European Commission

Thematic Report

Personal Mobility Devices

Mobility and Transport

This document is part of a series of 20 thematic reports on road safety. The purpose is to give road safety practitioners and the general public an overview of the most important research questions and results on the topic in question. The level of detail is intermediate, with more detailed papers or reports suggested for further reading. Each report has a 1-page summary.

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Version	December 2024
Author	Original: Freya Slootmans (Vias institute) Update: Maartje de Goede (SWOV)
Internal Review:	Dimitrios Nikolaou (NTUA)
External Review:	Philippe Crist (ITF/OECD)
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Summary

Personal mobility devices (PMDs) have seen a market boom in recent years. These vehicles are seen as an easy way to travel around the city, and they contribute to solving the "last-mile" problem. This report focuses mainly on electric scooters (e-scooters). Shared e-scooters are mainly used for leisure activities, during the weekend and by young men. Privately owned e-scooters are more often used for commuting. A high proportion of crashes with a PMD are caused by falls. The most common injuries for (shared) e-scooter users are head injuries, followed by fractures of the lower and upper limbs, soft tissue injuries, and injuries and fractures of the face and neck. Increasing helmet use would prevent head injuries.

The vast majority of crashes involving an e-scooter do not involve another road user. However, the most severe casualties (over 80% of e-scooter rider deaths and 50% of trauma patients' injuries) result from crashes that do involve a heavier motor vehicle.

To develop safe infrastructure for micro-mobility, research suggests that e-scooters should be banned from pavements. Cycle paths need to be wide enough to allow different types of vehicles to use this infrastructure together safely. Adequate lighting conditions of the used infrastructure would also add to safety. Ideally, designated parking spots for e-scooters should be created.

A number of characteristics of the vehicle can pose a threat to road safety. Setting universal technical requirements for e-scooter design could reduce this risk. Replacing narrow, hard wheels with wider and softer wheels would reduce the likelihood of users falling when there are bumps on the road. A wider platform also provides greater stability. In addition, improvements to shock absorbers are needed to avoid falls caused by potholes or other road bumps. PMDs would be safer with direction indicators, a sound signal, rear-view mirrors, and reflective materials. A minimum value for the braking deceleration and maximum value for acceleration as well as two independent braking devices, at least one of which works independently of the vehicle's electrical system, are recommended. Anti-sabotage measures' as well as protection against electromagnetic inference as well as moisture ingress are reported measures to ensure that the controllability of the vehicle is not affected.

Active enforcement of the legal blood alcohol content, speeding, and positioning on the roadway is advisable. Speed is also a key factor wherever vulnerable road users such as e-scooter users mix with motor vehicles, therefore lower speed limits such as a 30 km/h limit in urban

areas could bring safety benefits. It has been suggested that micro-mobility vehicles need to operate in a regulatory framework that defines where they can be used, at what speed, after which training, as of what age and in compliance with which safety rules.

As e-scooter users are often injured during their first ride, training is important. In order to oblige PMD users to ride only where they are allowed, geofencing could be used. Training motor vehicle users to be prepared to interact with PMDs is equally important.

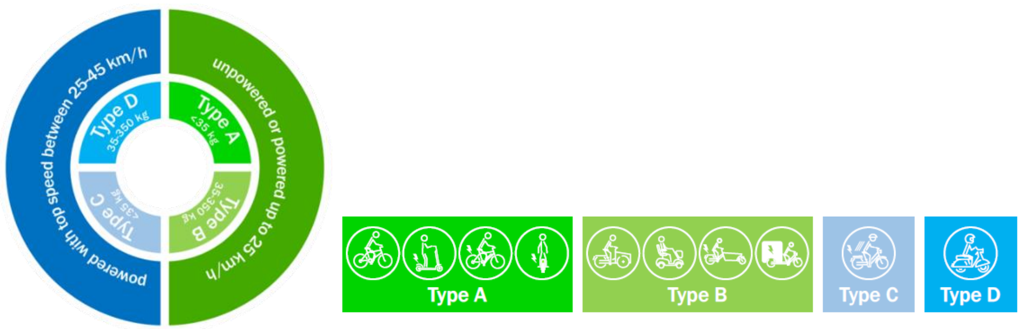
1. What is the problem?

Personal Mobility Devices (PDMs) can be defined as compact, motorised micromobility vehicles designed for individual transportation. These include electric scooters, electric bikes, electric skateboards, kick-scooters, self-balancing unicycles, and Segway-type scooters(European Commission et al., 2024). They have become popular for both recreation and practical urban transportation and provide a relatively new form of urban mobility solution. Besides their practical value they also bring about new challenges for the traffic system, since they entail new driving characteristics which need to be fit into the existing traffic system.

1.1 Definition

Since in general, existing (inter)national categorisations of PDMs are not developed from a safety perspective and do not easily lend themselves to incorporate new form factors, the OECD/ITF (OECD/ITF, 2020, 2024) proposed a classification according to maximum speed and/or their weight see Figure 1).

Figure 1. *Definition of personal mobility devices / micromobility (Source: OECD/ITF, 2024)*



Type A and Type B vehicles, such as electric bikes, kick-scooters, hoverboards, unicycles, e-scooters, Segway-type scooters, skateboards, roller blades, et cetera, travel up to a maximum speed of 25 km/h. Type C and type D vehicles include for example speed pedelecs and mopeds (OECD/ITF, 2020, 2024). We will only consider powered type A and type B PMDs in the remainder of this thematic report. Especially popular are shared e-scooters, which were first introduced in the United States in September 2017 (Alwani et al., 2020).

Some PMDs are relatively new types of vehicles, which means the number of scientific studies on these modes of transport is limited. A large proportion of those studies concerns e-scooters. Since most knowledge is available on e-scooters, this report will mainly focus on this type of vehicle. We will make a distinction between PMDs in general and e-scooters wherever possible. When discussing e-scooters, this mainly concerns shared e-scooters rather than privately owned e-scooters. Shared e-scooters are e-scooters that are made available by companies such as Lime and Bolt which can then be rented by users. Electric bikes are not included in this report, but see European Commission (2024).

1.2 Legislation

In recent years, legislation for e-scooter use has been put in place in several Europe countries. Since 2019 regulations have been developed to improve safety for riders and other road users. Based on data of the European Transport Safety Council (ETSC) (2023) the legal status and safety regulations of the e-scooters within European countries are mapped out in Table 1.

Table 1. *Overview of legal status and safety regulations in European countries*

Country	E-scooter permitted	Min age	Max speed (km/h)	Max power	Allowed on pavements	Drink-ride limit (per millage)	Helmet required	Mandatory insurance
Austria	Yes	12	25	600	No	0.8	<12yr	No
Belgium	Yes	16	25	-	No	Same as car	No	No
Bulgaria	Yes	16	25	-	Yes	-	<18yr	No
Czechia	Yes	n/a	25	250	<10y	0.0	<18yr	Yes
Denmark	Trial	15	20	-	No	0.5	Yes	Yes
Finland	Yes	No	25	1,000	No	No	Yes	No
France	Yes	12	25	-	No	-	On 80km/h roads	Yes
Germany	Yes	14	20	500	No	0.5, 0.0 for <21 yr	No	Yes

Country	E-scooter permitted	Min age	Max speed (km/h)	Max power	Allowed on pavements	Drink-ride limit (per millage)	Helmet required	Mandatory insurance
Greece	Yes	15	25	-	Yes	No	Yes	No
Hungary	Yes	16	20	300	No	0.0	Yes	-
Iceland	Yes	n/a	25	-	No	0.0	<16yr	No
Ireland	Yes	16	20	400	No	0.2 – 0.5	No	No
Italy	Yes	14	20	500	No	-	<18yr	No
Luxembourg	Yes	n/a	25	250	<10yr	-	No	No
Netherlands	No	-		-	-	-	-	-
Norway	Yes	12	20	No limit	Yes	0.2	<15yr	Yes
Poland	Yes	10	20	-	Yes	0.0	No	No
Portugal	Yes	No	25	1,000	< 10y	-	No	No
Slovenia	Yes	14	25	-	No	-	<18yr	-
Spain	Yes	14-16	25	1,000	No	0.5, 0.0 for <21yr	Yes	No
Sweden	Yes	NA	20	250	NA	-	<15yr	-
Switzerland	Yes	16	20	500	No	0.5	No	No

There are currently substantial differences between European countries with respect to the legal status and related behavioural rules governing micromobility. Only the Netherlands do not (yet) permit the use of e-scooters in public spaces. In Denmark e-scooters are allowed as part of a trial. In most countries, e-scooter riders have to use the bicycle infrastructure. They are allowed on the pavement in only four countries: Bulgaria, Greece, Poland and Norway. Maximum speeds on the pavement apply in Greece (6km/h), Norway (6km/h) and Poland (pedestrian speed).

Furthermore, the ETSC data indicate that e-scooter riders are obliged to have legal liability insurance only in Czech Republic, Denmark, France and Germany. A helmet is obligatory for 7 countries (children and youngsters), whereas only in Denmark, Finland, Greece and Spain a helmet is required for all riders. Age restrictions apply for the use of an e-scooter in 14 of the 22 reported countries: the minimum age ranges from 10 to 16 years old. In all countries there is a maximum speed limit of 20 km/h or 25 km/h.

In the context of a stakeholder discussion, the European Commission suggested that "Micro-mobility vehicles need to operate in a regulatory framework that defines where they can be used (e.g. roads, bike lanes, pavements, pedestrian areas, 30 kph areas), at what speed, after which training, as of what age and in compliance with which safety rules (e.g. protective equipment, lights, turn signals, etc.)" (European Commission, 2019).

1.3 Advantages and disadvantages

One of the potential advantages of PMDs is that they can contribute to solving the "first- and last-mile problem". The first and last mile are the first and last legs of people's journeys within a city — as they access public transport or after they park their car, come off a bus or metro, or simply make a quick trip to the corner shop, etc., — which is considered too long to walk (Allem & Majmundar, 2019). Some of the other benefits often mentioned are low cost, accessibility, and avoiding traffic jams by using cycle paths and pavements (Alwani et al., 2020; Nisson, Ley, & Chu, 2020). The minimal physical effort makes them easier to use than, for example, a bicycle. E-scooter users do not sweat while riding, so they can easily ride in office clothing (Tuncer & Brown, 2020b). It is also a more environmentally friendly mode of transport compared with motor vehicles (Gössling, 2020; Sikka, Vila, Stratton, Ghassemi, & Pourmand, 2019). Notably, the environmental impact of e-scooters depends on ownership, showing a lower impact for privately owned e-scooters compared to shared e-scooters (ITF, 2024). The International Transport Forum at the OECD has looked at research in cities across the world and concludes that the shift in transport mode from car/taxi to shared e-scooter use is somewhere between 8% (France) and 50% (Santa Monica, United States). The lowest figures were observed in Europe and New Zealand, the highest figures in the United States. The authors say: "This most likely reflects the varying levels of car use across the world. In a city with very low car use, it is only natural that a very small fraction of e-scooter trips replaces car trips." (OECD/ITF, 2020, page 31) (see also 2.1).

Although many are convinced of the advantages of this mode of transport, questions also arise about the disadvantages and dangers of PMDs. These vehicles are also seen as a road safety challenge and a danger to other public space users (Cha Sow King et al., 2020; Gössling, 2020). E-scooters were introduced to circumvent busy traffic, but several studies show that they lead to an increase in the number of injuries (Bresler et al., 2019; Cha Sow King et al., 2020; Kobayashi et al., 2019; Trivedi et al., 2019). From 2019 to 2022 a 185% increase in admissions of e-scooter riders to major trauma centres in France was reported (A. James et al., 2023). For comparison, for bikes (conventional and electrical) an increase of 24% was reported. Clough, Piatt, Cole, Wilson, and Aylwin (2023) reported for England and Wales fatality rates of 2.7% among e-scooter riders versus 1.7% among cyclists after experiencing major trauma.

PMDs share the same space as pedestrians, cyclists, and motorised traffic. They have a higher mass than pedestrians and move at higher speeds. This means that there are consequences for pedestrians if they share footpaths with them. When e-scooters ride on footpaths, although forbidden in most countries in Europe, this can be risky for pedestrians (Sikka et al., 2019). PMDs are very quiet vehicles, and they do not have the same powerful lighting as cars and motorbikes. This makes them particularly difficult for pedestrians to anticipate, especially for seniors and the hearing impaired (Nisson et al., 2020). On the other hand, when sharing the road with motorised vehicles, it is the PMD user that is at particular risk given the large difference in mass and speed. Furthermore, critics argue that PMDs will make people walk less.

Looking at shared e-scooters in particular, it must be noted that despite the fact that there is an increase in designated parking spaces, users still simply leave their e-scooters on the pavement, blocking the way for pedestrians (Gössling, 2020; Jiao & Bai, 2020). The OECD/ITF (2024), therefore, recommends that consistent parking guidelines should be formulated, to ensure that PDMs do not impede pedestrians and to contribute to safer urban environments. Moreover, irresponsible behaviour (speeding, using the pavement, random parking, etc.) and vandalism (damage caused, for example, by throwing down the e-scooter) are also factors that often gain media attention (Gössling, 2020).

Finally, there are also drawbacks in the actual design of the e-scooter. The standing posture, the fork-steerer column angle , the narrow width of the foot platform as well as the small (solid rubber) wheels contribute to the relatively low stability of these vehicles (European Commission et al., 2024; OECD/ITF, 2024). Visibility and audibility, which is paramount for the safety of e-scooter riders and surrounding traffic of e-scooters is very limited. In a study in which rental e-scooters are compared to privately owned e-scooters, it was shown that the lighter e-scooters made for private use are often more unsafe that the heavier rental ones (Li, Kovaceva, & Dozza, 2023) Rental scooters often have larger wheels, better steering and braking capacities and better suspension systems. Compared to bicycles, overall e-scooters require a longer braking distance. This implies that e-scooters need more time to come to a safe stop in emergency situations (Dozza, Violin, & Rasch, 2022). E-scooters also have faster acceleration which can lead to dangerous situations, especially for inexperienced users (European Commission et al., 2024).

2. How PMDs participate in traffic

2.1 Usage

Degele et al. (2018) have studied the length of shared e-scooter trips in Germany. They calculated that 5% of journeys with a shared e-scooter were up to 1 km long, 25% between 1 and 3 km and 33% between 4 and 6 km. In another third of the journeys, the shared e-scooter was used for a distance greater than 6 km. They conclude that the shared e-scooter is not just a 'last mile' mode of transport. Commuters who need to get from A to B on time find it difficult to rely on shared vehicles scattered haphazardly throughout the city. Logically therefore it is more likely that shared e-scooters will often be used by tourists and casual users (Tuncer & Brown, 2020).

Shared e-scooters can be an alternative to the less environmentally friendly use of a car. However, research in New Zealand (Fitt & Curl, 2019) shows that 52% of the 591 people surveyed would have walked if they had not used the shared e-scooter for their most recent trip, 11% would not have made the journey at all, and 6% would have used a bicycle or skateboard. So, for 69% of trips, the shared e-scooter does not appear to have replaced the car. Respondents who had used a shared e-scooter more than once were more likely to have replaced a car trip with a shared e-scooter trip. Research from the United States shows similar trends: about a third of shared e-scooter users would have used the car if there had not been an e-scooter, but about half of them would have walked or cycled instead (Zagorskas & Burinskienė, 2019). E-scooters and other PMDs are not just replacing the car but public transport, walking and cycling as well Data from VOI[1] and the UK rental e-scooter trials (all operating in England) (UK department of Transport, 2022) show that the following percentages of replacement by e-scooter journeys: walking:36-42%, cycling:10-12%, public transport: 18-30% and car & taxi journeys: 12-21%. Overall, it can be concluded that a modal shift to e-scooters is largely dependent on the existing travel mode distribution. Where there is a lot of walking and public transport use, e-scooters will replace a large share of these trips.

There are also considerable differences in usage between owners of private scooters and users of sharing schemes. Riders who own their own vehicle use the e-scooter more often compared to riders who rent an e-scooter. Furthermore, e-scooter renters are mostly replacing walking trips, while e-scooter owners are showing a considerable mode-shift away from private car trips (Laa & Leth, 2020).

[1] https://www.voi.com/blog/impact/

Shared e-scooters are mainly used (a) to ride through the city for leisure activities, and (b) when there is little time pressure, but less so for commuting (Tuncer & Brown, 2020). According to Tuncer & Brown (2020), the pleasure of riding an e-scooter, but also the feeling of freedom and continuous movement and the minimum amount of effort involved, are important motivations for using a shared e-scooter, as is optimising travel time. First-time users usually rent an e-scooter for fun, and while later use is probably still motivated by pleasure, regular users also notice the practical advantages such as how much faster it is to travel with an e-scooter compared to other means of transport (Fitt & Curl, 2019).

Analysis of usage data in the United States shows that there is a peak in the renting of e-scooters during the weekend, mainly on Saturdays. On weekend days, the average distance covered in one trip is greater than the average distance on weekdays, but the speed is lower on weekend days. On weekdays, there is a peak in the use of the e-scooter at 1 pm and 5 pm. On weekend days the peak is different: most users start their trip after 11 am and use remains high until late in the afternoon (Jiao & Bai, 2020; Noland, 2019).

2.2 Users

Surveys of e-scooter users (renters and owners) and analysis of user data show that e-scooters are mainly used by young, employed men (Christoforou, Gioldasis, de Bortoli, & Seidowsky, 2021; Laa & Leth, 2020; OECD/ITF, 2020). There is also a significant proportion of users between 45 and 50 years old. This age group covers longer distances in a single ride. Usage tails off after 45-50 years of age (Fitt & Curl, 2019; Jiao & Bai, 2020).

3. PMDs and road safety

3.1 Underreporting of crashes

Since PMDs are a relatively new vehicle category, most often these type of vehicles are not yet, or only have been recently, been included as a distinct vehicle category in road traffic crash registrations (SWOV, 2021). Most data have been collected for hospital records, which do not always provide details on the crash itself. Furthermore, these records do not give a reliable indication of the number of crashes that happen with a PMD, since these records do not cover non-injury or mild injury crashes/incidents.

3.2 Crash risk

Like pedestrians, PMD users tend to have higher per-kilometre crash casualty rates than motorised vehicles, but not necessarily per trip. This is because a typical pedestrian or PMD trip is much shorter than, e.g., a car trip (OECD/ITF, 2024). Bruneau and Maurice (2012) looked at the risk pedestrians and different types of PMDs pose to others. They concluded that the risk of pedestrians injuring others is low, while the risk of powered e-scooters injuring others is medium, as is the risk to skaters, skateboarders, and people using push-scooters.

This is supported by more recent research[2] (based on crash tests) that indicates that in the event of a collision between an e-scooter and a pedestrian, the pedestrian is likely to be more seriously injured than the e-scooter rider.

Based on fairly recent available data, it appears that shared e-scooter risk overall has diminished in Europe and the US. It is however unclear whether this decrease in risk is due to changes in safety or changes in exposure (OECD/ITF, 2024). Table 2 provides an overview of casualties requiring medical treatment per million shared e-scooter trips across various European countries.

Table 2. *Shared e-scooter casualties requiring medical treatment per million trips, based on available data (Source: Micro-Mobility for Europe (MMfE) 2023a. Incident Data Involving Shared E-Scooters)*

Country	2021	2022	Delta
Austria	4.1	1.5	-63.6%
Belgium	7.1	7	-1.8%
Czechia	9.2	15.6	69.3%
Denmark	8.6	14.8	72.3%
Finland	5	2.9	-41.6%
France	9	12.1	34.8%
Germany	4.3	4	-7.7%
Italy	12.1	4.4	-63.3%
Norway	3.2	2.7	-17.5%
Poland	4.9	4.5	-8.0%
Portugal	22.3	25	12.0%
Spain	22.4	14.8	-34.1%
Sweden	5.2	5.3	0.5%
Switzerland	2.2	4.3	100.3%
UK	31.9	20.6	-35.7%
		Cumulative	-25.7%

[2] Testing by UTAC Millbrook for Tin Man Communications on behalf of Guide Dogs UK

3.3 Types of crashes

The few studies on crashes involving PMDs in general show that many of these crashes are self-caused, probably at least partly due to unskilled driving and that the proportion of crashes with a pedestrian or cyclist is low (Cha Sow King et al., 2020; Lee, Kim, & Kim, 2017).

The great majority of crashes with e-scooters only involves the rider and no other road users. According to Toofany, Mohsenian, Shum, Chan, and Brubacher (2021) these single-road user crashes account for almost 93% of all reported e-scooter related injuries. Reported causes are falls, collisions with stationary objects, loss of control etc. Across different studies it appears that 8 up to 19% of all e-scooter related injuries result from a collision with a motorised vehicle, whereas more than 80% of all e-scooter fatalities are caused by these types of collisions (National Traffic Safety Board, 2022; OECD/ITF, 2020, 2024).

3.4 Types of injuries

Types of injury have been mapped out in various hospital studies. Cha Sow King et al. (2020) studied crashes involving a PMD in an emergency department in Singapore. Most patients were injured in a crash involving an e-scooter, but they also encountered crashes with skateboards and powered bicycles. A large proportion of those patients arrived at the emergency department on their own and stayed for a couple of hours. Minor injuries were most common: external injuries, but also injuries to the upper and lower limbs. Most patients had been injured as a result of a fall.

Head injuries are by far the most common injury sustained in crashes with an e-scooter (Bauer et al., 2020; Beck, Barker, Chan, & Stanbridge, 2020; Benhamed, Gossiome, Ndiaye, & Tazarourte, 2022; Leyendecker et al., 2023) but records also often indicate fractures of the lower and upper limbs (Benhamed et al., 2022; Kobayashi et al., 2019; Leyendecker et al., 2023; Stormann et al., 2020), soft tissue injuries (such as abrasions and bruises) (Alwani et al., 2020; Badeau et al., 2019; Bekhit, Le Fevre, & Bergin, 2020; Liew, Wee, & Pek, 2020); and injuries and fractures of the face and neck (Bauer et al., 2020; Yarmohammadi et al., 2020).

3.5 Reported fatalities

The number of deaths resulting from an e-scooter crash is very low, but a significant proportion of patients require surgery or even end up in the intensive care unit (Dhillon et al., 2020; Liew et al., 2020).

Based on available data, estimates are that less than 1% of the injuries sustained by e-scooter riders are fatal (OECD/ITF, 2024)l.

3.6 Risky behaviours

From a road safety point of view there is considerable concern about the behaviour of PMD users. However, there is a dearth of data describing their actual behaviour. Where information is available, it relates primarily to cyclists and then to e-scooter users, but not other PMD users.

Hospital studies show that drink-driving is a problem among e-scooter users, just as it is among other road users (Leyendecker et al., 2023). The magnitude of the problem is unclear, but the percentage of e-scooter users in hospital who were under the influence of alcohol is higher compared to the number of car drivers hospitalised due to alcohol abuse (Badeau et al., 2019; Dhillon et al., 2020; Stormann et al., 2020; Yarmohammadi et al., 2020).

With regard to helmet wearing, the conclusions of various observational and hospital studies are unanimous: very few shared e-scooter riders wear a helmet (European Transport Safety Council (ETSC), 2023; OECD/ITF, 2024).

The OECD (OECD/ITF, 2020) indicates that only up to 7% of all e-scooter users had been wearing a helmet at the time of a crash. According to Tuncer & Brown (2020), e-scooter users consider riding without a helmet to be the norm and find it absurd to take a helmet with them. A study by Haworth and Schramm (2019) indicated a lower use of helmets among shared bikes and e-scooters compared to privately owned vehicles.

Che, Lum, and Wong (2020) found that pedestrians and cyclists feel safest when e-scooter users ride at a maximum speed of only 15 km/h. A virtual reality study showed that pedestrians feel safer when the e-scooter user overtakes at a maximum speed of 10 km/h. However, this was considered too slow by the participants driving an e-scooter (Che et al., 2020). The risk of instability is much higher at a speed of 10 km/h (Che et al., 2020). KFV (2020) has observed that e-scooter users in Austria travel at an average speed of 15,1 km/h, with the highest speed measured being 31 km/h.

Several studies show that e-scooter users do not always ride in the right place in urban environments. According to e-scooter users, motor vehicles drive too fast and are unpredictable, making them feel unsafe, and this is why they often ride on the footpath (Tuncer & Brown, 2020a). However, according to another study (Fitt & Curl, 2019), only half of the e-scooter riders feel that the footpath is a suitable environment for driving an e-scooter. Most of them think that cycle paths and quiet streets are more suitable. They think that the e-scooter is too fast to use near pedestrians, but on the other hand users also find it dangerous to ride on roads used by fast and heavy vehicles.

Finally, parking an e-scooter is not always carried out correctly. They should be parked so as not to obstruct other public space users, especially pedestrians. An observational study assessed just over 600 parked e-scooters: 16% were parked incorrectly, and 6% of the e-scooters blocked the footpath(O. James, Swiderski, Hicks, Teoman, & Buehler, 2019).

4. Countermeasures

Since a large part of the literature deals with e-scooters, most of the measures suggested apply to this type of vehicle. Wherever possible, we try to include measures aimed at all PMDs.

For e-scooters, poor road surface conditions, e-scooter speed, riders under the influence of alcohol or drugs, inexperienced users and lack of helmet use combined with the limited stability and high acceleration of an e-scooter contribute to the cause and severity of injuries. The OECD/ITF (2024) as well as the European Commission (European Commission et al., 2024) have developed recommendations which address these issues in relation to e-scooters' (lack of) safety. A great part of the recommendations below is based on the OECD/ITF report.

4.1 Infrastructure

The most important infrastructural issues in relation to micromobility are: the required space and a safe location (including lighting conditions) to ride, the quality of the road surface, and the parking of e-scooters. Concerning the location, in current traffic systems, there is no one-size-fits-all solution. In an ideal world, there would be special paths that separate PMDs from both pedestrians and motorised traffic (Fitt & Curl, 2019; European Commission et al., 2024; Nisson et al., 2020; OECD/ITF, 2020). PMD users themselves express a clear preference for cycle paths, but for safety reasons the design standards would have to be upgraded. However, cycle paths should be wide enough so that different types of vehicles can use this infrastructure together in complete safety. It is important that the road surface is smooth and well maintained. Damage to the road surface must therefore be repaired as quickly as possible (European Commission et al., 2024; OECD/ITF, 2020, 2024).

It is clear that parking zones need to be set up to prevent users from leaving their e-scooters wherever they like, thereby creating an obstacle for pedestrians and other road users. This requires consistent micromobility parking guidelines and delineated parking zones, with systematic enforcement. At the same time, these zones should not elicit illegal car parking and should allow sufficient space for operators' support vehicles (OECD/ITF, 2024).

4.2 Road users

Due to the vulnerability of PMDs, in areas with high micromobility traffic the speed limit should be 30 km/h. In places where micromobility riders are allowed or forced to use the footpath, speeds should not exceed 10 km/h, to enhance pedestrian safety.

Studies show that many e-scooter users are injured during their first few rides. The main reason mentioned is that they are surprised by the speed, acceleration and handling of the vehicle (Basky, 2020; Nisson et al., 2020; Vias, 2020). Training before the first ride can help, preferably combined with practice in a closed area under the supervision of authorised trainers (Vias, 2020). The safety of micromobility does not just depend on training PMD users: driver training for motor vehicle users is equally important, especially since most e-scooter fatalities are a result of a crash with a motorised vehicle (see Section 3.5) (OECD/ITF, 2020). Also a minimum age can help to prevent crashes due to experience (European Commission et al., 2024).

Head injuries are very common in PMD crashes and helmet wearing rates are currently low among PMD users (see Section 4.4). However, it has been argued that making helmet wearing compulsory for PMDs could make these vehicles less attractive in comparison to far more dangerous vehicles such as mopeds and motorcycles. An alternative might be to increase awareness of the need for a helmet, through both policy-makers and the micro-mobility companies themselves. "Nudging" can offer a way forward. For example, e-scooter users who share a photo of themselves with a helmet on could be rewarded by the company providing the e-scooter. Yet another option is to create new helmet designs with better portability. After all, a survey of e-scooter users showed that they found it difficult to carry the helmet with them. One example is folding helmets, which could be distributed by the companies renting e-scooters (Nisson et al., 2020). In addition, the relatively high incidence of face and jaw injuries warrants investigation whether e-scooter-specific helmets could be developed, providing protection against these types of injuries (OECD/ITF, 2024).

We have reported that users of e-scooters also often suffer fractures of the upper limbs when they are involved in a crash. Wrist guards, which have been shown to reduce the severity of fractures in roller skaters, could be recommended for users of e-scooters (Aizpuru et al., 2019; Liew et al., 2020).

4.3 Legislation and enforcement

Since alcohol seems to play a substantial role in e-scooter crashes (see Section 4.4), communication and active enforcement of the legal blood alcohol content should also include users of PMDs/e-scooters alongside other road users. Another option is for e-scooter sharing companies to install motion sensors on their vehicles to detect excessive wobbly motion and reduce the vehicle speed in situations where the rider is impaired by alcohol, drugs, a pillion rider or for any other reason (OECD/ITF, 2020)

Along with enforcement of rules on driving under the influence, better communication and enforcement of current legislation regarding speeds and positioning on roads and footpaths are recommended. With respect to exceeding speed limits, this may be exacerbated by the pay-per-minute tariff systems used when renting an e-scooter. This payment method is also an incentive to carry out dangerous manoeuvres, such as driving through a red light or not giving way to pedestrians. The time-dependent nature of the pricing system should be reduced: it could be complemented or replaced with a price-per-kilometre travelled, a price per journey, or even a monthly subscription (OECD/ITF, 2020, 2024).

With respect to positioning on roads, a technology called 'geofencing' could be used to oblige e-scooters to ride and park only where they are legally allowed (European Commission et al., 2024). Speed could also be regulated using geofences. A geofence is a set of digital boundaries, defined by geographical coordinates, that demarcate an area where specific regulations apply. Within these areas, speed can then be regulated automatically, but access to the area or parking within the area can also be prohibited. However, geofences only apply to shared e-scooters, and it is therefore impossible to regulate privately owned e-scooters (and other PMDs) in this way (Basky, 2020; Gössling, 2020).

4.4 Vehicles

E-scooter users are usually injured in the event of a fall. The stability of the vehicle is therefore a design priority. Setting universal technical requirements for e-scooter design could reduce this risk. Replacing small wheels with narrow and solid tyres with larger wheels with wider and more pliant tyres would reduce the likelihood of users falling when they encounter potholes or other obstacles. A wider foot platform also provides greater stability. In addition, improvements to shock absorbers are needed to avoid falls caused by potholes or other road bumps (Alwani et al., 2020; Nisson et al., 2020; OECD/ITF, 2024).

E-scooter riders have to keep both hands on the handlebar in order not to fall, which prevents them from sticking out their arm in order to signal the direction in which they want to go. Equipping e-scooters with a direction indicator can remedy this problem (Fitt & Curl, 2019; OECD/ITF, 2024). The addition of a bell or other sound signal to warn other road users is also recommended. The same recommendations apply to PMDs in general: they should be equipped with a sound signal and direction indicators, where riders cannot effectively signal their intent or presence. The addition of rear-view mirrors is also a consideration for PMDs. Moreover, they should be subject to safety tests and standards for the braking system, weight, dimensions etc.

In some countries, road users are required to wear fluorescent clothing when using an e-scooter. However, they often ignore this rule, and enforcing it seems difficult because of its low acceptance. It would therefore be more effective to impose the use of reflective material on the vehicles themselves (OECD/ITF, 2020).

KFV, which carried out braking test for commercially available e-scooters, recommends setting a minimum value for the braking deceleration at 4 m/s2. They also recommend two independent braking devices, at least one of which works independently of the vehicle’s electrical system (ETSC, 2020). A mandatory brake on every wheel would ensure that all available power is used to reduce speed and could improve stability under harsh braking. This also ensures that one can still brake when one brake fails. (European Commission et al., 2024) Next to minimum deceleration, in the report by European Commission et al. (2024) a maximum acceleration of 2 m/s2 is also suggested.

Finally, anti-sabotage measures as well as protection against electromagnetic inference as well as moisture ingress are reported measures to ensure that the controllability of the vehicle is not affected (European Commission et al., 2024)

5. Further reading

European Transport Safety Counsil (ETSC). (2023). *Recommendations on Safety of E-scooters*.
European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Guy, I., Beard, G., Smith, L., Jenkins, D. et al. (2024). Study on the need for harmonised rules to support the rise of micro mobility and increased road safety for personal mobility devices – Final report (1.0), Publications Office of the European Union. https://data.europa.eu/doi/10.2873/8572224
OECD/ITF. (2020). Safe Micromobility
OECD/ITF. (2024). Safer micromobility: Technical background report

6. References

Aizpuru, M., Farley, K. X., Rojas, J. C., Crawford, R. S., Moore, T. J., Jr., & Wagner, E. R. (2019). Motorized scooter injuries in the era of scooter-shares: A review of the national electronic surveillance system. Am J Emerg Med, 37(6), 1133-1138. doi:10.1016/j.ajem.2019.03.049
Allem, J. P., & Majmundar, A. (2019). Are electric scooters promoted on social media with safety in mind? A case study on Bird's Instagram. Prev Med Rep, 13, 62-63. doi:10.1016/j.pmedr.2018.11.013
Alwani, M., Jones, A. J., Sandelski, M., Bandali, E., Lancaster, B., Sim, M. W., ..., Ting, J. (2020). Facing Facts: Facial Injuries from Stand-up Electric Scooters. Cureus, 12(1), e6663. doi:10.7759/cureus.6663
Badeau, A., Carman, C., Newman, M., Steenblik, J., Carlson, M., & Madsen, T. (2019). Emergency department visits for electric scooter-related injuries after introduction of an urban rental program. Am J Emerg Med, 37(8), 1531-1533. doi:10.1016/j.ajem.2019.05.003
Basky, G. (2020). Spike in e-scooter injuries linked to ride-share boom. CMAJ, 192(8), E195-E196. doi:10.1503/cmaj.1095848
Bauer, F., Riley, J. D., Lewandowski, K., Najafi, K., Markowski, H., & Kepros, J. (2020). Traumatic Injuries Associated With Standing Motorized Scooters. JAMA Netw Open, 3(3), e201925. doi:10.1001/jamanetworkopen.2020.1925
Beck, S., Barker, L., Chan, A., & Stanbridge, S. (2020). Emergency department impact following the introduction of an electric scooter sharing service. Emerg Med Australas, 32(3), 409-415. doi:10.1111/1742-6723.13419
Bekhit, M. N. Z., Le Fevre, J., & Bergin, C. J. (2020). Regional healthcare costs and burden of injury associated with electric scooters. Injury, 51(2), 271-277. doi:10.1016/j.injury.2019.10.026
Benhamed, A., Gossiome, A., Ndiaye, A., & Tazarourte, K. (2022). Characteristics and comparison between e-scooters and bicycle-related trauma: a multicentre cross-sectional analysis of data from a road collision registry. BMC emergency medicine, 22(1), 1-7.
Bresler, A. Y., Hanba, C., Svider, P., Carron, M. A., Hsueh, W. D., & Paskhover, B. (2019). Craniofacial injuries related to motorized scooter use: A rising epidemic. Am J Otolaryngol, 40(5), 662-666. doi:10.1016/j.amjoto.2019.05.023
Bruneau, J. F., & Maurice, P. (2012, 2012). A legal status for personal mobility devices. Paper presented at the 13th International Conference on Transport and Mobility for Elderly and Disabled.
Cha Sow King, C., Liu, M., Patel, S., Goo, T. T., Lim, W. W., & Toh, H. C. (2020). Injury patterns associated with personal mobility devices and electric bicycles: an analysis from an acute general hospital in Singapore. Singapore Med J, 61(2), 96-101. doi:10.11622/smedj.2019084

Che, M., Lum, K. M., & Wong, Y. D. (2020). Users' attitudes on electric scooter riding speed on shared footpath: A virtual reality study. International Journal of Sustainable Transportation, 15(2), 152-161. doi:10.1080/15568318.2020.1718252

Christoforou, Z., Gioldasis, C., de Bortoli, A., & Seidowsky, R. (2021). Who is using e-scooters and how? Evidence from Paris. Transportation Research Part D: Transport and Environment, 92. doi:10.1016/j.trd.2021.102708

Clough, R. A., Piatt, E., Cole, E., Wilson, M., & Aylwin, C. (2023). Major trauma among E-Scooter and bicycle users: a nationwide cohort study. Injury prevention, 29(2), 121-125.

Degele, J., Gorr, A., Haas, K., Kormann, D., Krauss, S., Lipinski, P., Hertweck, D. (2018). Identifying E-Scooter Sharing Customer Segments Using Clustering. Paper presented at the 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC).

Dhillon, N. K., Juillard, C., Barmparas, G., Lin, T. L., Kim, D. Y., Turay, D., .., Ley, E. J. (2020). Electric Scooter Injury in Southern California Trauma Centers. J Am Coll Surg., 231(1), 133-138. doi:10.1016/j.jamcollsurg.2020.02.047

Dozza, M., Violin, A., & Rasch, A. (2022). A data-driven framework for the safe integration of micro-mobility into the transport system: Comparing bicycles and e-scooters in field trials. Journal of Safety Research. doi:10.1016/j.jsr.2022.01.007

ETSC. (2020). Austrian warnings over e-scooter safety. https://etsc.eu/austrian-warnings-over-e-scooter-safety/.

European Commission. (2019). Conference. Micro-mobility: the next big thing? https://ec.europa.eu/transport/sites/transport/files/2019-10-14-micro-mobility-background-note.pdf

European Commission. (2024). Road safety thematic report – Cyclists. Brussels

European Transport Safety Council (ETSC). (2023). Recommendations on Safety of E-scooters

Fitt, H., & Curl, A. (2019). E-Scooter Use in New Zealand: Insights around Some Frequently Asked Questions. Canterbury, New Zealand

Gössling, S. (2020). Integrating e-scooters in urban transportation: Problems, policies, and the prospect of system change. Transportation Research Part D: Transport and Environment, 79. doi:10.1016/j.trd.2020.102230

European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Guy, I., Beard, G., Smith, L., Jenkins, D. et al. (2024). Study on the need for harmonised rules to support the rise of micro mobility and increased road safety for personal mobility devices – Final report (1.0), Publications Office of the European Union. https://data.europa.eu/doi/10.2873/8572224

Haworth, N. L., & Schramm, A. (2019). Illegal and risky riding of electric scooters in Brisbane. Med J Aust, 211(9), 412-413. doi:10.5694/mja2.50275

ITF. (2024). Greener Micromobility. Paris

James, A., Harrois, A., Abback, P. S., Moyer, J. D., Jeantrelle, C., Hanouz, J. L., ..., French Observatory for Major, T. (2023). Comparison of Injuries Associated with Electric Scooters, Motorbikes, and Bicycles in France, 2019-2022. JAMA Network Open, 6(6), e2320960. doi:10.1001/jamanetworkopen.2023.20960

James, O., Swiderski, J., Hicks, J., Teoman, D., & Buehler, R. (2019). Pedestrians and E-Scooters: An Initial Look at E-Scooter Parking and Perceptions by Riders and Non-Riders. Sustainability, 11(20). doi:10.3390/su11205591

Jiao, J., & Bai, S. (2020). Understanding the Shared E-scooter Travels in Austin, TX. ISPRS Int J Geoinf, 9(2). doi:10.3390/ijgi9020135

KFV. (2020). E-Scooter im Straßenverkehr. Unfallzahlen, Risikoeinschätzung, Wissensstand und Verhalten von E-Scooter-Fahrern im Straßenverkehr. Wien

Kobayashi, L. M., Williams, E., Brown, C. V., Emigh, B. J., Bansal, V., Badiee, J.,..., Doucet, J. (2019). The e-merging e-pidemic of e-scooters. Trauma Surgery & Acute Care Open, 4(1), e000337. doi:10.1136/tsaco-2019-000337

Laa, B., & Leth, U. (2020). Survey of E-scooter users in Vienna: Who they are and how they ride. Journal of Transport Geography, 89. doi:10.1016/j.jtrangeo.2020.102874
Lee, S., Kim, S. H., & Kim, T. H. (2017). A Comparison Study on the Risk and Accident Characteristics of Personal Mobility. Journal of the Korean Society of Safety, 32(3), 151-159. doi:doi.org/10.14346/JKOSOS.2017.32.3.151
Leyendecker, J., Hackl, M., Leschinger, T., Bredow, J., Krane, F., Eysel, P., Harbrecht, A. (2023). Lessons learned? Increasing injury severity of electric-scooter accidents over a period of one year: a monocentric follow-up study at a level 1 trauma center. European Journal of Orthopaedic Surgery & Traumatology.
Li, T., Kovaceva, J., & Dozza, M. (2023). Modelling collision avoidance maneuvers for micromobility vehicles. Journal of Safety Research, 87, 232-243. doi:10.1016/j.jsr.2023.09.019
Liew, Y. K., Wee, C. P. J., & Pek, J. H. (2020). New peril on our roads: a retrospective study of electric scooter-related injuries. Singapore Med J, 61(2), 92-95. doi:10.11622/smedj.2019083
National Traffic Safety Board. (2022). Micromobility: Data Challenges Associated with Assessing the Prevalence and Risk of Electric Scooter and Electric Bicycle Fatalities and Injuries. Safety Research Report.
Nisson, P. L., Ley, E., & Chu, R. (2020). Electric Scooters: Case Reports Indicate a Growing Public Health Concern. Am J Public Health, 110(2), 177-179. doi:10.2105/AJPH.2019.305499
Noland, R. B. (2019). Trip patterns and revenue of shared e-scooters in Louisville, Kentucky. Transport Findings. doi:10.32866/7747
OECD/ITF. (2020). Safe Micromobility
OECD/ITF. (2024). Safer micromobility: Technical background report
Sikka, N., Vila, C., Stratton, M., Ghassemi, M., & Pourmand, A. (2019). Sharing the sidewalk: A case of E-scooter related pedestrian injury. Am J Emerg Med, 37(9), 1807 e1805-1807 e1807. doi:10.1016/j.ajem.2019.06.017
Stormann, P., Klug, A., Nau, C., Verboket, R. D., Leiblein, M., Muller, D., . . . Lustenberger, T. (2020). Characteristics and Injury Patterns in Electric-Scooter Related Accidents-A Prospective Two-Center Report from Germany. Journal of Clinical Medicine, 9(5). doi:10.3390/jcm9051569
SWOV. (2021). Light electric vehicles. The Hague
Toofany, M., Mohsenian, S., Shum, L. K., Chan, H., & Brubacher, J. R. (2021). Injury patterns and circumstances associated with electric scooter collisions: a scoping review. Inj Prev, 27(5), 490-499. doi:10.1136/injuryprev-2020-044085
Trivedi, B., Kesterke, M. J., Bhattacharjee, R., Weber, W., Mynar, K., & Reddy, L. V. (2019). Craniofacial Injuries Seen With the Introduction of Bicycle-Share Electric Scooters in an Urban Setting. J Oral Maxillofac Surg, 77(11), 2292-2297. doi:10.1016/j.joms.2019.07.014
Tuncer, S., & Brown, B. (2020a). E-scooters on the Ground: Lessons for Redesigning Urban Micro-Mobility. Paper presented at the Conference on Human Factors in Computing Systems.
Tuncer, S., & Brown, B. (2020b). E-scooters on the Ground: Lessons for Redesigning Urban Micro-Mobility. doi:10.1145/3313831.3376499
UK department of Transport. (2022). UK Department for Transport, National evaluation of e-scooter trials, Findings report.
Vias. (2020). E-steps ongevallen. Explorative studie. Overzicht: België. Brussel, Belgie
Yarmohammadi, A., Baxter, S. L., Ediriwickrema, L. S., Williams, E. C., Kobayashi, L. M., Liu, C. Y., Korn, B.S., Kikkawa, D. O. (2020). Characterization of Facial Trauma Associated with Standing Electric Scooter Injuries. Ophthalmology, 127(7), 988-990. doi:10.1016/j.ophtha.2020.02.007

European Commission

Zagorskas, J., & Burinskienė, M. (2019). Challenges Caused by Increased Use of E-Powered Personal Mobility Vehicles in European Cities. Sustainability, 12(1). doi:10.3390/su12010273

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