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SAFETY OF E-SCOOTERS ON POLISH ROADS BETWEEN 2022 AND 2024

Summary. The rapid growth of micromobility devices in cities has raised many concerns about their users' safety. This article focuses on the safety of e-scooters in Poland from 2022-2024. Police database analysis indicated 4295 collisions and 1842 accidents involving e-scooters, resulting in 11 fatalities and 1565 injuries, including 537 serious injuries among e-scooter users. In this paper, KSI (i.e., the percentage of killed and seriously injured persons among the total number of victims) was used to assess the severity risk for individual categories of accidents and victims. The most important risk factors for e-scooter users were carriageways (as the location of accidents), with the highest KSI of 39.9%, and rollover of e-scooters (as the type of accident), with a KSI of 40.9%. Two main causes of severe accidents were excessive speed (KSI=42.4%) and alcohol influence (KSI=39.9%). Injury severity increased with user age (reaching a KSI of 53.8% for those aged 65+ years). Men have a clearly higher risk of serious injury than women KSI=37.4% vs. 29.9%). Results from behavior monitoring of 1765 e-scooter users collected in three Polish voivodeships in 2022 by external and direct observations showed that the speed of e-scooters and other motorized micromobility devices was 20.6 km/h, with 54.2% of vehicles exceeding the speed limit. Only 5% of e-scooter riders used reflective vests and other reflective elements at night, and 6% wore helmets. Two types of analysis presented in this article provide knowledge about the state of road safety for this new group of road users. Many international recommendations for e-scooter safety were adopted in Poland, but there is a need to tighten them, mostly through enforcement and education/training. In order to improve the head protection, legislative action was taken in July 2025 to introduce mandatory helmet wearing for all users under 16 years old riding an e-scooter. This action was carried out indirectly due to the findings of the present study.

1. INTRODUCTION

For over 15 years, shared mobility and micromobility systems have experienced continuous evolution in urban environments across the globe, including in Poland, since 2018. These systems encompass a range of micromobility vehicles and devices, such as electric scooters (e-scooters), electric bicycles, segways, e-skateboards, and solo wheels. Functioning as environmentally friendly alternatives to traditional motor vehicles, these innovative transport solutions significantly reduce air pollution and traffic congestion.

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Micromobility options have gained preference over walking and cycling, particularly for short-distance travel and as integral components of first/last-mile connectivity. Research suggests that e-scooters could supplant passenger cars for short-distance journeys of up to 2.0 km, with possibilities of serving as alternatives for longer trips spanning several kilometers. These systems not only provide an alternative transportation method within urban settings but also enhance community relations. The primary advantages of micromobility include cost-effectiveness, increased accessibility, and the ability to circumvent traffic congestion by utilizing cycle paths and sidewalks.

However, this mode of transport presents risks to both pedestrians and cyclists [1, 2]. The lower physical exertion required for e-scooters renders them more user-friendly than traditional bicycles, thereby encouraging a shift in travel mode choice behavior, particularly in congested urban environments. The introduction of e-scooter sharing systems in the United States marked the inception of urban shared micromobility. Subsequently, e-scooters have surpassed other transport-sharing services, such as bike-sharing, in terms of rental frequency. Notably, in 2018, e-scooter usage eclipsed that of bicycles, with shared e-scooter trips doubling in 2019 compared to the previous year and representing two-thirds of all shared micromobility journeys in the United States [3].

In Poland, shared urban e-scooter systems have experienced continuous growth since their introduction in 2018 despite the long-term mobility restrictions imposed by the COVID-19 pandemic. An analysis of the market indicates that the number of available devices in 2021 increased by 146% relative to 2020. During the peak of the 2021 season, over 46,000 shared e-scooters provided by ten operators were available for rental across 60 locations in Poland. A remarkable surge in the number of these devices was observed in 2022, with e-scooter sharing services expanding to 208 cities by September 2023, in contrast to 161 in September 2022. The total supply of these vehicles by four main operators (Bolt, Lime, Tier, Dott) has reached nearly 94,000 units, marking a twofold increase compared to 2021 [4].

2. RATIONALE FOR THE PRESENT RESEARCH

On May 20, 2021, Poland introduced new regulations for e-scooters, other motorized micro-mobility devices and non-motorized micromobility devices as part of the Polish Road Traffic Act. This was the first comprehensive set of rules governing the use of micromobility devices in Poland. The regulations-initiated discussions between city authorities and operators of sharing systems. According to the law, users of e-scooters and other micromobility devices must adhere to specific speed limits, and the maximum permitted speed is 20 km/h. In areas without bicycle paths, e-scooter speeds on sidewalks or pavements must match pedestrian speeds. The minimum age for using these devices is 10 years. E-scooters must be parked in designated areas; if such areas are unavailable, they should be parked parallel to the outer edge of the sidewalk. Users between 10 and 18 years of age are required to possess either a bicycle card or a valid driving license. Additionally, all vehicle drivers, including those using micromobility devices, are prohibited from riding under the influence of alcohol or any substances with similar effects. It is also forbidden to carry passengers, animals, or objects, or to tow or be towed by another vehicle while operating an e-scooter or other micromobility device [5].

In Poland, the Polish Road Safety Observatory classifies several types of micromobility devices. These include e-scooters, other motorized micro-mobility devices, and non-motorized micro-mobility devices. An e-scooter is defined as a two-axle vehicle powered by electricity, featuring handlebars and designed for a single rider, without a seat or pedals, and not intended for passengers. A non-motorized micromobility device refers to sports and recreational equipment designed to transport a person in an upright position, powered by human muscles. Examples of this type of device include rollerblades, roller skates, and skateboards. Another type of motorized micro-mobility device is an electrically powered vehicle, distinct from an e-scooter that also lacks a seat or pedals and is intended for use by a single person. This category encompasses devices such as electric roller skates, electric skateboards, and self-balancing devices, including hoverboards, segways, and solo wheels [6].

The European Union's Community Database on Road Accidents (CARE) provides data on accidents involving motorized micromobility devices from 2020 [7]. According to the Community Database

on Road Accidents glossary, motorized micromobility devices include e-micro-scooters, segways, monowheels, and self-balancing unicycles. These devices must have at least one wheel, be designed for a single rider, and be equipped with an electric motor capable of reaching a maximum speed of 25 km/h. Table 1 reflects countries in Europe collecting accident data of motorized micromobility devices between 2022 and 2023. This type of accident accounts for as little as 0.7% of all road accidents (in Belgium) to as much as 21.1% (in Iceland). In Poland, this percentage was 2.6% in 2022. The number of motorized micromobility device accidents increased in two years in seven of 12 countries (Table 1), and the overall share of e-scooter accidents increased from 2.9% in 2022 to 3.5% in 2023.

Since a legal framework for e-scooter operation was established, this distinct category of vehicle has been recognized, but its status varies across European nations. Only the Netherlands does not (yet) permit the use of e-scooters in public spaces, while in Denmark, they are allowed as part of a trial. In most countries, e-scooter riders are required to use bicycle lanes. However, they are allowed to use sidewalks in only four countries: Bulgaria, Greece, Norway (with a max speed of 6 km/h), and Poland (at pedestrian speed). Legal liability insurance for e-scooter riders is compulsory only in the Czech Republic, Denmark, France, and Germany. Additionally, helmets are mandatory for specific user groups - particularly, children and young riders—in Austria, Iceland, Norway, and Sweden. All e-scooter riders are required to wear a helmet only in Denmark, Finland, Greece, Hungary, and Spain. The minimum age for e-scooter riders varies from 12 years in Austria and France to 14 years in Italy and 16 years in Switzerland. In nearly all countries, there is a maximum speed limit of either 20 km/h or 25 km/h for e-scooters [8].

Table 1

European countries with motorized micromobility devices (2022-2023) [6, 7]

Country Name	2022				2023			
	No. of Accidents		Fatally injured	Injured (seriously and slightly)	No. of Accidents		Fatally injured	Injured (seriously and slightly)
	e-scooters	% of total			e-scooters	% of total		
Belgium	262	0.7%	1	203	1653	4.5%	2	1478
Denmark	34	1.3%	0	30	29	1.2%	1	27
Estonia	339	20.3%	1	331	324	19.2%	0	306
France	2045	3.9%	35	1886	2291	4.4%	44	2081
Germany	8341	2.9%	10	7417	9425	3.2%	21	8404
Iceland	191	21.1%	1	188	154	15.8%	0	152
Italy	2929	1.8%	16	2787	3365	2.0%	21	3195
Lithuania	166	5.8%	0	127	161	5.7%	2	122
Poland	555	2.6%	3	448	558	2.7%	3	463
Slovenia	205	3.4%	2	193	201	3.3%	0	187
Spain	4647	4.7%	8	4315	6058	6.0%	10	5670
Switzerland	449	2.4%	2	416	510	2.8%	2	462
Total	20163	2.9%	79	18,341	24,729	3.5%	106	22547

Micromobility vehicles offer various benefits, but they are also increasingly seen as a challenge to road safety due to the risks they pose to other users. While these environmentally friendly vehicles can enhance urban transport, they have been linked to a rise in the number of injuries, particularly when they interact with pedestrians, cyclists, and motorized traffic in shared spaces. Allowing e-scooters on sidewalks can create dangerous situations for pedestrians. Since e-scooters are generally heavier and faster than people on foot, collisions can have severe consequences. When these vehicles share road infrastructure with other modes of transport, they often compete for space, speed, and safety with passenger cars, which can exacerbate safety concerns [2].

Micromobility devices are typically quiet and often lack the strong lighting that cars and motorcycles have. This can make it difficult for pedestrians, especially seniors and individuals with hearing impairments, to notice them [8]. Additionally, when micromobility riders share the road with motorized

vehicles, the significant differences in mass and speed place them at considerable risk. Moreover, because there are no regulations regarding designated parking for these devices, they are often left on sidewalks, obstructing pathways for pedestrians [9]. Irresponsible behaviors, such as speeding and improper parking, are widespread and often accompanied by acts of vandalism, including the intentional damage or throwing of e-scooters.

Additionally, the design of e-scooters makes them particularly sensitive to road pavement irregularities, which can cause riders to lose their balance. Currently, there are no established minimum standards for critical features such as wheel diameter, tire width, ground clearance, or stability, which exacerbates safety concerns [10]. Poland has been regulating the use of micromobility devices since May 20, 2021, and collecting data on accidents involving these vehicles since 2022. The purpose of this article is to analyze risk factors associated with mobility of e-scooters in Poland (infrastructure, alcohol, speed, and helmets) since 2021 and compare them with data from the literature.

3. LITERATURE REVIEW

The literature on e-scooters consistently highlights safety as a major concern. Researchers have investigated e-scooter incidents by examining factors such as accident characteristics, injury severity, alcohol involvement, helmet use, and environmental conditions (e.g., location, weather, and lighting). They have also investigated the types of accidents, conflicts with pedestrians and vehicles, and instances of illegal riding. Since the e-scooter boom began in the United States in 2017, substantial research has examined this innovative mode of transport, which is part of the larger movement toward shared mobility and micromobility systems [1]. However, much of the existing literature has focused on case-based reports regarding the impacts of e-scooters rather than their characteristics, the infrastructure they use (e.g., dedicated lanes or roads), or their relationship to public transportation (i.e., whether they serve as a complementary or competing mode of transport) [11]. Impact studies on e-scooters, which provide data on casualties (fatalities and injuries), have shown a range of outcomes influenced by various factors. A comprehensive review of the literature on micromobility categorized the impacts of e-scooter fleets into three broad areas: safety, user behavior (performance), and environmental effects [12]. Additionally, the authors of the article "E-scooter Micromobility Systems: Review of Attributes and Impacts' classified the data into five key impact areas, known as key performance indicators (KPIs): (1) the environment, (2) society-users, (3) the economy, (4) transport performance, and (5) safety [11]. The data collected for these KPIs offer a more comprehensive understanding of road safety levels than traditional statistical data. KPIs enable the early detection of emerging problems and facilitate the measurement of the effectiveness of interventions. Key factors influencing these concerns include road infrastructure, the use of protective equipment (such as helmets and pads), device speed, and user behavior (which includes risky actions and alcohol consumption).

The vulnerability of e-scooter riders in road accidents is a significant area of concern, with 37% of studies addressing safety issues. The literature indicates a lack of dedicated infrastructure for e-scooters, with only 11% of studies considering the use of bicycle lanes. In contrast, 51% of the reviewed studies reported that e-scooter riders share the road with other users, including vehicles and pedestrians, while 37% of studies do not provide relevant information on this aspect [13].

E-scooter accidents predominantly manifest as single-vehicle incidents, accounting for approximately 83% of all reported cases. Of these incidents, 72% do not involve interactions with other road users. Comparative analysis reveals that e-scooter-related accidents have exhibited a consistent annual increase from 2019 to 2022, when juxtaposed with incidents involving other modes of transportation. Notably, e-scooter riders have experienced a higher incidence of accidents relative to e-bike riders, with reported accident rates of 74.4% and 25.6%, respectively [13].

Research investigating accident locations reveals significant variability in the percentage of injuries sustained in different environments. Specifically, the occurrence of injuries on sidewalks ranged from 3.3% to 46.2%, while injuries occurring on carriageways varied between 13% and 71% [14]. According to a report [14], e-scooter riders feel most secure when utilizing bicycle lanes (76.9%) than sidewalks

(17.9%) and carriageways (5.1%). Furthermore, another study highlighted that most e-scooter accidents (67%) occur at intersections [15, 16]. According to the literature, 50% of accidents involving e-scooters occur in mixed-traffic environments (carriageways), 14% occur on sidewalks, and 25% occur at intersections (Mitropoulos et al.) [11]. In a detailed examination of e-scooter incidents, one study assessed the severity of injuries among 105 adult e-scooter riders injured in Washington, DC, in 2019. This study indicated that the majority of injuries took place on sidewalks (58%) or roads (23%). The leading causes of these injuries were attributed to riders attempting to avoid pedestrians (10%), encountering surface features (25%), facing infrastructure-related issues (16%), and experiencing falls (27%) [17].

E-scooter usage typically exhibits a pronounced peak during the spring, summer, and autumn months, which correlates with an increase in reported injuries [18]. Various studies have presented different perspectives on the temporal distribution of e-scooter accidents. Some suggest a higher incidence of accidents during weekdays, while others indicate that weekends may pose greater risks [19]. A study conducted in the United Kingdom in 2021 analyzed a total of 1352 incidents and revealed that e-scooter accidents are significantly more prevalent during weekday afternoons in comparison to weekday mornings [16]. In contrast, broader accident data indicate peaks in both morning and afternoon periods. Furthermore, there is a marked decline in e-scooter accidents during weekend afternoons when compared with weekdays. Although some studies suggest that the majority of accidents occur on weekends, they are distributed throughout the day. Additionally, several investigations have highlighted that nighttime collisions contribute disproportionately to e-scooter rider fatalities [18].

The main causes of e-scooter solo accidents are surface features (25%), infrastructure issues (16%), and various other factors, such as falls (27%) [11]. An analysis of 160 different collision scenarios through computer simulations of e-scooter interactions revealed that speed is the primary factor influencing the severity of pedestrian head injuries. E-scooter speeds between 10 and 15 km/h are critical for pedestrian safety, while speeds not exceeding 11 km/h on shared paths are considered safe for both riders and pedestrians [13]. Observations of e-scooter riders by the Austrian Road Safety Board made in Austria in 2019 revealed that they traveled at an average speed of 15.1 km/h, with the highest speed being 31 km/h (KFV, 2019, as cited in [8]). Overall, injury severity tends to increase with higher travel speeds. Accidents on sidewalks, where e-scooters share space with slower-moving pedestrians, often result in less severe outcomes but can lead to increased conflicts [17]. Excessive speed accounted for 30% according to international studies [20].

The consumption of alcohol and drugs significantly contributes to injuries associated with e-scooter use [14, 18]. Research indicates that injured riders who tested positive for alcohol exhibited a markedly higher likelihood of sustaining severe head and brain injuries than other riders. Furthermore, a substantial proportion of injured riders were found to have consumed various substances, including cannabis, amphetamines, and opioids, prior to their incidents. According to the literature, e-scooter riders under the influence caused 4% of accidents [15]. The detrimental effects of alcohol and drug use on riding performance have been well documented and correlate with an elevated risk of accidents and injuries [14]. Moreover, the practice of riding with multiple individuals on a single e-scooter adversely affects maneuverability, impairs braking capabilities, induces instability, and heightens the risk of falls. Approximately 30% of surveyed riders reported riding with a passenger [21], as cited in [14]. Studies have also recorded occurrences of double riding in injury-related accidents, with reported frequencies ranging from 4-14% [14, 17]. In exploring demographic factors associated with e-scooter usage and injury rates, it was observed that males engage in e-scooter riding with a greater frequency and sustain injuries at a higher rate than females [16, 18]. According to an international study, 30% of female e-scooters caused crashes (vs. 70% of males) [11]. An analysis of 41 hospital-based injury studies indicated that males represent approximately 60% of all individuals injured while riding e-scooters. Furthermore, within the United States, data reveal that roughly 63% of injured riders are aged 15-44 years [14].

International studies and reports show that helmet use by e-scooter users reduces the number of head injuries by 44% [11]. The prevalence of protective helmet or pad usage among e-scooter riders is alarmingly low, ranging from 1.2-10.9%, except in countries where helmet use is mandated [13, 14, 17]. According to two studies [22, 23], as reported in [14], none of the injured riders were wearing protective gear, including knee, elbow, or wrist pads. In Portland, Oregon, only 10% of riders wore helmets, a

figure attributed to the city's initiatives that distribute free helmets and raise awareness about the importance of helmet use, [24], as cited in [14]. Conversely, a study conducted in Tel Aviv between 2019 and 2020 [18] revealed that fewer e-bike users than e-scooter riders wore helmets (34% vs. 41%). While no significant differences were noted in terms of injury location, treatment type, or hospitalization needs between helmet-wearing and non-helmet-wearing e-scooter riders, it was found that blood alcohol levels were significantly higher among those who did not wear helmets. This trend suggests a pattern of irresponsible e-scooter use, which may be exacerbated by a lack of proper training on the safe use of micromobility modes.

4. METHODOLOGY AND SCOPE

The relevant research questions are whether the rise in popularity and availability of electric scooters has caused the increased risks to this group of road users in Poland and what the most important accident risk factors are. Two distinct research methodologies were employed to evaluate the safety of e-scooter users. One focuses on accident statistics, and the other focuses on observations of users' behavior. The first research method examines traffic accident data collected from the nationwide Accident and Collision Register (SEWiK), which is managed by the Police General Headquarters. According to the common definition, road incidents recorded by the police are accidents or collisions that occurred on a public road and involved at least one vehicle. A road accident is a road incident with at least one fatality or injured person. A fatality is a person who died on the spot or within 30 days of a road accident because of sustained body injuries. A seriously injured person is one who has suffered injuries causing a health disorder lasting longer than seven days. A slightly injured person is one who has suffered injuries other than those specified for a seriously injured person. Unfortunately, in Polish statistics, there are no data on accidents that involve only one e-scooter and are not reported to the police. Those people are registered in hospitals, but these data are not available at the national level.

Data from SEWiK were analyzed at the Polish Road Safety Observatory (managed by the Motor Transport Institute) for the years 2022-2024. This analysis includes statistics on the number of accidents, fatalities, and injuries involving e-scooters. It emphasizes various factors, such as accident type, the time when the accident occurred, the primary causes of accidents, conflicts with pedestrians and other vehicles, accident locations, and rider demographics (including age and gender). E-scooters are a very new means of transport, and data on accidents involving them have only been collected by the police since 2022. Therefore, only data available from a three-year period from 2022-2024 were analyzed, during which a total of 1842 accidents occurred in Poland, in which 11 people died and 1554 were injured. Attempts were made to analyze risk factors using a statistical regression model, but the results were inconsistent and unreliable due to the small sample size. Instead, a method was used to assess the severity of accidents by determining the KSI percentage (share of people killed and seriously injured among the total number of victims/casualties) for individual categories of accidents and victims.

The second analysis method on e-scooter user behavior stemmed from a 2022 Polish study conducted by the Motor Transport Institute for the National Road Safety Council [25]. This study monitored e-scooter users' traffic behavior, emphasizing aspects such as vehicle speed, hazardous distances between vehicles, and the use of passive safety devices, including items like helmets and reflective vests. The selection of survey points and the method of conducting observations followed the methodology used in international (baseline) and national surveys. Survey teams were trained so that observations were conducted in the same way and under the same conditions.

Conducted between May 10 and June 10, 2022, the study encompassed three Polish voivodeships: Masovian, Silesian, and Greater Poland. Eighteen survey points were established in urban areas, with six points in each voivodship (three on sidewalks and three on bicycle paths). The analysis utilized both video recordings and behavioral observations by research teams to assess the use of passive safety devices and to measure speed. Most observations occurred on weekdays during daylight hours, while the assessment of reflective elements was carried out at night. To ensure comparability across survey points, tests were conducted under similar weather conditions. The collected video footage was used to ascertain

whether the required sample size was achieved. Twenty-four hours of footage were analyzed at each survey point, with some observations taking several days to meet the minimum sample size criteria. Evaluations regarding the use of reflective elements and helmets were conducted separately from speed measurements. The recorded material was extended by direct observations that lasted not less than four hours at each point to provide additional data.

The designated survey points met all the necessary criteria regarding road type. A minimum requirement was established for the number of e-scooters at each survey point, set as at least 50, to facilitate speed measurements and observations of passive safety device usage. The study utilized external observation techniques, incorporating both picture image recording and direct field observations. Speed measurements were performed using microwave radars with a 45° measurement angle, which recorded the required traffic parameters. A field survey on the use of helmets and reflective elements was conducted using video recording, followed by encoding and processing of the collected data. Image recording was carried out using high-resolution video cameras (1920 × 1080 px, full HD). Speed recording devices and cameras operate in a way that does not affect the behavior of road users. The survey collected data on 1765 e-scooter users, including 973 at night.

5. E-SCOOTERS' IMPACT ON SAFETY AND USER BEHAVIOR IN POLAND

5.1. E-scooter safety in Poland from 2022-2024

Recent findings on e-scooter safety in Poland have been established based on statistical data regarding accidents reported by police between 2022 and 2024. These findings shed light on several key characteristics, including the types of accidents, the percentage of conflicts on sidewalks, pedestrian and bicycle crossings, and bicycle paths or lanes and on carriageways, as well as factors such as rider demographics (age and gender) and the effects of speed and alcohol.

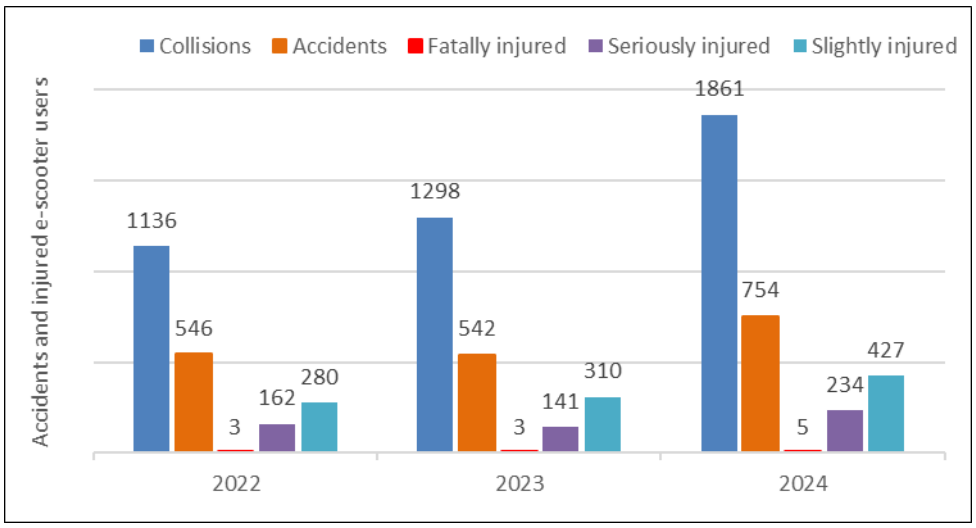

Fig. 1. Collisions, accidents and victims among e-scooter users in Poland by injury severity (2022-2024) [6]

From 2022 to 2024, there were 4295 collisions and 1842 accidents involving e-scooters in Poland, resulting in 11 fatalities and 1565 injuries, including 537 serious injuries, among e-scooter users (Fig. 1, Table 2). In those accidents, in addition to e-scooter users, other road users were also affected: two pedestrians were killed, and 90 pedestrians, 128 cyclists and 39 victims in other vehicles were injured. The trend in the number of collisions, accidents, and injuries is increasing from year to year.

Table 2

E-scooter accidents by location, type, and cause or fault (2022-2024) [6]

	No. of accidents		Fatally injured	Seriously injured	Slightly injured	Total	KSI%
Location of accident							
Carriageway	549	30%	8	206	323	537	39.9%
Footpath/sidewalk	415	23%	0	92	176	268	34.3%
Cycle crossing	340	18%	0	100	230	330	30.3%
Bicycle path, bicycle lane	328	18%	2	82	163	247	34.0%
Pedestrian crossing	138	7%	1	37	85	123	30.9%
Other	72	4%	0	20	40	60	33.3%
Type of accident							
Collision of vehicles in traffic: front, side or rear impact	1108	60%	8	324	683	1015	32.7%
Rollover of vehicle	373	20%	2	154	225	381	40.9%
Hitting a pedestrian	205	11%	0	10	18	28	35.7%
Hitting an object on road	61	3%	0	18	43	61	29.5%
Other	95	5%	1	31	48	79	40.5%
Cause or fault of the e-scooter driver							
Failure to give priority to a vehicle	544	30%	3	43	83	129	35.7%
Excessive speed	373	20%	3	133	185	321	42.4%
Improper maneuvers (overtaking, passing, turning)	311	17%	2	29	62	93	33.3%
Improper use of bicycle crossing	298	16%	0	2	5	7	28.6%
Not yielding at pedestrian crossing	117	6%	0	2	4	6	33.3%
Other fault	117	6%	0	29	53	82	35.4%
E-scooter driver under the influence of alcohol	226	12%	0	75	113	188	39.9%
Total	1842	100%	11	537	1017	1565	35.0%

KSI = killed and seriously injured

Table 2 presents the distribution of e-scooter accidents by location, crash type and cause of accident, as well as the distribution of victims by injury severity. E-scooter crash locations indicate the carriageway as the most frequent site for reported accidents in Poland (30%) and especially for fatal accidents, with eight persons killed in three years. According to the literature, 50% of accidents involving e-scooters occurred in mixed-traffic environments (carriageways). Roughly 23% of e-scooter crashes in Poland occurred on sidewalks, compared to 14% in other countries, according to Mitropoulos et al. [11], which indicates a high frequency in Poland at this location. Poland has the same frequency (25%) of e-scooters' crashes at pedestrian and bicycle crossings (at intersections) as other countries [11].

About 18% of accidents occurred on bicycle lanes over three years. The primary type of accident involving e-scooters is colliding with other vehicles, which accounted for 1108 incidents (60% of the total). These collisions resulted in eight deaths and 1007 injuries, with 324 of those injuries classified as serious. The high risk of serious injury at this location is confirmed by the highest KSI percentage. Most studies show that hitting another vehicle in traffic is the main type of accident in which e-scooters are involved (62%), followed by falling off or rollover (22%) and hitting a pedestrian (9%) [11]. According to Polish data, the frequencies of these accident types are 60%, 20%, and 13%, respectively. The KSI percentage value is the highest (40.9%) for rollover, indicating that this is the riskiest type of accident.

Rider-related faults, such as failure to yield to oncoming vehicles, excessive speed (20% in Poland versus 30% in international studies), improper use of bicycle lanes, and other dangerous maneuvers,

contributed to 1526 accidents. These faults led to eight fatalities, 542 injuries, and 207 serious injuries from 2022-2024 (Table 2). High KSI percentages for excessive speed and alcohol influence indicate that these two causes of accidents are the highest severe injury risk factors. In Poland, 12% of crashes were caused by drunk riders of e-scooters. This rate in Poland is much higher than that mentioned in Shah et al. [16] on shared e-scooters, indicating 4% accidents related to alcohol consumption. What is most disturbing is comparing 12% crashes caused by drunk riding e-scooters to 7% of accidents caused in Poland by drivers/riders of all other vehicles under the influence of alcohol. High numbers of e-scooter users riding under the influence of alcohol require more enforcement and public awareness campaigns to highlight the risks of alcohol use.

Table 3 presents distributions of e-scooter user victims by age groups and gender by injury severity. The age group most frequently involved in these accidents was individuals aged 25 to 34, who accounted for 364 total victims (23%), with one fatality, 131 serious injuries and 232 slight injuries. KSI percentages indicate that injury severity generally increases with age, reaching 53.8% of fatally and seriously injured people among those above 65 years. Another age group with a high risk of serious injury is those aged 7-9 years.

Men were more often injured in accidents than women, with 1056 male victims (67%) and 502 female victims (32%). Among the 11 fatalities recorded in Poland, 10 were men and only one was a woman. KSI values also indicate that men have a higher risk of serious injury. An international study report on e-scooter crash victims by gender showed 70% males and 30% females [11], which is similar to the Polish finding.

Table 3

Distribution of e-scooter user victims by age, gender, and injury severity (2022-2024)

	Fatally injured	Seriously injured	Slightly injured	Total victims		KSI%
Age						
0-6	0	0	2	2	0%	0.0%
7-9	0	8	13	21	1%	38.1%
10-14	1	69	182	252	16%	27,8%
15-17	1	52	102	155	10%	34.2%
18-24	1	77	173	251	16%	31.1%
25-34	**1**	**131**	**232**	**364**	**23%**	**36.3%**
35-44	3	111	189	303	19%	37.6%
45-54	2	45	64	111	7%	42.3%
55-64	2	23	41	66	4%	37.9%
>65	0	21	18	39	2%	53.8%
Unknown	0	0	1	1	0%	0.0%
Total	11	537	1017	1565	100%	35.0%
Gender						
Men	10	385	661	1056	67%	37.4%
Women	1	149	352	502	32%	29.9%
Unknown	0	3	4	7	0%	42.9%
Total	11	537	1017	1565	100%	35.0%

KSI = killed and seriously injured

As shown in Fig. 2, most e-scooter accidents occurred between 12:00 and 19:00, totaling 998 accidents, which represents 54% of the total. A smaller morning peak is visible between 7:00 and 9:00, with 184 accidents (10%). Notably, all fatalities occurred during the daytime.

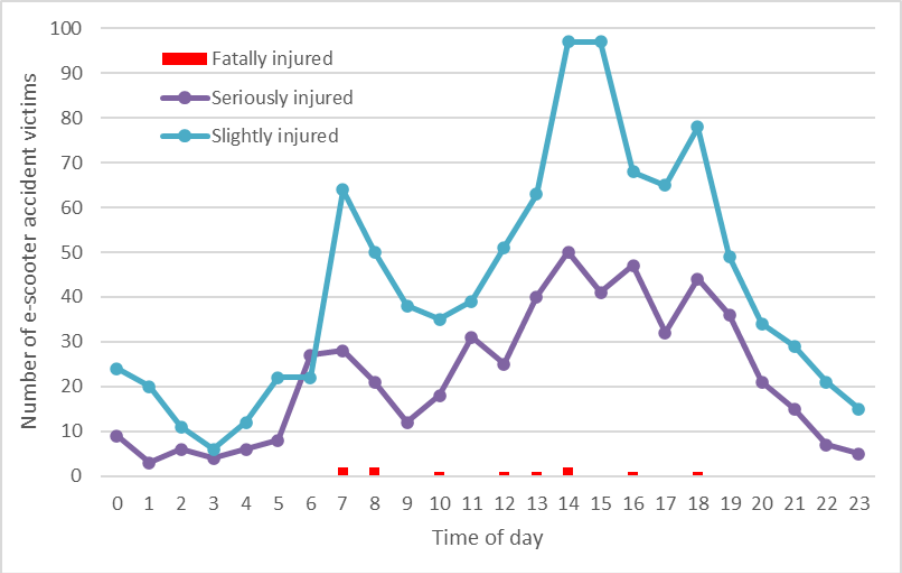

Fig. 2. E-scooter user accident victims in Poland (2022-2024) by time of day

Most e-scooter accidents (1462, 79%) and all fatal injuries in Poland occurred during daylight, with 78% (771) slightly injured and 81% (435) seriously injured. The distribution of e-scooter crashes by lighting conditions in Poland differs from international data, which indicate that 52% of them took place during daylight and 48% occurred at night [11].

Fig. 3 presents the distribution of e-scooter accidents and victims in Poland by month. As expected, e-scooter use is seasonal: a great majority of accidents occurred between May and October, as 1462 accidents (80% of all e-scooter-related incidents) were reported during these six months.

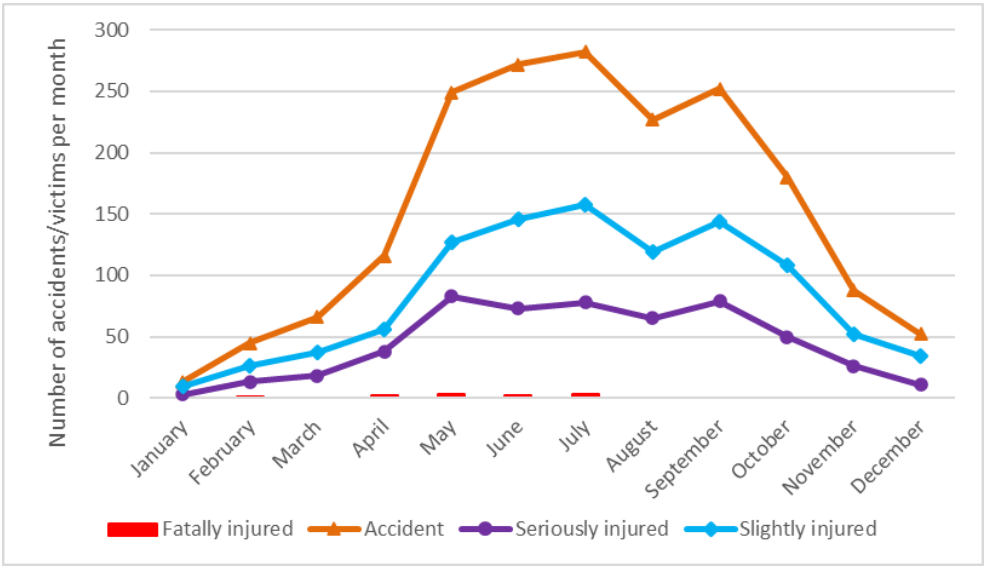

Fig. 3. E-scooter user accidents and victims in Poland (2022-2024) by month [6]

Fig. 4 presents the average number of e-scooter accidents for 3 years (2022-2024) among the 21 largest Polish cities against urban area populations. Numbers of accidents are not proportional to the population, perhaps because different numbers of e-scooters are available for rent and due to other factors such as topography. Kraków recorded the highest number of e-scooter-related accidents, with 228 incidents in three years. Warsaw, which has a 2.3-times larger population, reported only 149 accidents during the same period.

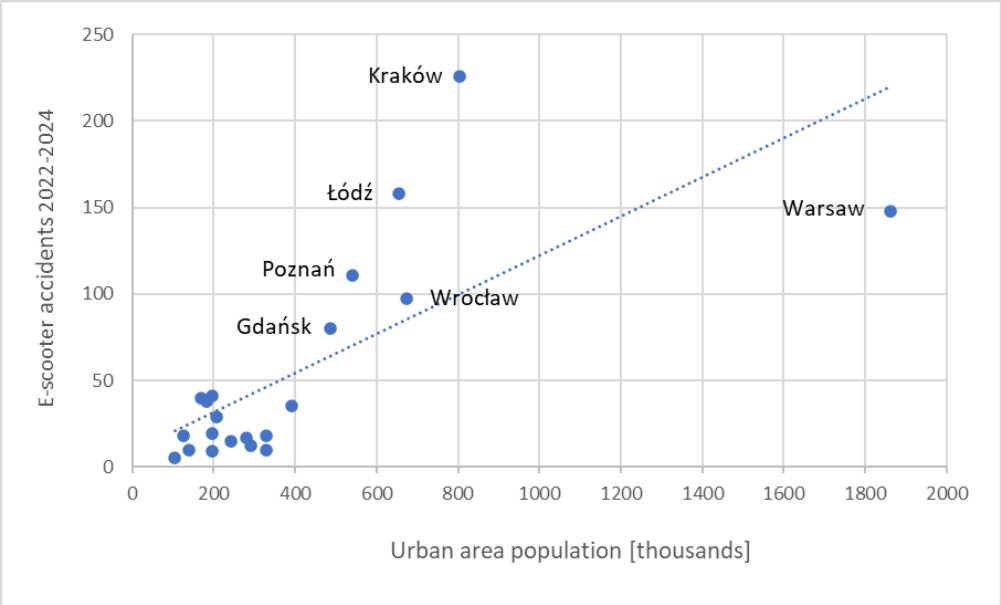

Fig. 4. E-scooter accidents in cities vs. urban areas from 2022-2024 [6]

5.2. User behavior of e-scooter riders in Poland in 2022

The Motor Transport Institute surveyed e-scooter user behavior for the National Road Safety Council in Poland in 2022 [25]. This study monitored e-scooter users' traffic behavior, emphasizing aspects such as vehicle speed, hazardous distances between vehicles, and the use of passive safety devices, including items like helmets and reflective vests.

For speed analysis, data on 1171 e-scooters (559 on bicycle lanes and 612) and 22 other motorized devices (14 on bicycle lanes and eight on sidewalks) were collected. During speed measurements on a sample of 1193 users of those micromobility devices, the instantaneous speed and the timing of each vehicle's appearance at the survey cross-section were recorded.

The data allowed for the calculation of the average speeds of two types of vehicles: e-scooters and other motorized micromobility devices (defined in Section 2). The average for both device types was 20.6 km/h, with 54.2% of vehicles exceeding the speed limit and 1.6% maintaining dangerously close distances, measured by the gap between two vehicles. Incidents of speeding were more prevalent on bicycle lanes compared to sidewalks.

According to the 2021 amendment to the Polish Road Traffic Law, the maximum travel speed limit for e-scooters and other motorized micromobility devices is 20 km/h. This limit was applied to calculate the proportion of speed violations. A second parameter calculated was the share of violations exceeding the speed limit by more than 4 km/h. The findings reveal that 58% of e-scooter and other motorized micromobility device users exceeded the speed limit on bicycle lanes, with 20.9% exceeding the limit by more than 4 km/h. On sidewalks, 50.5% of users exceeded the limit, and 14% reached speeds over 24 km/h. The average speed was 21.1 km/h on bicycle lanes and 20.2 km/h on sidewalks, with only 20% of users maintaining speeds below 18 km/h. Additionally, 3% of users traveled at speeds exceeding 30 km/h. Unlike muscle-powered bicycles, the electric motors of e-scooters and other motorized micromobility devices provide high acceleration and rapid speeds.

Data from 1765 e-scooters were collected to evaluate the use of passive safety devices, such as helmets. Only 6% of e-scooter riders wore helmets, with helmet usage being more common among privately owned scooters compared to rented ones. Despite regulations requiring helmets for rental e-scooter users, compliance with this requirement was low. Among the 1765 observed e-scooter riders, 973 were observed at night, of which only 5% wore reflective vests or other reflective materials. The study was conducted in cities where most streets are adequately lit, limiting visibility issues typically

encountered in less urbanized areas. The primary aim of this study was to provide statistical and behavioral insights into e-scooter usage and its impact on road safety. The data collected are essential for effective monitoring, programming, and evaluating initiatives aimed at improving road safety in Poland. The findings are crucial for supporting the National Road Safety Council's efforts to enhance safety on Polish roads. Based on these results, further actions to improve e-scooter safety should be incorporated into the National Road Safety Program for 2021-2030.

6. CONCLUSIONS

Accident statistics analysis and observations of e-scooter users' behavior presented in this article show that the rise in popularity and availability of electric scooters (a 400% increase in the number of shared e-scooter devices in Poland between 2020 and 2022) has increased the risks faced by this group of road users. An analysis of road safety data shows that in 2024, compared to 2022, there was an increase in collisions by 64%, accidents by 38%, fatalities by 67%, and serious injuries by 44%.

The percentage of killed and seriously injured (KSI) was adopted as an indicator of serious injury risk for individual categories of accidents and victims to assess the most important accident risk factors of e-scooters. An in-depth analysis of KSI of e-scooter users between 2022 and 2024 indicated that the highest risk factors were:

- accident location: carriageways, with the highest KSI percentage of 39.9%
- type of accident: rollover, with the highest KSI percentage of 40.9%
- cause of accidents: excessive speed with the highest KSI percentage of 42.4% and alcohol influence, with a KSI of 39.9%
- age: above 65 years, reaching a KSI percentage of 53.8%, and 7-9 years old
- gender: men have a clearly higher risk of serious injury than women (KSI = 37.4% vs. 29.9%)

Data from user behavior surveys in 2022 revealed that the average speed of e-scooters and other motorized micromobility devices was 20.6 km/h. Notably, 54.2% of vehicles exceeded the speed limit. The average speed recorded on bicycle lanes was 21.1 km/h, while on sidewalks the average speed was 20.2 km/h. Alarmingly, the use of passive safety devices among e-scooter riders was very low, with only 6% wearing helmets and just 5% using reflective vests or other reflective materials at night. The visibility of e-scooter riders, particularly at night, is a major concern in areas outside built-up zones.

As e-scooters become an increasingly popular mode of urban mobility, they require heightened attention and improved safety measures on the roads. The European Transport Safety Council (ETSC) [10] has recommended several key measures for enhancing e-scooter safety: setting a factory speed limit of 20 km/h, using larger wheels, banning riding with passengers and riding on sidewalks, mandating helmet use, establishing a minimum rider age requirement of 16 years and implementing parking regulations to ensure that e-scooters do not obstruct pedestrian pathways. Some of these recommendations have been adopted in Poland, such as the speed limit of 20 km/h, banning riding with passengers, a minimum age requirement of 10 years old and parking regulations. E-scooter riders are allowed to ride on sidewalks, but they must give priority to pedestrians. In line with the ETSC recommendation, legislative action has been taken recently (July 2025) to introduce the obligation for children and adolescents under 16 years old to wear a helmet when riding an electric scooter, bicycle, or motorized micromobility device. This action is carried out indirectly due to the findings of this study.

Given the rising number of casualties and injuries in Poland, there is an urgent need to tighten e-scooter regulations. Separating vulnerable road users from motor vehicles, enforcing appropriate speed limits, addressing drink-driving, and prioritizing education and training are essential for creating a safer urban environment for all road users, including e-scooter riders.

The article aimed to publicize findings from new data on e-scooter riders on Polish roads that affect road safety. Statistical analyses of accident data show that speed measurements and user behavior surveys provide information for the effective monitoring, programming, and evaluation of actions to improve road safety in Poland. Based on the conclusions, it is possible to undertake additional actions and

projects aimed at improving the safety of users of e-scooters and other motorized micromobility devices in the Implementation Programs of the Polish National Road Safety Program for 2021-2030 [26].

The increasing number of accidents and injuries involving e-scooters in Poland requires further long-term analysis, focusing on the number of trips and kilometers traveled in the largest cities. Further analyses of data on the types of injuries sustained by e-scooter users collected by hospitals are underway.

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