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Evidence review on micromobility safety

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1. Introduction

As E-scooters become more widespread in many countries worldwide, there has been a heated debate regarding their use among both supporters and opponents. Major concerns of opponents are related to safety, parking and road congestion, with safety being the most significant reason for aversion to use (Timsit, 2022). In cities that introduced E-scooters early like Paris and Singapore, safety has turned out to be the primary obstacle to moving forward.

The term 'micromobility' refers to lightweight, personal vehicles and includes both E-bicycles and E-scooters (Cook et al., 2022). E-scooters (either seated or standing), refers to powered vehicles with a centre column and floorboard, but without operable pedals and self-balancing (SAE International, 2019). Based on an international evidence review of both scholarly and grey literature, this paper investigates what elements affect the safety of micromobility with a focus on E-scooters. Conclusions are drawn to provide policy recommendations on safety regulation.

2. Method

Scholarly literature was drawn from both Scopus and Web of Science Core collection in early March 2023 and comprised two search waves. The first search used phrases (TITLE ((scoot* OR micromobility) AND safe*) OR KEY ((scoot* OR micromobility) AND safe*)) to capture literature that is relevant to E-scooter and micromobility safety. The second search used phrases (TITLE((cycling OR e-bike) AND safe*) OR KEY ((cycling OR e-bike) AND safe*)), and the query was limited to review articles aiming to encompass cycling-related safety pieces, which may provide longer-standing experiences on micromobility safety. Both searches were restricted to certain subject areas (Engineering, Social/Environmental/Decision Sciences in Scopus; Transportation, Economics and Risk Assessment in Web of Science). Search results were limited to English, OECD countries, and dated from 2012 to March 2023. After removing duplicated and irrelevant articles a total of 90 articles were included (72 journal articles, 17 conference proceedings and 1 book section). Grey literature was drawn from news pieces, blogs and reports from various sources.

3. E-scooter rider behaviour

3.1. Helmet

Data from hospital emergency departments confirms that among all the consequences of collisions relating to standing E-scooters, head injuries are one of the most commonly seen (Serra et al., 2021, Hoffeld et al., 2022). This is influenced by the design of E-scooters – with small wheels and the rider's centre of gravity located forward, the rider's head can be in great danger in a fall (Winchcomb, 2022). The literature supports the idea that helmets can provide crucial (if not full) head protection for E-scooter users in a traffic collision (Wei et al., 2023).

3.2. Speed

Generally speaking, a decreased riding speed is associated with an increased safety level (Che et al., 2020). Both the rider's control and vehicle design (speed range) can affect the E-scooter operating speed. E-scooter speed limits vary in different countries. Depending on the road space they are allowed to operate on, the maximum speed limit is commonly 20–25 kph (Voro Motors, 2019).

3.3. Alcohol

Alcohol is the one of the most common types of drug influence regarding E-scooter riding (Gioldasis et al., 2021). There is consensus that regulations should consider an alcohol unit limit that is safe for E-scooter riding, what population group the enforcement should pay particular attention to, and when. Currently, regulations in some jurisdictions apply the blood alcohol limit for motor vehicle drivers to e-bikes and E-scooters, but with extra requirements. In Germany the blood alcohol limit is 0.05%, but people under 21 years old must be completely alcohol-free (Criminal Law in Nuremberg/Germany, 2023). Research on E-scooter alcohol impact is currently limited (Mehdizadeh et al., 2023) but growing.

3.4. Interactions with other road users

In many countries, infrastructure cannot keep pace with the number of E-scooters on the roads. As a result, E-scooters often operate on roadways, bike paths or footpaths. This phenomenon has increased the possibility of congestion and therefore collisions between E-scooters and other road users, such as pedestrians, cyclists, and car users. Existing literature has addressed such interactions on safety-critical nodes with a focus on intersections, where traffic streams join each other (della Mura et al., 2022), and on micromobility-pedestrian collisions (Liu et al., 2022). It is also important to consider future E-scooter interaction such as with autonomous vehicles (Sanders and Karpinski, 2022).

3.5. Shared schemes vs private E-scooters

Users of shared schemes usually perform more risky behaviours than private E-scooter users (Haworth et al., 2021). This might be because) shared scheme users do not own the E-scooter and / or they are not frequent users so they don't understand the dangers as well. Generally speaking, dockless E-scooters are more convenient compared to docked ones, but mis-parked E-scooters generate a bigger problem for other road users (Brown et al., 2020). The E-scooter parking controversy is among many regulatory gaps around dockless E-scooters and requires further consideration (Carroll, 2022).

4. Safety of the vehicle

4.1. Vehicle design

E-scooters, like bicycles, are single-track vehicles that lack lateral stability when stationary, and the balance can only be generated when moving. Thus, many experiences that a user learnt from bicycles may be applicable to E-scooters. However, bicycles and E-scooters have quite different parameters: E-scooters have smaller and more rigid wheels and E-scooter riders commonly stand on the device instead of sitting on it (García-Vallejo et al., 2020). To achieve a safe outcome for E-scooters, there is a need for further exploration on the ergonomics of vehicle design and safety management. Issues identified which can potentially be improved to increase the safe use of E-scooters mainly focus on the effects of the braking system (Siebert et al., 2021) and wheel design (Lee et al., 2021).

4.2. Batteries

Battery explosions have become one of the most noticeable problems associated with E-scooters and e-bikes, with a rising number of reports (Australian examples include (Sciberras, 2023, Vujkovic, 2022)). The key debate is on the material of the batteries. Almost all E-scooters on the market use lithium-ion batteries, which can cause fire in situations of overcharging and overheating. There is potential for other more-sustainable materials to replace lithium-ion batteries, such as aluminum-ion (Australian Institute for Bioengineering and Nanotechnology, 2021) and hydrogen (Sugiyama et al., 2018). Product standards also play a role in preventing battery explosions of electric personal mobility devices. Importing laws are relevant because many of the devices in Australia come from overseas manufacturers (Australian Government, 2021) who may have lower quality.

5. Infrastructure

Infrastructure significantly affects the safety of micromobility. Existing literature has paid special attention to how the design of micromobility paths can increase safety. Table 1 is a summary of micromobility path features deemed to be helpful in increasing the safety of users.

Table 1: Features of safe micromobility paths

Safety feature	Scholarly literature
Dedicated infrastructure	(Austin Public Health, 2019)
Curbed by concrete or vegetation	(Fonseca-Cabrera et al., 2021)
One way instead of two ways	(Thomas and DeRobertis, 2013)
Separated away from parked or moving motorized traffic	(Fonseca-Cabrera et al., 2021)
Adopt pavement materials with great skid resistance but less vibrations, such as concrete, asphalt, and rough painted tile pavements	(López-Molina et al., 2023, Ma et al., 2021)
Softer (soil, for example, is safer than concrete)	(Chontos et al., 2022)
Highlighted with colours (commonly red, green and blue) to improve attraction, legibility and intuitiveness of riders and others, which is especially helpful at intersections and junctions	(Autelitano and Giuliani, 2021)
Clear legislation and information	(Useche et al., 2022)

6. Effective regulation

6.1. Legislation

The absence of uniform regulations around E-scooters is widely acknowledged as a major obstacle of safe use (Salas-Nino, 2022). It is important and urgent to form a clear and comprehensive code of conduct. The key point should be statutory recognition and definition of emerging types of micromobility devices, which should serve as a base of road rules and possible risk analysis to increase safety (Iroshnikov et al., 2020).

6.2. Licencing and messaging

Safety education and skills training are crucial to realise a safe outcome with micromobility, because many safety issues are related to inexperience, lack of protective gear, and poor riding skills. With the existence of clear and comprehensive legislation, licensing requirements on micromobility can increase safety awareness and ability of users, especially beginners and short-time users like tourists. Moreover, persuasive messaging can also play a positive role in increasing safety (Pangbourne, 2023).

6.3. Data and decision-making process

Regulation and policy making is a decision-making process which largely relies on data. Traditionally, road safety has been evaluated based on motor vehicle data, but the popularity of micromobility requires new data sets with often tech-driven collection and interpretation methods (Karpinski et al., 2022b).

6.4. Demographic considerations

To better regulate micromobility safety, policymakers should consider the demographic difference of micromobility riders, as a base to adjust the intensity, frequency, and timing of regulation enforcement. This should take account of age and gender (Karpinski et al., 2022a) (Iroz-Elardo and Currans, 2021), user frequency (Tian et al., 2022), population of children (Heydari et al., 2022), and socio-economic characteristics of neighbourhoods (Sanders et al., 2020).

7. Policy recommendations and conclusions

Based on the state-of-art evidence review, several policy recommendations to address micromobility safety in Australia are offered (Table 2).

Table 2: Ideal scenarios to minimise safety risks and maximise modal benefits of micromobility/E-scooters

Category	Optimum	Level of government
Legislation/ regulatory framework	Address an explicit definition, categorisation and product standard of micromobility vehicles (in reference to the SAE J3194 standard (SAE International, 2019))	Commonwealth, state
	Clearly outline responsibilities and obligations of riders of micromobility vehicles and other road users	Commonwealth, state
	Align with existing and future road infrastructure facilities	State, local
	Be supported by sufficient enforcement efforts	State, local
	Share consistency in shared schemes and the use of private E-scooters	State, local
	Acknowledge the holistic and interdependent nature of infrastructure treatments and other interventions to achieve a comprehensive and effective approach to safety	Commonwealth, state, local
Licencing and messaging	Mandatory safety education and skills training (probably via rider licencing). Also, school education programs and persuasive messaging on micromobility safety.	Commonwealth, state
Data and decision-making process	Rely on new ways of data collection and analysis methods enabled by technological developments. In addition to rider data from police and emergency departments, data directly from the vehicle and data from non-riders should also be considered.	Commonwealth, state, local
Demographic considerations	Promote an approach to safety management that is user-based, location-based, and time-based. Specifically consider demographic characteristics of riders - locations with high safety risks (e.g., road intersections, sidewalks, low socio-economic neighbourhoods, and areas with a high population of children); time periods with high safety risks (night and days with bad weather).	State, local

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