traffic Accidents based on Bayesian Network in China. *Journal of Advanced Transportation*, Volume 4, pp. 1–14

Chen, T., Zhang, C.H., Xu, L., 2016. Factor Analysis of Fatal Road Traffic Crashes with Massive Casualties in China. *Advances in Mechanical Engineering*, Volume 8(4), pp. 1–11

Chen, Z., Fan, W., 2019. Modeling Pedestrian Injury Severity in Pedestrian-Vehicle Crashes in Rural and Urban Areas: Mixed Logit Model Approach. *Transportation Research Record*, Volume 2673(4), pp. 1023–1034

Cheng, W., Gill, G., Sakrani, T., Dasu, M., Zhou, J., 2017. Predicting Motorcycle Crash Injury Severity using Weather Data and Alternative Bayesian Multivariate Crash Frequency Models. *Accident Analysis and Prevention,* Volume 108, pp. 172–180

Dong, C., Clarke, D.B., Nambisan, S.S., Huang, B., 2016. Analyzing Injury Crashes using Random-Parameter Bivariate Regression Models. *Transportmetrica A: Transport Science*, Volume 12(9), pp. 794–810

Ghandour, A.J., Hammoud, H., Samar, Al-H., 2020. Analyzing Factors Associated with Fatal Road Crashes: A Machine Learning Approach. *Environmental Research and Public Health*, Volume 17(11), pp. 1700–1705

Islam, M., Mannering, F., 2021. The role of gender and temporal instability in driver-injury severities in crashes caused by speeds too fast for conditions. Accident Analysis & Prevention, Volume 153, 106039

Kim, M., Kho, S.Y., Kim, D.K., 2017. Hierarchical Ordered Model for Injury Severity of Pedestrian Crashes in South Korea. *Journal of Safety Research*, Volume 61, pp. 33–40

Kim, S., Ulfarsson, G.F., 2019. Traffic Safety in An Aging Society: Analysis of Older Pedestrian Crashes. *Journal of Transportation Safety and Security,* Volume 11(3), pp. 323–332

Ma, J., Kockelman, K.M., Damien, P., 2008. A Multivariate Poisson-Lognormal Regression Model for Prediction of Crash counts by Severity, using Bayesian Methods. *Accident Analysis and Prevention*, Volume 40(3), pp. 964–975

Mothafer, G.I.M.A., Yamamoto, T., Shankar, V.N., 2016. Evaluating Crash Type Covariances and Roadway Geometric Marginal Effects using the Multivariate Poisson Gamma Mixture Model. *Analytic Methods in Accident Research*, Volume 9, pp. 16–26

Nashad, T., Yasmin, S., Eluru, N., Lee, J., Abdel-Aty, M.A., 2016. Joint Modeling of Pedestrian and Bicycle Crashes: Copula-Based Approach. *Transportation Research Record: Journal of the Transportation Research Board*, Volume 2, pp. 119–127

Onieva-García, M.Á., Martínez-Ruiz, V., Lardelli-Claret, P., Jiménez-Moleón, J.J., Amezcua-Prieto, C., de Dios Luna-Del-Castillo, J., Jiménez-Mejías, E., 2016. Gender and Age Differences in Components of Traffic-Related Pedestrian Death Rates: Exposure, Risk of Crash and Fatality Rate. *Injury Epidemiology*, Volume 3(14), pp. 1–10

Park, S., Jang, K., Park, S. H., Kim, D. K., & Chon, K. S. (2012). Analysis of injury severity in traffic crashes: a case study of Korean expressways. KSCE Journal of Civil Engineering, 16(7), pp. 1280–1288

Petrescu, L., Petrescu, A.I., 2017. Vehicle-Pedestrian Collisions – Aspects Regarding Pedestrian Kinematics, Dynamics and Biomechanics. *In:* IOP Conference Series: Materials Science and Engineering, Volume 252

Wang, K., Ivan, J.N., Ravishanker, N., Jackson, E., 2017. Multivariate Poisson Lognormal Modeling of Crashes by Type and Severity on Rural Two-Lane Highways. *Accident Analysis and Prevention*. Volume 99(Part A), pp. 6–19

Wedagama, D.M.P., Wishart, D., 2018. The Relationship between Self-Reported Traffic Crashes and Driver Behavior in the Road Transportation of Goods and Freight in Bali. *International Journal of Technology,* Volume 9(3), pp. 558–567

World Health Organization (WHO), 2018. *Global Status Report on Road Safety 2018*. Available Online at https://www.who.int/publications/i/item/9789241565684

Zahra, A.N., Herlily, 2018. Reclaiming the Street for Pedestrians as a Sustainable City Approach. *International Journal of Technology,* Volume 9(7), pp. 1365–1374

Zeng, Q., Wen, H., Huang, H., Pei, X., Wong, S., 2017. A Multivariate Random-Parameters Tobit Model for Analyzing Highway Crash Rates by Injury Severity. *Accident Analysis and Prevention*, Volume 99(Part A), pp. 184–191

Zuraida, R., Iridiastadi, H., Sutalaksana, I.Z., 2017. Indonesian Drivers' Characteristics Associated with Road Accidents. *International Journal of Technology,* Volume 8(2), pp. 311–319