Review of the literature on the safety of micromobility

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1 INTRODUCTION

The introduction of micromobility services such as electrically assisted scooters (e-scooters) and cycles (e-bikes) in many cities is leading to significant changes in urban transportation on a daily basis, bringing new and pressing challenges for policymakers at the national level. In 2019, 3.7 million e-bikes were sold and, by 2030 e-bike sales are expected to reach 17 million annually in the EU28 while e-scooter market is anticipated to be driven by increasing e-scooter sharing services. The rise of micromobility share highlights the necessity of examining its safety. This paper aims to analyze the most recent safety trends of e-scooters and e-bikes based on the existing literature focusing on the traffic safety impact of both shared and owned e-scooters and e-bikes. For this purpose, an extensive review of the scientific and "grey" literature was conducted. Findings at the international level regarding the two modes were summarized and synthesized. Lastly, the overall conclusions and policy recommendations are discussed.

2 METHODOLOGY

Up to the time of the abstract submission, eighty-one (81) relevant studies were identified and considered appropriate for this review. The number of reviewed studies is expected to grow as more papers/reports are published and the authors aim at presenting the most updated overview. Among those, four peer review papers were identified while about 10% of the remaining studies are reports published by policy organizations, governmental organizations, or service providers. The year of publication of the e-scooter studies ranges between 2018 and 2023. Most of those studies is based on the 2018-2020 data. On the contrary, resources on e-bikes are dated from 2007 to 2022 and are based on data from the same period.

3 MICROMOBILITY CRASH AND INJURY

In the framework of this paper the traffic safety of e-scooters and e-bike operations were investigated based on 58 studies and analyses.

2.1 Safety of e-scooters operations

E-scooter safety is a topic that has garnered significant attention in recent years. The majority of the literature on e-scooter safety focuses on the injury severity levels that e-scooter riders are subject to, as well e-scooter risk considering various exposure measures.

By synthesizing the literature, it is evident that when a crash involves an e-scooter then it is quite rare not to have an injury (6-27%), with the injuries mostly affecting the upper body and head. Most of the time (61-

76%) it results in a minor injury (e.g., scratch) while severe injuries correspond to 18 to 33% of the times. Falls specifically account for a significant number of crashes (~80%) and injuries (64-85%). Several research findings demonstrate that the more a person is using an e-scooter the more their safety with this mode is improved.

It is important to note that in their majority e-scooter reported injuries are due to single-user crashes. Single-user e-scooter injuries mostly involve the rider and secondly, pedestrians who either are hit by a moving e-scooter (29.5%) or they trip over a parked e-scooter. Specifically, pedestrians, compared to other road users, are considerably affected by e-scooters partially because in some countries, e-scooters had to use the sidewalk, or in other contexts, e-scooterists ride on the sidewalk, especially in the absence of bike lanes. Pedestrian injuries make up 1 to 10% of all injuries related to e-scooters, which is a result of pedestrians sharing the same space with e-scooter riders. While e-scooter and motor vehicle collisions account for a relatively small portion of injuries (8-19%) they are mostly responsible for e-scooter fatalities (~85% of fatalities).

The literature on e-scooter safety identifies several risk factors, including reduced lighting conditions, riding under the influence of alcohol, poor road infrastructure, and riding on sidewalks. Helmet use is also low among injured riders, and head and face injuries are common among e-scooter injuries. E-scooter providers have developed measures to address some of these risk factors, such as app-based features to detect rider sobriety levels, speed restriction software, night lights, and noise features. Cities are also implementing bike lane networks and car-free/low-car/low-speed zones to encourage micromobility modes. Education and communication can improve user compliance and behavior, and helmet laws have been found to be effective in improving user behavior and compliance.

2.2 Safety of e-bikes operations

E-bikes are becoming increasingly popular worldwide, having several benefits, including enabling a more diverse population to ride a bike and leading to health benefits due to the shift from motorized vehicles. The literature on the safety of e-bikes is relatively sparse and mainly covers the pre-pandemic era. Existing studies tend to be concentrated in certain European countries, some US states, and China. For this review a total of twelve (12) studies on e-bikes were analyzed, ten (10) of which are scientific papers, one (1) is review (white paper), and one is a report.

Crash and injury data as well as exposure data for bikes are much more abundant and reliable compared to e-scooter data. Bikes are still disproportionally affected by crashes in relation to other vehicles. Safety data exist from earlier (e.g., before 2018) implementations of e-bikes; there are mixed findings of the safety of e-bikes compared to bikes, especially between EU and US studies. However, these earlier data do not capture e-bike great post-pandemic expansion (e.g., use in logistics).

Several studies in European countries where e-bikes are allowed to offer pedal assistance up to 25 km/h showed that e-bike crashes are in general equally severe as conventional bike crashes. Crash and injury risk factors associated with e-bikes are similar to those of conventional bikes and e-scooters, namely: nighttime riding, alcohol consumption, riding on roads with high speeds and no bike, and helmet use. However, the literature on these factors is sparse and does not allow for proper estimation of their overall effect.

4 SURROGATE SAFETY

Given the fact that e-scooters and e-bikes have been only recently massively deployed, crash data is not always readily available to allow for reliable safety analysis, the use of surrogate safety data is expected to provide insightful information on the crash mechanism. The findings from these studies can be used to complement crash- and injury-based studies for a deeper understanding of the risk factors associated with e-scooters and e-bikes operations. For e-scooters and e-bikes eleven (11) surrogate safety studies have been identified and reviewed for this analysis.

The findings on surrogate safety data for e-scooters reveal that pedestrians experience greater impact by e-scooter trips. When e-scooter riders travel on bike lanes, their speed is comparable to but slightly higher than that of conventional bikes. E-scooters require a longer braking distance compared to bikes, which affects conflicting interactions. E-scooters also develop higher speeds in low-traffic streets compared to sidewalks.

The research on surrogate safety for e-bikes is limited and mainly based on old research without a common methodological framework and aiming to investigate the safety performance of e-bikes compared to conventional ones. Based on two studies in China and one in Germany, the conflict rate of e-bikes is higher than conventional bikes without taking into account the fault. On sidewalks and bike lanes, the probability of conflicts and interactions involving e-bikes is not significantly different from conventional bikes.

5 SAFETY IMPLICATIONS OF MODAL SHIFT

To investigate the modal shift from car, public transport, and other active modes to e-scooters and e-bikes and asses modal shift findings in relation to safety, more than twenty (>20) papers and publications from 2007 to 2022, with a focus on region and transport mode were taken into account.

The highest modal shift from cars to e-scooters and e-bikes was observed in the US, where shared e-scooter users replace 46.3% of their car trips and e-bike users replace 57%. In European cities, e-scooters are most likely to replace walking trips followed by public transport trips, while e-bikes are causing a considerable substitution of cars, public transport, and conventional bike trips. The substitution rate of riding e-scooters for public transport trips is significantly higher in Europe (33.6%) compared to the US and New Zealand, while public transport is reported as the most common mode to combine e-scooters with mainly in European cities. In China, a significant substitution of public transport (54%) is observed with e-bike usage, while auto trips do not seem to be significantly affected.

A modal shift from auto (private car, taxis, TNCs) to micromobility is expected to improve micromobility as the number of motorized vehicles on the road decreases and so, micromobility modes are exposed to risky interactions. However, the case that micromobility takes users out of public transport is not considered beneficial for safety as public transport has high safety level.

6 CONCLUSION

This study aimed to analyze the most recent safety trends of e-scooters and e-bikes internationally, based on the existing literature. Most existing studies rely on the analysis of crash and injury data to assess the safety of the two micromobility modes, while several studies have relied on surrogate safety measures. A wide body of literature has focused on the modal shift caused by the introduction of e-scooters and e-bikes.

Micromobility safety results are not black and white; they depend on infrastructure, traffic volumes and speed and safety culture. Future efforts in the understanding of micromobility safety should focus on constantly renewing the findings from the literature to capture as early as possible the current trends. Additionally, efforts should focus on extracting real-world datasets and conducting analyses to capture safety trends, modal split and shift, etc. that can improve current knowledge.

Overall, addressing e-scooter and e-bikes safety requires a combination of measures, including improving infrastructure, promoting responsible behavior through education and communication, and implementing regulations such as helmet laws.

7 REFERENCES

As this is a review paper, references are omitted from this abstract due to space constraints.