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IMPACT OF E-SCOOTERS ON ROAD SAFETY: A CASE STUDY IN LITHUANIA

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Abstract. The rapidly growing popularity of electric scooters in recent years has allowed the road user to choose another alternative mode of transportation. On the one hand, it is an ecological means of transportation in the city, allowing you to quickly reach your destination; on the other hand, it is a vehicle that causes risk to road safety. Although this is a fairly new mode of transport, it is already of great concern for road safety authorities. E-scooter accidents are recorded with all road users – pedestrians, bicyclists, motor vehicles, other e-scooter riders, or even alone. In this article, the analysis made according to the accident data of 2019–2020 showed that the highest number of accidents occurred between e-scooters and vehicles. Most e-scooter accidents with motor vehicles occur in the intersection zone or during a vehicle turning manoeuvre to (or from) side streets and exit lanes. A descriptive statistical analysis showed that the proportions of the distribution of road accidents between accident participants changed significantly during the analysis period – the number of road accidents between e-scooters and bicycles increased, while the number of accidents between e-scooters and pedestrians decreased. The road accidents between e-scooters and other vulnerable road users are usually caused by sudden, unexpected manoeuvring of road users. Identification of accident schemes and locations is an additional tool for traffic organisation specialists and road safety professionals to prevent accidents, injuries, and fatalities.

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Introduction

The ways of people mobility in the city have changed dramatically over the last decade. This could be caused by the changing attitudes of both professionals and road users toward a more sustainable urban mobility and by the growing popularity of shared micromobility systems, especially bicycles and e-scooters (Luo et al., 2020; Ma et al., 2021; Smith & Schwieterman, 2018; Zagorskas & Burinskienė, 2020). Introduced in 2017 in the United States, e-scooters quickly became a popular mode of transportation in many cities around the world. The National Association of City Transportation Officials (NACTO) in 2019 annual report on shared micromobility services indicates that in 2018 in the United States of the total amount of 84 million trips on shared micromobility (bike share, scooter share), e-scooters made 45.8% of trips. In particular, the number of e-scooter trips in the United States has changed during the COVID-19 pandemic: scooter ridership increased from 38.5 million in 2018 to 88.5 million in 2019 and thus increased by 129%. In Lithuania, e-scooter sharing services were introduced in 2019. Based on data from one of the services, in 2019, 82 thousand registered users performed 350 thousand trips (Technologijos.lt, 2019); according to the data from another service – 440 000 km were driven by the rented e-scooters during the 2019 season (Verslo žinios, 2019).

The literature analysis shows (Liu et al., 2019; Statista, 2021) that e-scooters are generally used for short distance trips – 0.8–3.2 km. The National Association of City Transportation Officials (NACTO) in 2019 annual report on shared micromobility services indicates that the average length of a scooter in the United States is 1 mile (1.6 km), duration – 12 min. Zagorskas & Burinskienė (2020) note that in European cities e-scooters are commonly used for short distances of 0.5 to 5 km, with an average travel time from 15 to 25 min. In Lithuania, according to the data for e-scooter sharing services, the average travel length is 2 to 4 km, travel time – 21 min (Technologijos.lt, 2019).

The popularity of e-scooters was determined by their mobility, accessibility, ability to reach any destination, that is, geographically unrestricted accessibility to the destination, a fast way of travelling to avoid traffic jams, and no need to have a right to ride such a vehicle, etc. Besides, it is a lightweight, easily foldable device (sufficiently small and light, flexible) and can be carried, making it convenient to use when combining different modes of transportation (to carry it on a train, bus or to put in a car).

In spite of the above-mentioned convenience and advantages of e-scooters, this vehicle has also brought confusion into the traffic – conflict situations with other road users, especially pedestrians, including people with special needs (such as the visually impaired), the lack of traffic rules or unclear legislation of e-scooters, unpredictable behaviour of the scooter riders when changing riding trajectories, driving of several people in one scooter, ignoring safety helmets, disorderly parking in public spaces, unregulated control, injured or even killed road users. Considering this fact, some European countries have already taken some regulatory actions to address the issues of safe scooter traffic and to integrate them into the transport system as safely as possible. These are extremely timely solutions, since according to Svegander (2020), the number of scooters available from scooter-sharing services will at the same time grow from 774 000 at the end of 2019 to 4.6 million vehicles in 2024, excluding private e-scooters.

In order to successfully integrate e-scooter traffic into the transport system in terms of road safety, it is necessary to get understanding of e-scooter accidents in Lithuania. The aim of this study is to identify the types of road accidents, road accident schemes, and elements of the street where conflict situations occur most often between e-scooter riders and other road users. The task is to compare changes in accident characteristics between 1) the period 2019–2020 and 2) in the cities of Lithuania where the most e-scooter accidents were registered.

1. Literature review

Though e-scooter traffic has become popular recently, the challenges they pose have forced policymakers to define certain traffic rules or requirements related to e-scooter traffic or even to tighten them. A review of various sources shows that the requirements for e-scooter traffic vary from country to country.

An overview of the rules shows that the countries of the European Union today do not have uniform traffic rules for e-scooters (Table 1). Analysis shows a large difference in both: the level of detail of the rules (i.e., how detailly this type of traffic is regulated) as well as regulations set for the speed of e-scooters, their place on roads, age of riders, use of helmets, registration of e-scooters, etc. At present, in some countries, including Lithuania, the Road Traffic Rules have no special regulations related to e-scooter traffic.

At present, there are not many studies related to e-scooter traffic. Existing studies on e-scooters are mainly related to the injuries of e-scooter riders and to the analyses of road user surveys. It should be noted that when talking about injuries of e-scooter riders, both types of injuries are meant – caused by collision with another road user and single injuries without involvement of another road user.

The first study related to e-scooter injuries was launched in the United States. The analysis carried out in 2018 by the Health Department Environmental Health Services in Multnomah County (USA) (Multnomah County Health Department, 2019) showed that out of 700 000 e-scooter trips, made within a period of 5 months, 176 riders visited emergency departments for certain injuries, that is, the e-scooter injury rate was 25.14 injuries per 100 000 trips.

Another analysis conducted in the same year showed (Austin Public Health, 2019) that in Austin City (Texas, USA) during the reporting period of three months 936 110 e-scoter trips were made. 190 e-scooter riders visited urgent care clinics for certain injuries. In this case, e-scooter injury rate was 20.30 injuries per 100 000 trips. The analysis also found that 48% of injured riders belonged to 18–29 years old group, and the median age of the injured riders was 29 years. The analysis of the types of injuries showed that 48% of riders had injuries to the head (Austin Public Health, 2019). Nearly half of those injured suffered a severe injury, of which even 84% suffered bone fractures. It should be noted that only one of 190 riders wore helmet, and 37% of injured riders reported that excessive e-scooter speed contributed to their injury. The survey of injured riders found that 55% were injured on the street and 33% on the sidewalk. 16% of the incidents with injured riders involved a motorized vehicle.

Santacreu et al. (2020) in the Report on Safe Micromobility indicate that fatality risks for shared e-scooters ranges between 78 and 100 fatalities per billion trips.

E-scooter riders often use combination urban infrastructure to reach their destination due to its convenience and ability to shorten travel time. Considering this aspect, e-scooter drivers often use sidewalks or pedestrian paths. Maiti et al. (2019) note that insufficient allocation of space for sidewalks and bike lanes can lead to unsafe encounters between e-scooters and pedestrians. If a bike lane is not present, e-scooter riders may feel compelled to use sidewalks meant for pedestrians. Despite the fact that in many cities e-scooters are allowed to use sidewalks if their speed is close to the speed of pedestrians (3–7 km/h), Zuniga-Garcia et al. (2021) report that e-scooter users ride much faster – 15.2 km/h on weekdays and 13.7 km/h on weekends. KFV (2019) found that e-scooters travelled with a mean speed of

15.1 km/h and a maximum speed of 31 km/h. Such speeds are too high and unsafe with respect to the pedestrian and may become a decisive factor in the occurrence of road accident.

There are very few studies on the injuries of pedestrians in e-scooter-involved accidents. Trivedi et al. (2019) reported that of 249 patients who suffered injuries in road accidents with e-scooters, 21 were pedestrians. 11 were struck by a scooter, 5 were tripped over a parked scooter, and 5 were injured while trying to lift or carry a scooter not in use.

Siman-Tov et al. (2017) by using data from the Israel Trauma Registry reported that out of 795 hospitalized patients due to e-bike or motorized scooter accident, 8% were pedestrians. Among the total casualties, 33% were children aged 0–14 years and among pedestrians 42% were children and 33% were seniors (ages 60+). Five persons died in hospital – 3 riders and 2 pedestrians.

Data collected by Santacreu et al. (2020) about the fatalities in crashes involving standing e-scooters show that pedestrians represent less than one in ten fatalities in crashes involving standing e-scooters.

Very few studies are related to the infrastructure elements. A study on e-scooter riding infrastructures was conducted by Zhang et al. (2021). The study, conducted in the Virginia Tech campus (from September to October 2019), showed that e-scooter users were willing to travel 59% and 28% longer on segments with bikeways and multi-use paths. Local roads, such as tertiary roads or one-way roads (including roads with wide medians to separate right of the ways) are also found to be attractive, as the perceived travel distances are reduced by 15% and 21%, respectively. Bikeways display the largest positive estimated coefficients and are the most preferred infrastructures. Stairs on walkways are considered unattractive, and e-scooter users are willing to travel 55% longer to avoid them.

A survey conducted in Vienna (Austria) showed that e-scooter trips mostly replaced walking and public transport as a mode (Laa & Leth, 2020). A survey also showed that a modal shift from cyclists to e-scooter riders usually did not happen; however, e-scooter riders also used infrastructure intended for cyclists, and this suggested that the need for cycling infrastructure was becoming even more pressing (Laa & Leth, 2020). A survey by Laa & Leth (2020) is distinguished by the attempt to find out differences between two basic groups of e-scooter users – renters and owners. Results have shown that e-scooter owners seem to use these vehicles more often. In general, 70.7% of e-scooter owners indicated that they used them several times a week or more often, whereas 44.5% of users of sharing schemes indicated that they used

Table 1. E-scooter laws in countries

Country	E-scooter speed limit, km/h	Part of the road do e-scooter have to use			Driver's license	Registration	Forbidden to use mobile phone / headphones	Helmet		Compulsory insurance
		Street carriageway	Bike path / lane	Pedestrian area (sidewalk, pedestrian path)				Compulsory	Recommended	
Lithuania	25	Yes	Yes	Yes (e-scooter speed: 3–7 km/h)	No	No	NA	Yes, <18	NA	No
Latvia	25	Yes, if speed limit ≤50 km/h	Yes	Yes (e-scooter speed: 3–7 km/h)	The riders till 14 years old are required to have the same qualifications as for cycling	No	No	No	No	No
Germany	20	Yes, if speed limit ≤50 km/h	Yes	No	No	Yes	NA	NA	Yes	Yes
France	25	Yes	Yes	No (unless a mayor authorizes it)	No	No	Yes	Yes, <12		No
Italy	25	Yes, if speed limit ≤30 km/h	Yes	Yes (e-scooter speed: 6 km/h)	No	No	NA	Yes, <18	NA	No
Poland	20	Yes, if speed limit ≤30 km/h	Yes	Yes (e-scooter speed: 5 km/h)	The riders of 10–18 years old are required to have the same qualifications as for cycling	NA	Yes	NA	Yes	NA
Malta	20	Yes	Yes, 10 km/h	Yes (e-scooter speed: 10 km/h)	No	No	No	NA	Yes	Yes
Denmark	20	Yes	Yes	No	No	No	No	NA	Yes	Yes
Finland	15	Yes	Yes	No	No	No	No	NA	Yes	No
Spain	25	Yes	Yes	No	No	No	Yes	Yes, <16	NA	No

them several times a month and even 23.6% responded that they only tried them once.

It is very difficult to assess in detail e-scooters in view of road accidents, since road accidents involving e-scooters are usually classified as collisions with a bicycle. To make a detailed analysis of this type of accidents, it is necessary to update accident databases by separating scooter-involving accidents into a separate accident type and to record additional parameters such as accident location (cycle path, cycle lane, sidewalk, carriageway or etc.) and accident participants (pedestrian, scooter rider, bicycle, motor vehicle, etc.). The International Transport Forum Report on Safe Micromobility (2020) indicates that police and public health casualty databases should also accommodate information on the shared or private ownership of the vehicle and on the name of the shared micromobility company if applicable. This is to enable linkages with trip data that are available from each company and because trip data are likely less available for privately owned vehicles.

2. Research data and methods

As mentioned above, it is complicated to analyse the data of e-scooter-involved road accidents, since today in Lithuania, as in many other countries (Santacreu et al., 2020), those accidents are classified as bicycle collisions. Therefore, to gather general or more detailed information about e-scooter-involved accidents, it was necessary to use various data sources – to ask the police to provide this type of information, to read interviews with police officers, representatives of insurance companies on social media, etc. The authors of this article are grateful to the Lithuanian Road Police Service for the detailed data about e-scooter-involved accidents in 2019–2020. Data analysis gives an opportunity to not only analyse the tendencies in accidents involved with e-scooters, but also to identify characteristics of road accidents. It should be noted that the two-year study period (2019–2020) was chosen because a more intensive use of e-scooters in Lithuania began in 2019, when the e-scooter sharing services were launched. Private e-scooters have been used before, but the official accident statistics show that no accidents with e-scooters were registered in 2017 and in 2018 only 3 e-scooter-involved accidents involved with e-scooters occurred.

The data collected for the study were grouped according to the following accident variables, which were registered in the police records:

- Gender of the e-scooter rider;
- Age of the e-scooter rider;
- Day of week;

- Type of day;
- Time of day;
- Weather conditions;
- Cities, where an e-scooter accident occurred.

More detailed information regarding the location and participants of e-scooter accidents was grouped by the authors according to the type of road user and additional circumstances presented in the police records.

To assess tendencies in e-scooter-involved accidents, a descriptive statistical analysis was performed. In a descriptive statistical analysis, the quantitative variables are presented as mean ± standard deviation. To compare the means between 2019 and 2020, the t-test for independent samples was used. To compare the means between cities, the one-way ANOVA was applied. The categorical variables in the frequency tables are presented as the number of cases *n* and their percentage, *n*, (%). The Chi-squared test was used to check the independence of categorical variables, and where the number of cases was small – the Fisher's exact test.

3. Results

The analysis of road accidents involving e-scooters shows that 2019–2020 there has been an extremely rapid growth in the number of accidents and their victims: the number of accidents increased by 58.06%, the number of injured by 57.58% and the number of fatalities doubled. Despite the extremely rapid increase in accidents, there is no possibility to assess more accurately the extent of accident growth and to express them in certain relative accident rates, e.g., according to the number of e-scooters, since at present e-scooters are not registered vehicles, and it is not known how many of them can participate in traffic. The age of e-scooter riders involved in road accidents varies from 6 to 87 years, and the age of victims of road accidents ranges from 1 to 91 years. The analysis of road accidents shows that in 2019 4.84% of road accidents with e-scooters (in 2020 – 6.12%) involved intoxicated road users and all of them were e-scooter riders.

Table 2 shows a comparison of injuries in e-scooter accidents in 2019–2020 according to certain accident parameters. The difference in male and female between 2019 and 2020 is not statistically significant (p = 0.87). In both years the number of females injured in e-scooter accidents was lower: 36.92% and 39.42%, respectively. The average age in 2020 is slightly lower than in 2019, 25.87 ± 17.33 and 30.81 ± 20.72, respectively, but the difference is not statistically significant (p = 0.109). The lowest number of accidents was recorded on Saturdays in both years, the distribution of accidents was similar on other days, slightly more accidents were recorded on Wednesday in 2020 (28.85% of all days of the week), but this distribution of accidents between 2019 and 2020 was not statistically significant (p = 0.691). A higher proportion of accidents were recorded on working days in both 2019 and 2020, 83.33% and 81.73%, respectively. The difference in proportions between the years is not statistically significant (p = 0.952). The highest share of accidents in 2019 and 2020 was recorded during the daytime, 89.39% and 85.58%, respectively. The difference in the proportions between years is not statistically significant (p = 0.625). The majority of accidents in 2019 and 2020 occurred during the light time of the day, 83.33% and 79.81%, respectively. The difference in proportions between the years 2019 and 2020 is not statistically significant (p = 0.71).

In both 2019 and 2020, the highest number of accidents involved e-scooters and vehicles, 60.32% and 64.29%, respectively, the lowest number of accidents occurred between e-scooters, 3.17% and 3.06%, respectively. However, the difference in the proportions of all e-scooter accidents between 2019 and 2020 is statistically significant (p = 0.025): in 2020, the number of accidents between e-scooters and bicycles was significantly higher compared to 2019, 4.76% and 18.37%, respectively, and the number of e-scooter accidents with pedestrians halved in 2020, 23.81% and 10.2%, respectively.

Almost half of all accidents in both years were recorded in Vilnius, 53.03% and 42.31%, respectively. In other cities, significant changes were recorded between 2019 and 2020 (p = 0.025): in 2020, the number of accidents in Palanga increased significantly – from 4.55% to 10.58%, also in Klaipėda – from 6.06% to 14.42%, whereas in Kaunas the number of accidents in 2020 decreased from 18.18% to 6.73%. The increase in the number of accidents was also recorded in the other smaller cities which in this comparison were combined into one group called "Others" due to a low number of accidents in each of them. The distribution of age groups is not statistically significant between 2019 and 2020 (p = 0.398).

Although the first box-plot diagram (Figure 1) shows that the age distribution in the cities differs greatly, but the difference in the median age between the cities is not statistically significant (p = 0.432) (Table 3), the median age in all the cities varies about 30 years with a slightly younger median age in Kaunas – 21.84 ± 10.56. Concerning the median age in the cities by year (Figure 2), the median age in Palanga and Klaipeda was higher in 2019, although only a few accidents were recorded in each of these cities in 2019.

The proportion of males is slightly higher in Vilnius and Kaunas, but the difference is not statistically significant (p = 0.723) (Table 4).

Table 2. Comparison of injuries in e-scooter accidents

	2019	2020	*p*-value*
Total number of injuries	66	104	
Female, *n* (%)	24 (36.92%)	41 (39.42%)	0.87
Age (mean ± SD)	30.81±20.72	25.87±17.33	0.109
Day of accident:			
Monday, *n* (%)	13 (19.7%)	15 (14.42%)	
Tuesday, *n* (%)	9 (13.64%)	14 (13,46%)	
Wednesday, *n* (%)	14 (21.21%)	30 (28.85%)	
Thursday, *n* (%)	12 (18.18%)	11 (10.58%)	0.691
Friday, *n* (%)	7 (10.61%)	15 (14.42%)	
Saturday, *n* (%)	3 (4.55%)	6 (5.77%)	
Sunday, *n* (%)	8 (12.12%)	13 (12.5%)	
Day:			
Working days	55 (83.33%)	85 (81.73%)	0.952
Weekend	11 (16.67%)	19 (18.27%)	
Time of the day:			
Light time	59 (89.39%)	89 (85.58%)	0.625
Dark time	7 (10.61%)	15 (14.42%)	
Weather conditions:			
Sunshine	55 (83.33%)	83 (79.81%)	0.71
Overcast or rain	11 (16.67%)	21 (20.19%)	
Participants of road accidents:			
E-scooter with bicycle	3 (4.76%)	18 (18.37%)	
E-scooter with e-scooter	2 (3.17%)	3 (3.06%)	
E-scooter with pedestrian	15 (23.81%)	10 (10.2%)	0.025
E-scooter with vehicle	38 (60.32%)	63 (64.29%)	
E-scooter alone	5 (7.94%)	4 (4.08%)	
Cities:			
Vilnius	35 (53.03%)	44 (42.31%)	
Kaunas	12 (18.18%)	7 (6.73%)	
Klaipėda	4 (6.06%)	15 (14.42%)	0.025
Palanga	3 (4.55%)	11 (10.58%)	
Other	12 (18.18%)	27 (25.96%)	
Age group:			
≤6	2 (3.03%)	7 (6.8%)	
7–12	13 (19.7%)	22 (21.36%)	
13–18	7 (10.61%)	14 (13.59%)	
19–24	5 (7.58%)	16 (15.53%)	0.398
25–35	19 (28.79%)	17 (16.5%)	
36–45	8 (12.12%)	12 (11.65%)	
≥45	12 (18.18%)	15 (14.56%)	

Note: if averages are compared, the t-test for independent samples is used, if proportions are compared, the Chi-squared test is used.

In all cities, a large number of accidents occur during light hours of the day, the difference between cities is not statistically significant (p=0.584) (Table 5).

The difference between cities according to the weather conditions under which accidents occur, is statistically significant (p = 0.019): in overcast or rainy time of the day 25% of accidents occurred in Vilnius, whereas in other cities, in Palanga and Klaipėda no accidents took place under overcast or rainy weather conditions, in Kaunas these accidents made 15.79% (Table 6).

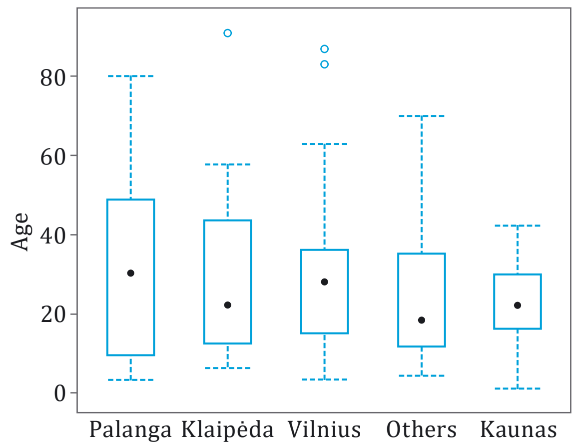

Figure 1. Age distribution of injuries in e-scooter-involved accidents by city in 2019–2020

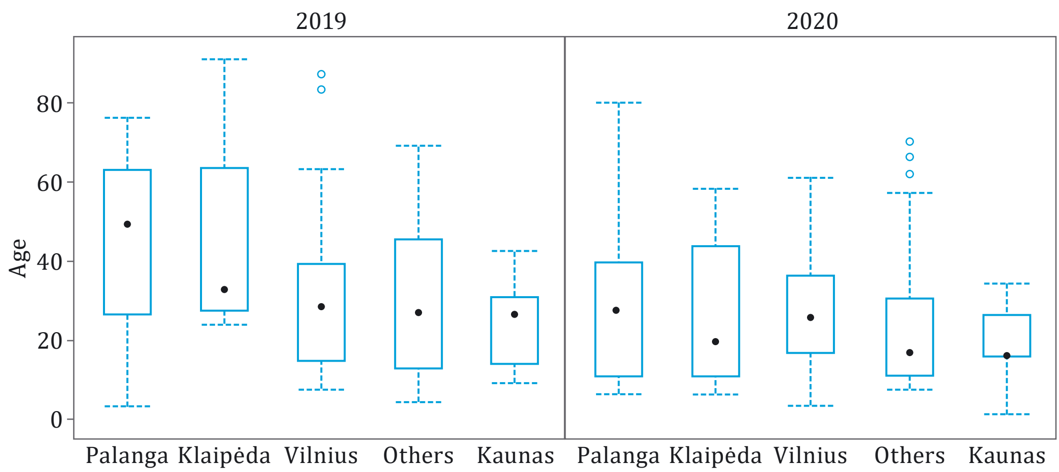

Figure 2. Age distribution of injuries in e-scooter-involved accidents by city and year

Table 3. The age distribution of injuries by city in 2019–2020

City	Min	Max	Median	Average	SD	*p*-value
Palanga	3	80	30.00	33.64	26.74	
Klaipeda	6	91	22.00	30.00	22.80	
Vilnius	3	87	28.00	28.41	16.87	0.432
Other	4	70	18.00	26.29	20.32	
Kaunas	1	42	22.00	21.84	10.57	

Table 4. The gender distribution of injuries by city in 2019–2020

City	Woman	Man	*p*-value
Palanga	6 (42.86%)	8 (57.14%)	
Klaipėda	9 (47.37%)	10 (52.63%)	
Vilnius	26 (33.33%)	52 (66.67%)	0.723
Other	17 (43.59%)	22 (56.41%)	
Kaunas	7 (36.84%)	12 (63.16%)	

Table 5. The distribution of injuries by time of the day and by city in 2019–2020

City	Light time	Dark time	*p*-value
Palanga	14 (100%)	0 (0%)	
Klaipėda	17 (89.47%)	2 (10.53%)	
Vilnius	68 (86.08%)	11 (13.92%)	0.584
Other	32 (82.05%)	7 (17.95%)	
Kaunas	17 (89.47%)	2 (10.53%)	

Table 6. The distribution of injuries by weather conditions and by city in 2019–2020

City	Overcast or rain	Sunshine	*p*-value
Palanga	0 (0%)	14 (100%)	
Klaipėda	0 (0%)	19 (100%)	
Vilnius	19 (24.05%)	60 (75.95%)	0.019
Other	10 (25.64%)	29 (74.36%)	
Kaunas	3 (15.79%)	16 (84.21%)	

The highest number of accidents in all cities, except Palanga, occurs between the e-scooter and vehicle. In 2019, in Kaunas and Klaipėda, this type of accidents made 78.95% and 70.59% of all accidents involving electronic scooters, respectively (Table 7). In Palanga, the number of accidents was rather low in 2019–2020; therefore, the distribution of accidents by their participants was slightly different: e-scooter accidents with vehicles and bicycles accounted for the same percentage of accidents, 33.33% each. A very low number of accidents was recorded between e-scooters, only a few cases in Vilnius and one in Palanga, and no accidents at all were recorded in other cities. The difference was not

Table 7. The distribution of e-scooter accidents and their participants by city in 2019–2020

City	E-scooter with bicycle	E-scooter with pedestrian	E-scooter with vehicle	E-scooter with e-scooter	E-scooter alone
Palanga	3 (33.33%)	2 (22.22%)	3 (33.33%)	1 (11.11%)	0 (0%)
Klaipėda	1 (5.88%)	3 (17.65%)	12 (70.59%)	0 (0%)	1 (5.88%)
Vilnius	11 (14.29%)	13 (16.88%)	44 (57.14%)	4 (5.19%)	5 (6.49%)
Other	5 (12.82%)	6 (15.38%)	27 (69.23%)	0 (0%)	1 (2.56%)
Kaunas	1 (5.26%)	1 (5.26%)	15 (78.95%)	0 (0%)	2 (10.53%)

Table 8. The distribution of e-scooter accidents by day of the week and by city in 2019–2020

City	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Palanga	2 (14.29%)	2 (14.29%)	0 (0%)	5 (35.71%)	2 (14.29%)	0 (0%)	3 (21.43%)
Klaipėda	4 (21.05%)	2 (10.53%)	8 (42.11%)	2 (10.53%)	2 (10.53%)	0 (0%)	1 (5.26%)
Vilnius	12 (15.19%)	9 (11.39%)	28 (35.44%)	12 (15.19%)	8 (10.13%)	4 (5.06%)	6 (7.59%)
Other	4 (10.26%)	7 (17.95%)	7 (17.95%)	2 (5.13%)	7 (17.95%)	3 (7.69%)	9 (23.08%)
Kaunas	6 (31.58%)	3 (15.79%)	1 (5.26%)	2 (10.53%)	3 (15.79%)	2 (10.53%)	2 (10.53%)

Table 9. The distribution of e-scooter accidents by day and by city in 2019–2020

City	Working days	Weekend	*p*-value
Palanga	11 (78.57%)	3 (21.43%)	
Klaipėda	18 (94.74%)	1 (5.26%)	
Vilnius	69 (87.34%)	10 (12.66%)	0.082
Other	27 (69.23%)	12 (30.77%)	
Kaunas	15 (78.95%)	4 (21.05%)	

statistically evaluated due to the low number of accidents (many zero cases).

Klaipėda and Vilnius represented a slightly higher percentage of accidents on Wednesday, 42.11% and 35.44% respectively, in Kaunas a slightly higher percentage was recorded on Monday – 31.58%, in Palanga – on Thursday – 35.71% (Table 8). On the remaining days, the recorded accidents had a similar distribution among the cities. The difference was not statistically assessed due to a low number of accidents.

A higher share of accidents in all the cities was recorded on weekdays (Table 9). A slightly higher percentage of accidents on weekends was recorded in other cities than Vilnius, Kaunas, Klaipėda and Palanga, i.e., 30.77%, but the difference between the cities when using the 0.05 significance level was not statistically significant ($p = 0.082$).

Based on the analysis of the description of accident circumstances, the most common accidents schemes between electric scooters and motor vehicles are as follows:

- Collision of motor vehicle turning into (out of) the exit lane with an e-scooter crossing the exit lane;
- In the intersection zone when an e-scooter user rides on a zebra pedestrian crossing or pedestrian crossing with traffic lights or bicycle passage.

When it comes to e-scooter accidents with pedestrians, they are most often on sidewalks, pedestrian, and cycle paths, in case of a sudden change in the trajectory of pedestrian or e-scooter movement.

Collisions between e-scooters and cyclists or collisions between e-scooters usually occur on straight sections of cycle paths, combined pedestrian and cycle paths when a safe distance is not maintained, and sudden and unexpected manoeuvres are made.

Discussion

The literature analysis showed that a majority of studies on e-scooters are mainly related to the injuries of e-scooter riders and to the analyses of road user surveys. There are a few studies related to the analysis of e-scooter accidents, and this, according to the authors, may be related to the lack of data on e-scooter accidents. This is also probably related to the fact that there is no separate group of road accidents with e-scooters, which means that researchers, students, or road safety specialists do not have the opportunity to analyse publicly available data regarding e-scooter road accidents. In addition, it can be assumed that today some road accidents involving e-scooters are not included in the police road accidents database, because they are simply not reported. Various activities and measures can be used to solve the above-mentioned problems, for example, to add a new type of road accident "Collision with a scooter or e-scooter" to the list of types of road accidents, to introduce compulsory registration of e-scooters, to introduce compulsory civil liability insurance, etc. The same situation applies to the number of e-scooters involved in traffic. Therefore, there is no possibility to develop a comparative analysis of tendencies in e-scooter accidents, since it is possible to only assess the number of e-scooters used for sharing services.

Although the aim of this study is related to the analysis of road accidents and the analysis of accident circumstances, it is necessary to note that there are many conflict situations due to e-scooters parked on bike paths and footpaths, and pedestrians and bicyclists. It is certainly related to e-scooters used for sharing services. This shows that the challenges of e-scooter traffic need to be studied more widely, and not only for traffic management or road safety specialists. This should also include e-scooter rental organisation, which could also contribute to safer e-scooter traffic.

Conclusions

1. E-scooters, which are rapidly gaining popularity and changing transport modes in cities, are not only an ecological means of promoting mobility, but also a means of challenging the safety of road users. The authors' analysis of existing traffic rules and requirements for e-scooter traffic has shown that the European Union countries have different requirements for both e-scooter riders (age, driving license or qualifications, helmet) and riding conditions (speed, locations where e-scooters are allowed to ride).
2. Recent tendencies in the increasing intensity of e-scooter traffic and in the number of e-scooter accidents have shown that the current situation requires additional activities or measures for the safe integration of e-scooter traffic into the overall transport system to ensure safe traffic for all road users. A detailed analysis of road accidents has demonstrated that accidents involving e-scooter riders occur between various groups of road users – pedestrians, cyclists, motor vehicle drivers and e-scooter riders themselves. The largest share of accidents is taken by collisions with a motor vehicle. Furthermore, a comparison of the proportions in the accident distribution in 2019 and 2020 has shown that they differ significantly (p = 0.025). The number of accidents between electric scooters

and bicycles is increasing, while the number of accidents between e-scooters and pedestrians is decreasing.

3. The analysis of road accident circumstance shows that the most common scheme of accidents between electric scooters and motor vehicles is as follows: 1) collision of motor vehicle turning into (out of) the exit lane with e-scooter crossing the exit lane and 2) in the zone of intersection when e-scooter user rides on zebra pedestrian crossing or pedestrian crossing with traffic lights or bicycle passage.

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