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Evaluation of electric scooter deployment in the City of Helsinki

A perspective on sociotechnical transitions dynamics and adaptive governance

Miloš N. Mladenović, PhD

Samira Dibaj, MSc

Daniel Lopatnikov, PhD

Spatial Planning and Transportation Engineering

Department of Built Environment

School of Engineering

Aalto University

November, 2022

Please cite as: Mladenović, M., Dibaj, S., Lopatnikov, D., (2022). Evaluation of electric scooter deployment in the City of Helsinki: A perspective on sociotechnical transitions dynamics and adaptive governance. Department of Built Environment, Aalto University. ISBN: 978-952-64-9624-5.

Table of Contents

Abstract

As part of a wider global transition in urban environments and their mobility systems, Finland and in particular Helsinki, has seen emergence of shared or private, standing, rechargeable lithium-ion battery-electric scooters (e-scooters). Following an increase in the number of emergency cases in the spring and summer of 2021, City of Helsinki has agreed with shared e-scooter operators to introduce a set of temporal and speed restrictions. However, the need for understanding the dynamics of socio-technical transition involving e-scooters and developing the corresponding adaptive governance processes has remained. Thus, this project has focused on the twofold and interdependent problem. The first aspect in focus is behavioural change of urban mobility system users, especially focusing on e-scooter users. The second aspect is institutional change among multi-level/sector transition actors, including all the parties involved in this project and beyond.

Overall, the project had four research questions, with corresponding methods. First, in order to understand the surface problem of objective traffic safety, the goal was to analyse spatio-temporal changes in the occurrence and severity of emergency cases. The methods used for this goal centred on retrospective analysis of e-scooter and bicycle related emergency cases. Second, to further understand the revealed behaviour and competences while riding e-scooters, the method focused on the analysis of streetscape video recordings at several locations in the City of Helsinki. Third, for analysing deeper perspectives on user behaviour but also for understanding perspectives from non-users, an online questionnaire and corresponding analysis were deployed. Last, in order to provide suggestions for developing responsible and adaptive governance processes, collaborative research methods have relied on site inspections of street infrastructure and multi-stakeholder interaction focused on a policy design framework.

The study finds that the safety level of e-scooter usage in Helsinki has improved over time, approaching the estimated level of safety for cycling. However, intoxication while riding has remained an issue also in 2022. In addition, the e-scooter observations revealed that about a quarter of riders showed very non-cooperative riding behaviours, which also varied based on street infrastructure. Besides these safety issues, other problematic behaviour observed was parents/adults riding with a child on the same e-scooter. Similarly, observational analysis also shows significant use of e-scooters by users under the age of 18, also associated with more unsafe behaviour. Analysis of questionnaire data shows that although most e-scooter users are males aged from late 20s to early 30s, usage in Helsinki includes all income groups and age categories. Leisure and socializing activities are the most common trip purposes, followed by commuting, which is even more common for those using a private e-scooter. In addition, shared e-scooter usage in Helsinki is mostly replacing buses or trams, taxi or other on-demand mobility services, and walking, while private e-scooter usage is more clearly associated with a reduction in private car driving. The most cited reasons for using e-scooters include being in a hurry and trying to travel faster than with other modes, as well as e-scooter riding providing a fun experience. The most cited reasons for not using e-scooters include being satisfied with the current means of travel, lack of a clear necessity, and perceived safety of riding in Helsinki. Both users and non-users agree that there is a need to improve street infrastructure, with non-users suggesting more often the need to improve rules, while users suggesting more often the need to improve parking behaviour.

Study recommends further co-development of policies in collaboration between different stakeholders to enable agonistic deliberation about different policy actions, by identifying their effectiveness in terms of behavioural change, as well as their implementability. Further policy measures should be developed and enforced in coordination with both the public and private sector campaigns and educational programs. Moreover, such agonistic collaboration efforts should rely on development of data collection and sharing procedures among different stakeholders. Besides overarching policies, there is a clear need to improve cycling infrastructure and the use of temporary traffic arrangements in specific locations in Helsinki. Finally, if Finland is to be at the forefront of urban mobility system transformation, there is a need to further develop a culture of adaptive multi-stakeholder governance in the transport sector and beyond.

Acknowledgement

This study was jointly funded by the City of Helsinki, Finnish Ministry of Transport and Communications, and three e-scooter operators: Voi, TIER, and Lime. The company Dott was initially part of the project group before exiting the Finnish market, and it did not provide funding for this project.

We acknowledge collation and sharing of injury data by both the Helsinki University Hospital and the Finnish Institute for Health and Welfare. We also acknowledge Olivia Halme and Sirje Lappalainen from the City of Helsinki in sharing electric scooter and cycling data.

We acknowledge help from companies Ryde and Bird in supplying data and disseminating the questionnaire.

We acknowledge Daniel Lopatnikov's affiliation to the Public University of Navarre (UPNA) while staying at Aalto University. His funding is part of the "Convocatoria de ayudas para la Recualificación del Sistema Universitario Español para 2021-2023. UPNA. Modalidad Margarita Salas" funded by the European Union (Next Generation EU).

We acknowledge the work of Alba Rodríguez Sayrol in video recording analysis, in affiliation with Universitat Politècnica de Catalunya while staying at Aalto University.

We acknowledge Aapo Lumikoivu and Åsa Enberg from Aalto University, for their effort in video recording installation, analysis and managing data privacy.

We acknowledge Riitta Särkisilta-Lundberg, Maiju Tikkanen and Joonas Lehtovaara from Aalto University, for their help with project communications.

List of Figures

List of Tables

1. Introduction

1.1 Positioning of the challenge in general – governance of emerging mobility technology

As part of a wider global transition in urban environments and their mobility systems (Behrendt et al., 2022; Cook et al., 2022; Creutzig et al., 2019; Mladenović & Stead, 2021; Pouri & Hilty, 2021; Stehlin et al., 2020), Finland and in particular Helsinki has seen emergence of standing, shared or private, rechargeable lithium-ion battery-electric scooters and other micromobility devices (Sundqvist-Andberg et al., 2021). As can be seen from the following Figure 1, micromobility includes a set of devices, applicable to urban mobility context, with a typical trip length under 15 km and total daily trip distance of under 80 kilometres (Behrendt et al., 2022). These devices can fully user-powered, partially motor-assisted, as well as fully motor-powered. The term 'micro' is seen in relation to automobility, with respect to energy demand, environmental impact, and the use of road space (Behrendt et al., 2022).

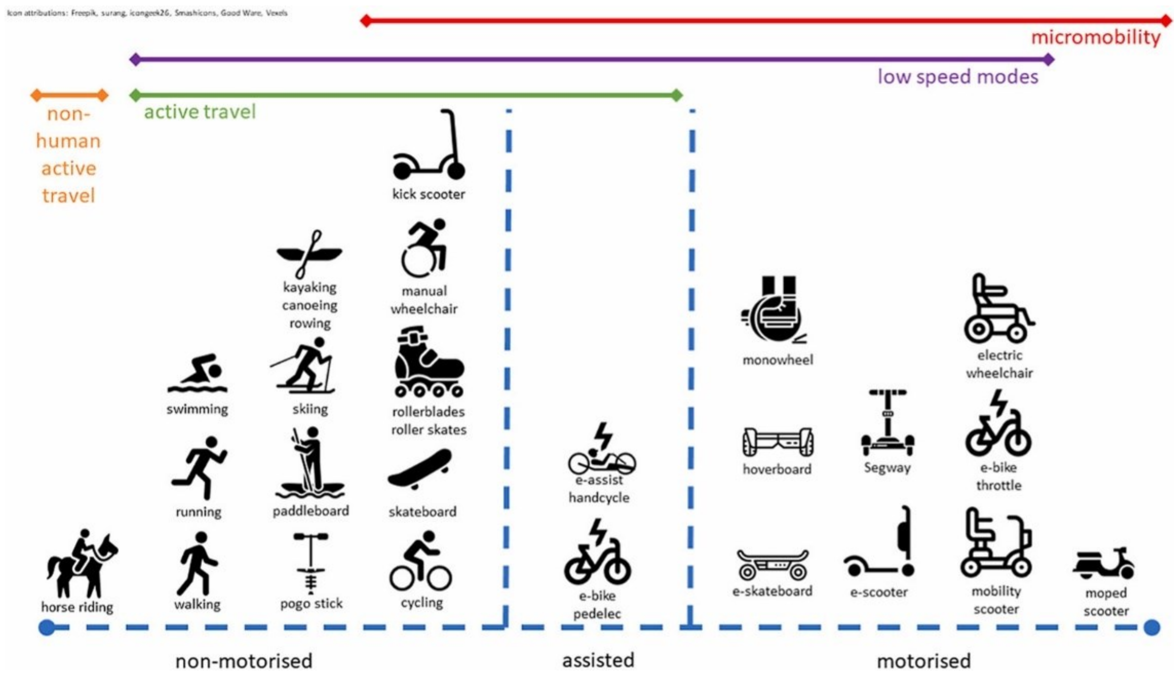


Figure 1: Taxonomy of active travel modes and related categories (Cook et al., 2022)

Figure 2 below depicts a three-level framework for thinking about this transition and societal learning during disruption (Geels, 2020). On the bottom level, broader trends both in Finland and globally play a role, such as climate crisis, demographic changes, pandemics, global supply chains, investments into sharing economy, etc. On the middle level, existing socio-technical regime of mobility services is also under change, driven by both technical aspects (e.g., battery technology, mobility apps, back-end digitalization, etc.) and social aspects (e.g., changes in sharing preferences, changes in ownership preferences, well-being preferences, etc.) (Mladenović et al., 2021a). With disturbance on both of these levels, also come pressures from the niche level, with electric scooters (e-scooters) being a clear example that relates to new technology, business models, and human behaviours.

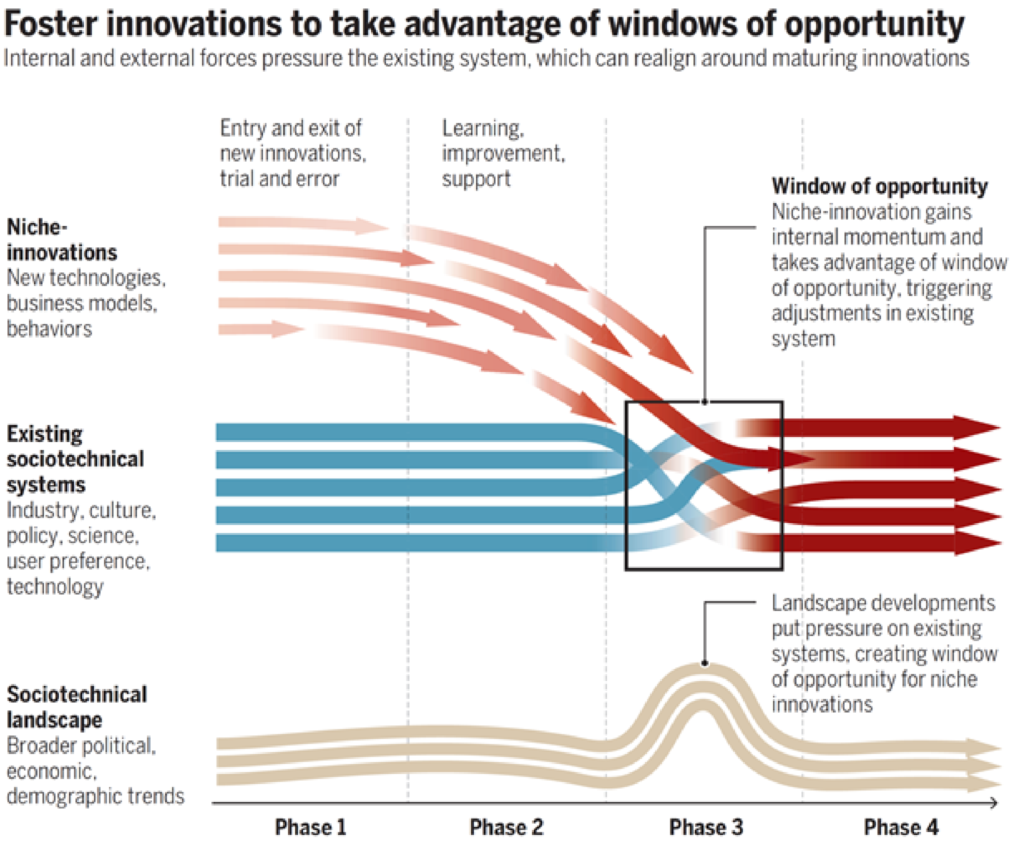


Figure 2: Three-level perspective on socio-technical transitions (Geels et al., 2017)

A specifically disruptive feature of the ongoing transition is the continuous development of multitude of technologies and services, leading to the blurring of boundaries and categories of traditionally discrete transport modes (see Figure 3). However, these technologies and services are not fixed and do not have stabilized meanings in the society, but they are still changing over time, hand in hand with the wider societal learning (Mladenović et al., 2021a; Mladenović & Haavisto, 2021). As such, these emerging technologies are bringing along significant uncertainties of their implications for urban areas, as well as new questions about roles and responsibilities in public-private networks of Finnish actors (Mladenović et al., 2021a). Managing this transformation involves significant uncertainties (Lyons, 2016), and facing a range of aggregate impacts, such as carbon emissions, as well as a range of distributed impacts across different groups of people, such as accessibility or safety (Rodrigue, 2020). Similarly, previous research informs us that micromobility comes with a potential plethora of positive and negative implications (Asensio at al., 2022; Gössling, 2020; Li et al., 2022; Oeschger et al., 2020; Milakis et al., 2020; Petersen, 2019). Moreover, this transition relies on governance of commons (Nogueira et al., 2021; Ostrom, 1990, 2010), as steering and safeguarding done by multi-sector multi-layer actors, through the processes that involve policy, business and technology-related decisions (Docherty et al., 2018; Marsden & Reardon, 2017; Mladenović et al., 2020a; Rhodes, 1996). However, we know that such transformation needs to rely on a modern sustainable mobility paradigm, (Banister, 2008; Nakamura & Hayashi, 2013), where, in order of priority, there is a need to:

1. Avoid > reduce the total amount of trips and their kilometres travelled, especially those travelled with motorized transport,
2. Shift > switch from private motorized passenger car travel to other more sustainable modes, such as walking, cycling, and public transport, in that order of priority, and
3. Improve > improve efficiency of our vehicles, such as their fuel sources and energy consumption, and efficiency of traffic flows, such as operational efficiency

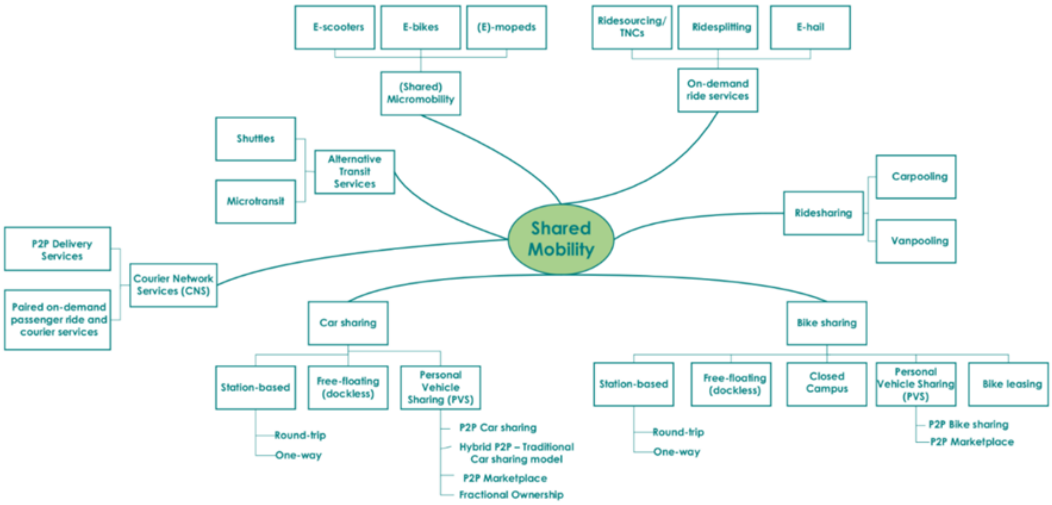


Figure 3: An example classification of shared mobility modes and services (Roukouni & Homem de Almeida Correia, 2020)

Despite the tendency to group many different technologies and services into the term micromobility, we have to recognize the particularities of e-scooters as devices at this stage of their technological trajectory. The current generation of e-scooters is a product of several iterations in the design of the vehicle, tracing its roots back to the 19th century electric devices. Overall, International Transport Forum has proposed one classification of micromobility devices including e-scooters, as can be seen on Figure 4. Thus, e-scooters are defined by limits in weight and maximum speed for type A. Similarly, SAE standard J3194_201911 - Taxonomy and Classification of Powered Micromobility Vehicles, has also tried to provide some uniformity of characteristics for powered standing scooter, including centre column with handlebar, foot platform, usage by one person, and having two (or three) wheels held in a frame in the longitudinal direction of travel. In Finnish regulation, e-scooters are classified as light electric vehicles, with power up to 1 kW, max speed of 25 km/h, 0.8 m maximum width, mandatory front light, reflectors and sound signalling device.

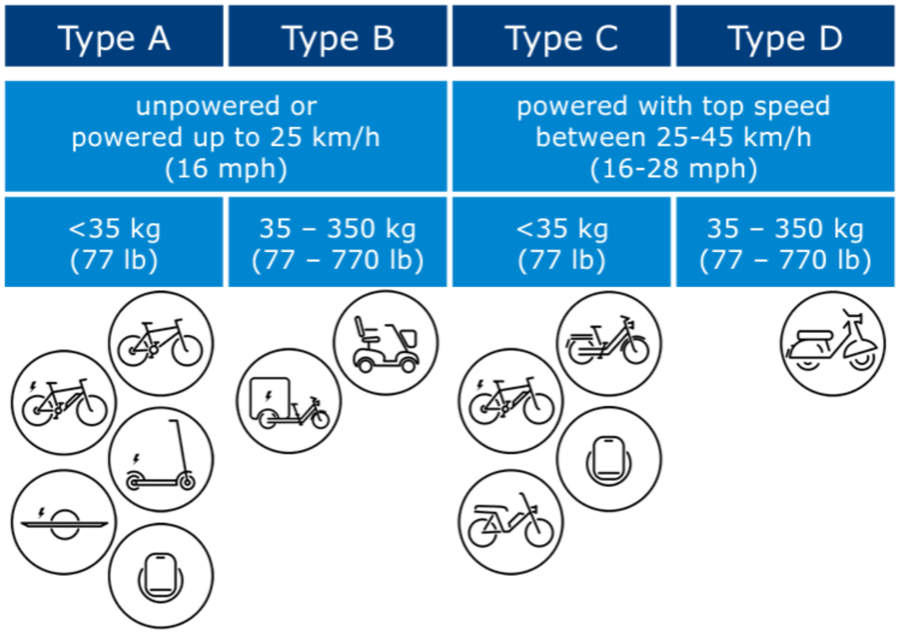


Figure 4: Proposed micromobility classification (ITF, 2020)

Keeping these vehicle properties in mind, the usage recommendations in Finland are such that the same rules of the road apply as to bicycles, where e-scooters should mainly be used on cycle paths[1]. However, when travelling at walking speed e-scooters may also be used on the footpath. Besides these general recommendations on space use, we have to recognize additional aspects of vehicle-human interaction. Namely, despite the range of design details across different e-scooter types, these vehicles do not have the same vehicle dynamics and rider kinematics as e.g., a modern bicycle or electric unicycle. These differences come from the vehicle design itself and from the lack of wider societal knowledge on how to operate these vehicles. A summary set of points, based on the following literature, is presented below (Arslan & Uyulan, 2022; Asperti et al., 2022; Boglietti et al., 2022; Cano-Moreno et al., 2021; Cano-Moreno et al., 2022; García-Vallejo et al., 2019; Garman et al., 2020; Schwab & Meijaard, 2013; Zagorskas & Burinskienė, 2019).

- E-scooters have relatively higher power in comparison to regular bicycles. For example, a regular cyclist can generate power of up to 300-400 W, while only professional cyclists can generate power of 700-1000 W in some instances.
- Similar to bicycles, relative speed that e-scooters can achieve in the urban environment is closer to other motorized vehicle traffic than to pedestrians.
- Wheel radius is relatively smaller than those of bicycles, thus providing different capability for climbing or crossing over surfaces with height differential, and in general resulting higher vibration magnitudes in poor street surface condition, be that by the nature of the material used (e.g., cobblestone) or its condition (e.g., pothole or cracks in asphalt pavement).
- Standing position while using e-scooter places the centre of gravity higher in relation to riding a bicycle, which introduces different dynamics during change in speed/acceleration, turning or collisions.

[1] https://poliisi.fi/en/blogi/-/blogs/electric-scooters-pose-challenges-for-the-police

- Standing position places the height of the eye relatively higher than the height of the eye while cycling, thus enabling slightly improved line-of-sight, but could also be a challenge for encountering vertical obstacles in the street space, such as lower edge of poorly designed traffic signs.
- Propulsion happens with a thumb rotation, interacting with a propulsion button mostly positioned on the right handlebar. Relatively to a bicycle, embodied feedback that one receives from operating e-scooter is smaller for the same vehicle speed, as bicycle engages a larger set of muscles.
- Turning radius of most of e-scooter models is slightly higher than the turning radius of standard bicycles, in the scale of several tens of centimetres.
- E-scooter standing surface and handlebar width affords more opportunities for different body and foot positions (see Figure 5) since the beginning of the use than a bicycle, which substantially affects tip-over stability.

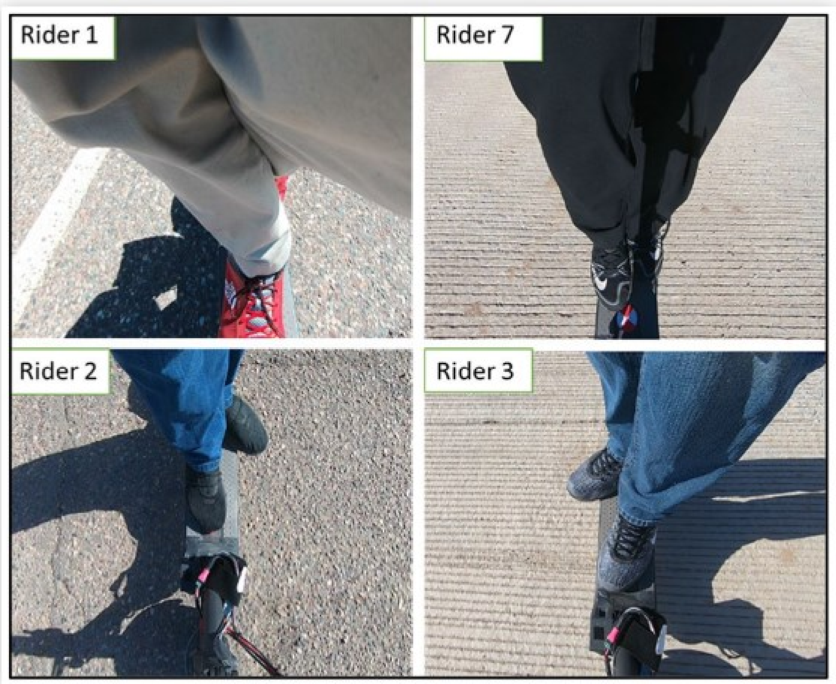


Figure 5: Examples of different foot positioning between different riders (Garman et al., 2020)

Over the last several years, e-scooter vehicle design and service design including the business model have evolved. Several details have been added or improved in quality for shared e-scooters, including tire size and surface texture, battery design, front suspension, turning lights, sensors, GPS and processing unit, ID plates, camera, hanging hook, etc. However, despite the improvements in some models, there is a much wider range of models available for purchase or leasing, where either there are lagging or leading features, such as a large variation in wheel design. In addition, many service features have also evolved, both in the pricing scheme (e.g., 24h pass, monthly pass, incentives for battery swap, promotional dates) and in-app features (e.g., map markers that can be seen from Figure 6, instructing users on parking and movement areas). Besides of user-focused features, many back-end details of service design and business model have also evolved, including maintenance, relocation, reparking, charging, and other back-end activities. In Helsinki in particular, several of the operators have taken actions for rider education on the rules for moving and parking, from media and leaflet campaigns, hang tags (see Figure 7), and in-app features, such as uploading the picture of the user with a helmet along with payment discounts, app-based reaction test, low speed limit for beginner users, end ride photo for parking, web-based riding instructions, in-app messages, warnings or blocking accounts when certain types of misbehaviour have been identified, etc.

Figure 6: Example of in-app map markers for informing the user (Source: Voi app)

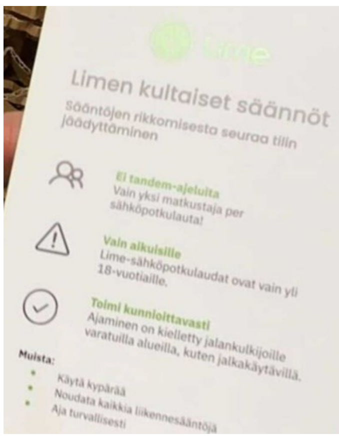


Figure 7: Example of hang tags on shared e-scooters with rules for riding (Source: Lime)

With the servitization and digitalization trends on the landscape level, it can be expected that shared e-scooter services will continue to emerge hand in hand with new ecosystems (Jacobides et al., 2018). In addition, besides these developments in the shared e-scooter services, there is an observable increase in the purchase and use of private e-scooters in Helsinki, as the offer and variety increase. Thus, this niche technology is gradually increasing its diffusion into society, effectively also reshaping the society around it. Simultaneously with co-constructing society, understanding technology management requires us to challenge the common misconception that “necessity is the mother of all invention”, since a working technology is the result and not the cause of it becoming a successful artefact (Diamond, 2013; Pinch & Bijker, 1984). As such, managing the transition requires understanding non-linear dynamics of socio-technical transitions, often depicted with X curve (Figure 8) that captures the chaotic patterns of build-up, breakdown, and their interactions (Hebinck et al., 2022). With a more specific example in urban mobility from Rotterdam depicted on Figure 9, one can understand that transitions-in-the-making require both stabilization of new niche elements, as well as phase-out of some existing elements of the mobility system (Rinscheid et al., 2021).

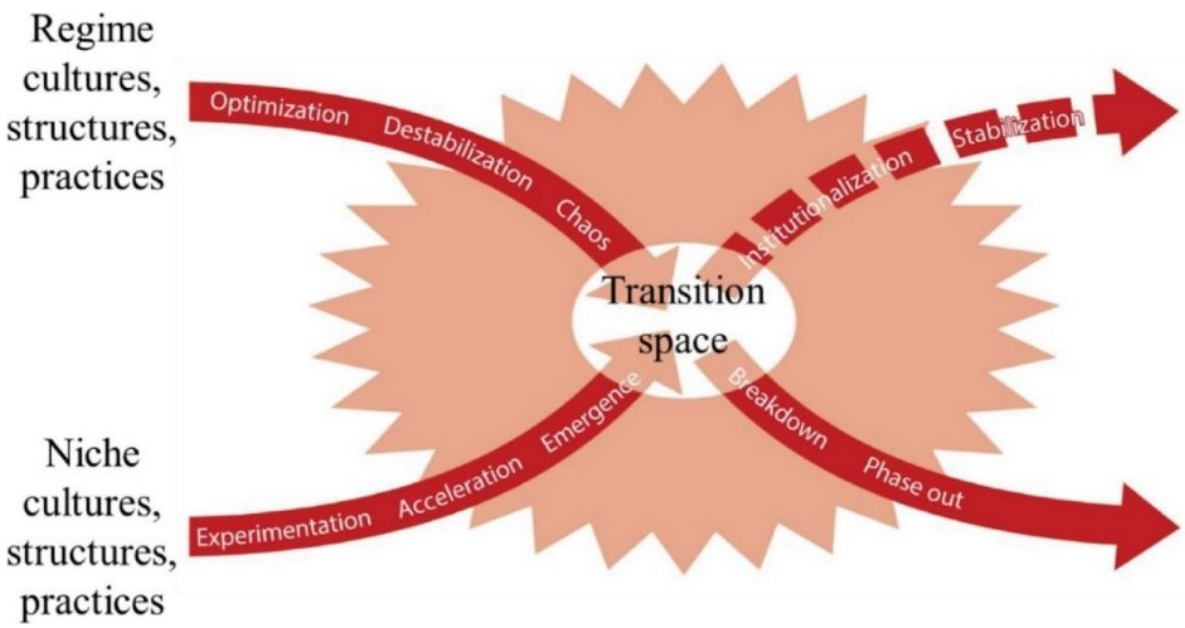


Figure 8: Transition dynamics phase-in and phase-out (Loorbach et al., 2017)

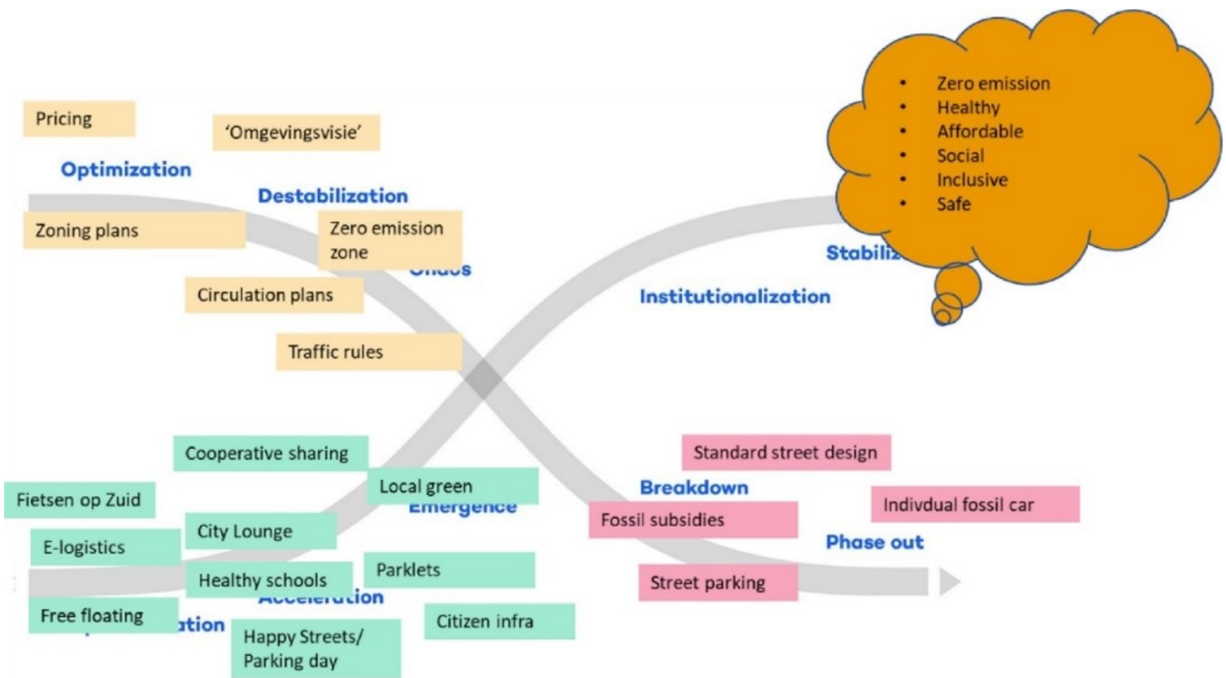


Figure 9: Transition strategy for just, sustainable mobility future in Rotterdam (Loorbach et al., 2021)

Especially during the emergence phase (Markard et al., 2020), technologies have large prominent re-distributive impacts and fast pace of change (Rotolo et al., 2015). Amidst the nonlinear dynamics of transition-in-the-making, the wider strategic transition and niche management (Raven et al., 2010; Panetti et al., 2018) and building of transformative capacity (Tuominen et al., 2022) faces a well-known Collingridge dilemma of technology studies (Genus & Stirling, 2018). This dilemma, also known as problem of pacing, explains a decision-making challenge where in early phase of technological trajectory, we have significant power to shape that trajectory, but relatively smaller amount of knowledge on impacts, while in the latter stages, as there is more knowledge of the effects, it is much harder to steer technological trajectory. This dilemma ultimately leads to an underlying question of what the boundary between innovation and regulation is, as focusing on changeable parts of the system as opposed to focusing on stabilized parts of the system.

Besides narrowly defined technical tasks and inertia from previous technologies (Mladenovic et al., 2016), expectations and discourse plays an important role in shaping technological trajectory, where there is a simultaneous framing of the societal challenge and technological solution, with intention to persuade, as well as align the activities of different actors (Borup, et al., 2006; Olin & Mladenović, 2022; Pangbourne et al., 2020; Petzer at al., 2020). Furthermore, the emergence of technology often challenges institutional landscape, structures, and patterns of interaction among actors in unanticipated ways, resulting in redistribution of roles, responsibilities, and power, while often facing an institutional void as well as distributed (ir)responsibility in hybrid institutional networks (Fearnley, 2020; Garud & Karnøe, 2003; Mladenović, 2021a; Mladenović et al., 2021a). For the sake of brevity of this section, we will not go into further details of transition and technology management at this stage, although it is important to note that details of vehicle, service, ecosystem and infrastructure design should be part of the whole package of actions for effective transformation management.

Finally, the authors of this report would explicitly underline that we do not subscribe to any version of technological determinism – justificatory, methodological, or normative (Wyatt, 2008). First, justificatory determinism argument focuses on the point that specific technological change is necessary to achieve unquestionable benefits. Second, methodological determinism renders technology opaque, simplified, and with transferred assumptions from earlier technologies without questioning them. Third, normative determinism is decoupling technology from political accountability and intervention. Thus, our premise is that e-scooters are not inevitable component of urban mobility ecosystem, and that if they are to exist in Helsinki or elsewhere, their niche in the mobility ecosystem has to be clearly delineated and managed, to avoid negative consequences for both individuals and the society at large. As such, we do not take a value position that is either technology positive or technology negative, but instead, aim for a position of technology realists.

1.2 Positioning of the challenge in particular – Helsinki

Rules[1] for e-scooter usage introduced in September 2021 in Helsinki focus on night-time service restrictions on weekends, between midnight and 5 am, and changes for maximum speed limit in general to 20 km/h, with 15 km/h between midnight and 5 am, and for the first ride. These restrictions have been introduced reactively, in response to the increasing number of emergency cases related to e-scooter usage hand in hand with a significant debate in media during the spring and summer of 2021. However, framing the issue at hand solely in terms of traffic safety or regulation will not provide us with a holistic approach to understanding challenges, and thus also restrict possibilities for creativity and innovation needed for managing the transformation. Instead, and as explained below in further details, this project positions the problem-at-hand as twofold:

A) Behavioural change of mobility system users, especially focusing on e-scooter users.
B) Institutional change of multi-level multi-sector transition actors, including all the parties involved in this project and beyond.

Behavioural change of mobility system users, especially focusing on e-scooter users

On the domain A, in contrast to the scale of the ongoing technological development and deployment, previous research in Finland and Nordic countries is limited. So far, there is an understanding that crashes involving falling or collisions often involve upper and lower extremities, as collision is sustained in a standing position (Toofany et al., 2021). More specific Finnish or Nordic studies on emergency cases do indicate that crashes are often single, during weekends, and involve alcohol intoxication, with the last being related to broader cultural features of these societies (Anjemark, 2020; Blomberg et al., 2019; Oksanen et al., 2020; Stockholms Stad, 2019). More specifically to Finland, analysis of data from Tampere University Hospital for periods of April 2019 – April 2021 shows that there were 18 emergency cases for 100,000 e-scooter rides, thus having a ratio of 0.018% (Reito et al., 2022). Research from the Helsinki University Hospital and University of Helsinki indicated that in 2021 42% of injuries was moderate, severe, or worse, with the approximated total cost of e-scooter injuries being 1.7 million euros (Vasara et al., 2022). Moreover, this research showed that the most common site of injury was the head, with crashes happening during weekends and night-time, with almost half of patients reported to be intoxicated by alcohol at the time of the injury.

Despite crash analysis being an important aspect of public policy, itself alone is not enough to identify all the diverse behavioural aspects and corresponding actions, i.e., policies. As recognized previously in studies of sociotechnical transitions (Bögel & Upham, 2018), there is a need to understand complexity of human mobility behaviour, and in Helsinki in particular. Only when understanding behaviour, one can be able to discuss challenges of short-term and long-term change – which irreducibly relates to

[1] https://www.sttinfo.fi/tiedote/vuokrattavien-sahkopotkulautojen-kayttoa-viikonloppuoisin-ja-nopeuksia-rajoitetaan-helsingissa?publisherId=60577852&releaseId=69917660

the institutional development under the theme B mentioned above. Unfortunately, a single comprehensive model of human behaviour, or even human behaviour in mobility systems does not exist, despite some quite comprehensive efforts in the past (Bandura, 1977). In addition, there is an underlying question of such model being directly applicable for policymaking processes. Nonetheless, this research will not attempt to develop a unified and comprehensive model, but has to rely on existing conceptualizations across different social science disciplines, with all their internal inconsistencies and frictions. As such, understanding human behaviour related to e-scooters relies on three main streams of thought.

Overall, human behaviour and its change with emerging mobility technologies relates to conscious and passive decision-making, having dynamically evolving and diverse user typologies and their practices, as well as novel and latent needs and capabilities. However, despite being dynamic and diverse, behaviour is also a multi-layered phenomenon (Van Acker et al., 2010), within and beyond the individual (Rinkinen et al., 2020). For example, we could talk about nanoscopic (e.g., decision to turn head left to observe space while moving) or microscopic (e.g., decision to accept a gap between two moving vehicles) layers of behaviour, which pertain more to vehicle control, guidance and navigation aspects of traveling in the public space. Similarly, we could also talk about more mesoscopic (e.g., deciding on a daily activity schedule that includes a certain combination of travel modes for the day) and macroscopic (e.g., deciding if one should purchase an e-scooter) decisions that are, metaphorically speaking, positioned on a higher spatio-temporal layer.

First, we take the model proposed by (Jensen, 2013) as useful in understanding the staging of mobility behaviour through top-down and bottom-up forces. As depicted in Figure 10, there is a process of staging from above, by planning, design, regulations and institutions at large (Blitz & Lanzendorf, 2020). Simultaneously, mobility behaviour is being staged by both embodied performances and social interactions, and has little to do with the traditional rational model of behaviour from neoclassical economics (Mladenović et al., 2021c). At the core, our behaviour is shaped by senso-motoric and information-processing constraints providing physiological feedback, but also individual's characteristics, such as personality, attitudes and motivation (Özkan & Lajunen, 2011). Just as there are dynamic interactions between subcortical and cortical brain regions, there are also dynamic interactions between cognitive and affective aspects (Blanchette, & Richards, 2010; De Vos, 2019). Besides these more intrinsic aspects, even the level of situational awareness is shaped by social influences (Cœugnet et al., 2019; Endsley, 2017), certainly also shaping our thoughts, beliefs, and expectations (Cialdini et al., 1990; Verplanken et al., 2008). Overall, these factors combine to a model where decisions are habituated and done routinely (Schneider, 2013). For a further overview of mobility behaviour concepts, the reader is referred to a summary presented in section 2.1 of (Te Brömmelstroet et al., 2021), as well as section on Market formation dynamics – supply, in (Mladenović et al., 2021a).

Figure 10: Conceptual depiction of staging mobilities (Jensen, 2013)

Following the above model by Jensen, the most recent case and review studies on e-scooter related behaviour outside of Finland do confirm some of traditional behavioural aspects related to emerging technologies, summarized below (Ali, 2021; Bao & Lim, 2022; Bozzi & Aguilera, 2021; Christoforou et al., 2021; Elmashhara et al., 2022; Esztergár-Kiss & Lizarraga, 2021; Fearnley, 2022; Flores & Jansson, 2021; Flores & Jansson, 2022; Gibson et al., 2022; Glavić et al., 2021; Jesper, 2022; Johansen, 2022; Kopplin et al., 2021; Liao & Correia, 2022; Luo et al., 2021; Milch et al., 2022; Mitra & Hess, 2021; Mouratidis, 2022; Nikiforiadis et al., 2021; Orozco-Fontalvo et al., 2022; Peci et al., 2022; Reck et al., 2021; Sanders et al., 2020; Wang et al., 2022; Weschke et al., 2022; Zhang & Kamargianni, 2022). Without an intention to simplify complexity of human behaviour, an often-mentioned fact is that e-scooter users do tend to be more male, younger and higher income adults, although these differences are not as high as in other emerging technologies, and they are context dependent. In several ways, the profile of users is similar to station-based and free-floating bikeshare programs, and modal change often comes from public transport, walking, and cycling. However, e-scooter usage also replaces driving, especially with longer e-scooter trips, if the e-scooter is privately owned, to destinations that are poorly served by public transport or when there is an explicit behaviour change scheme implemented. Most of the trips are short, around 2 km and 10 minutes, and do not just involve mobility for the last part of the trip chain, but also involve tighter time schedules, i.e., last mile – last minute. In average, trips are mostly made for leisure or social activities rather than for commuting or services.

Besides the utilitarian and functional perspective, usage is partly driven by environmental values, but even more by more hedonic aspects, as travel experience with e-scooter can provide a substantial positive affective activation (i.e., having fun while riding). Besides environmental values, there is also a potential for e-scooter use to manifest the value of social resistance, similar to the subculture of skateboarding (Beal, 1995), or denial of basic societal values (Coogan et al., 2014). Despite the age limits in some places, usage by youth can provide more independent mobility and contribute to increased activity outside the home. Finally, previous research has highlighted challenges in terms of multiple users riding on one e-scooter, and uneven and unfamiliar socio-spatial encounters between e-scooter riders and pedestrians. Previous research in Finland conducted before the most recent wave of e-scooter deployment has already identified high intention to use light electric vehicles (Hyvönen et al., 2016). Partial summaries of key aspects can be found in the following Figure 11 and Figure 12, underlining the need to understand the behavioural challenge at hand both on the system-level and on the user-level scale (Dibaj & Mladenović, 2022). Besides these important previous findings, we need further and more nuanced understanding of differences in user behaviour and user groups in Helsinki.

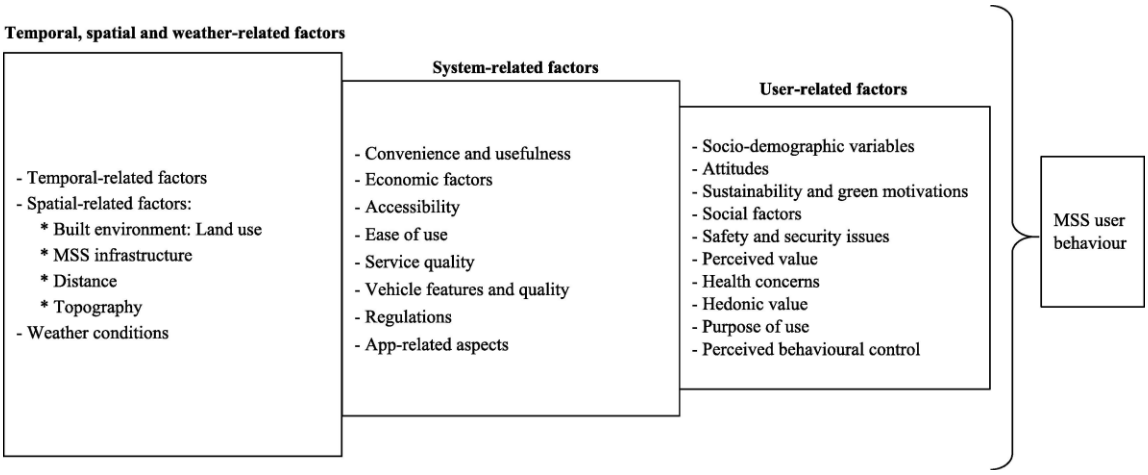


Figure 11: Summary of a range of factors influencing shared micromobility user behaviour (Elmashhara et al., 2022)

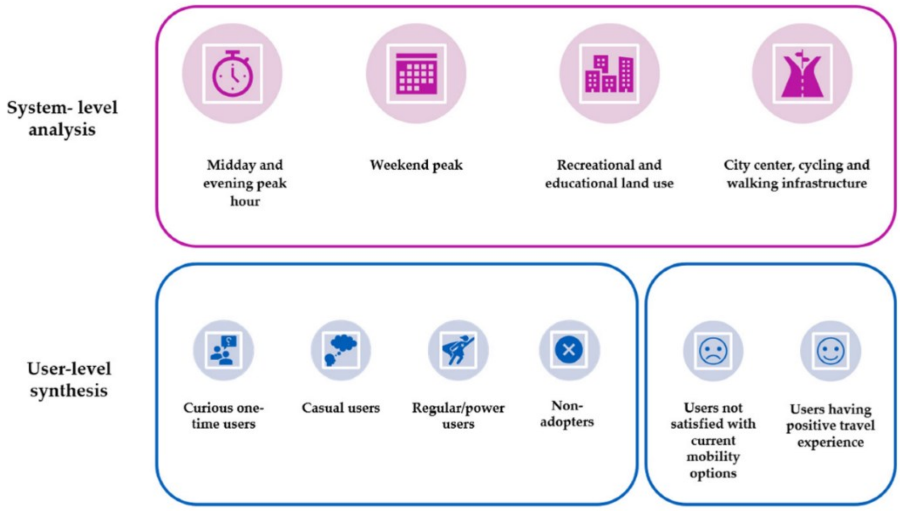


Figure 12: Summary of system-level analysis and user-level synthesis findings from the systematic review (Dibaj et al., 2021)

Second, we have to recognize that emerging mobility technologies usually involve the essential question of risk control and risk adjustment, more focused on the very task of riding e-scooter, as a lower layer behavioural aspect. Previous research informs us that there are three levels of psychological processing while driving a passenger car, as depicted in Figure 13, which could also apply to riding an e-scooter. A recent systematic literature review of e-scooter riders' psychosocial risk features concluded that individuals with the lowest degrees of risk perception remain more prone to engaging in risky road behaviours (Useche et al., 2022a). Besides weaving and passing a pedestrian too close, such risky behaviour can also include engagement in secondary tasks, such as checking the mobile phone while riding (Huemer et al., 2022). Moving beyond rational risk perception, modern social science theories inform us that riders are not behaving in rational way by taking into account actual traffic risks and their competences, but they have a tendency to habituate and automatize the riding activity through repeated riding experience (Summala, 1988; Cœugnet et al., 2019). As such, until a rider reaches a critical failure, such as a crash, they rely on experience of comfort through satisficing and do not consciously reflect on their risk (Summala, 2007). However, risky behaviour of e-scooter users can be explained not just as habituated automatization, but also through tendency for sensation seeking for novel, diverse and extreme experiences (Coogan et al., 2014; Horvath & Zuckerman, 1993; Hennessy, 2011). High sensation seekers often have higher willingness to undertake disproportionally high risks, and e-scooters might cater well to satisfying this desire given the inherent potential for speed, competition, and excitement. Previous research on e-scooters has found that young and male users are more likely to develop risky behaviours (Gioldasis at al., 2021). Besides sensation seeking, a high belief of control can also be associated with less safe behaviours (Boua et al. 2022). Similarly, more frequent e-scooter users and time longer trips are associated with the development of risky behaviours (Gioldasis at al., 2021). Ultimately, these psychological concepts about risk also lead back to sociological concepts, as culture has an important role in risk-taking behaviour (Kouabenan, 1998). For example, previous research from Norway informs us that younger people are more likely to report higher number of alcohol units consumed before riding an e-scooter as perceived to be safe (Mehdizadeh et al., 2022). From this perspective, speed limits are an effective policy for preventing risk-taking behaviour (Summala, 1988), but other means have to be sought as well.

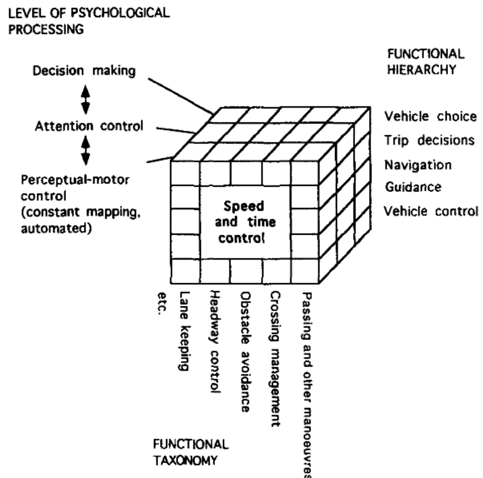


Figure 13: Driver task outlined in three dimensions relevant to accident causation (Summala, 1996)

Third, we take a stance that as values and desires are built into technology (Mladenovic & McPherson, 2016; Van den Hoven et al., 2015), we cannot only talk about what behaviour is, but we have to recognize that responsible governance is also about what behaviour should be. In the context of urban mobility, we start from the premise that this system belongs to the domain of goods often referred to as commons, with associated properties (Mladenović, 2021b). The premise is that mobility with e-scooters is fundamentally a question of social order and collective action in the public domain (Kollock, 1998), also related to the problem of collective risk (Rumar, 1988). The following Figure 14 is an extension of the traditional fourfold model of goods often discussed in economics literature, which is based on "free rider" excludability juxtaposed to rivalry in consumption (Hess & Ostrom, 2003). Expanding that traditional perspective, we envision urban mobility systems as a social practice of commoning (Nikolaeva et al., 2019), relies on including a dimension of anti-rivalry (Nikander et al., 2020) and prosumption as simultaneous production and consumption of the urban mobility good by the users. In addition, another dimension to categorize an optimal state of urban mobility system would be anti-excludability and cooperation. The notion of anti-excludability challenges the assumption of undesired "free rider" in the urban mobility system, largely rooted in the theories of justice, where being able to participate in the urban mobility system is a question of fundamental legal and moral rights (Mladenović, 2017; 2020). Besides the notion of anti-excludability, the notion of cooperation stems from long-term biological and cultural evolution of cooperation in human societies, based on such aspects as reciprocity, reputation, signaling, norm compliance and punishment (Fehr & Gintis, 2007; Henrich & Muthukrishna, 2021; Lindenfors, 2017; Rand & Nowak, 2013). Thus, although self-regarding and norm-regarding aspirations coexist, available opportunities and affordances of urban mobility technology or infrastructure largely frame the outcome of aggregate level of social cooperation.

	Large rivalry in consumption	***Small rivalry in consumtion***	***Anti-rivalry and prosumption***
Easy excludability of free-riders	Private parking	Tolled road	Video games
Hard excludability of free-riders	Public street	Library	Wikipedia
Anti-excludability and cooperation	Participatory budgets	Social media	**Mobility systems**

Figure 14: Conceptual representation of mobility systems as a type of good

Institutional change of multi-level multi-sector transition actors, including all the parties involved in this project and beyond

As elaborated in section 1.1., with the premise that e-scooter technology has passed from incipient into liminal phase of emergence, the domain B listed above focuses on the question of institutional adaptation within the wider societal transition. Simply put, institutions are habituated rules of organized processes but also their underlying norms and rationales. Besides that general adaptability, adaptive governance of emerging technology relates back to the boundary between changeable and stabilized parts of the system under purview (Brunner, 2010; Janssen & Van Der Voort, 2016; Marchau et al., 2010; Mergel et al., 2018; Rijke et al., 2012; Steelman, 2022). However, since emerging technologies usually operate within the institutional void (e.g., missing rules, missing processes, missing responsible actors), we cannot expect to find the necessary and solidified institution, as one would do so in other domains of traditional urban planning and management. Thus, we have to recognize that governance of this transition relies on an interplay of different actors and their constitutive elements (see Figure 15) – just as in the case of Helsinki. Contrary to the initial formulation of Collingridge dilemma where the nature of the problem is considered to be technical and organizational, we consider that the nature of the problem is also cultural, political, and moral (Bodrožić & Adler, 2022; Ribeiro et al., 2018). This is why, besides policy or business actors, or users themselves, it is important to underline that wider publics are part of the actor constellation shaping the transition trajectory (Dibaj et al., 2022a).

As in the case of other emerging technologies in modern democracies, there are underlying differences in public perception and opinion. For example, based on questionnaire conducted in Sweden, public opinion towards e-scooters is divided, where the presence of e-scooters is thought of as an excellent addition to the urban area by 46%, or it is considered annoying and/or unsafe by 44% of the respondents (Rachmanto et al., 2020). Similarly, based on questionnaire, (Useche et al., 2022b) found that e-scooter riders were overall perceived as significantly 'worse' riders than cyclists. Based on media analysis, (Johnson, 2018) found a strong division of opinions in the UK, between users on the one, and members of the public and professionals on the other hand. Similar analysis of media concludes that discourse on e-scooters has all the main features of moral panic, as heightened concerns, hostility, and disproportionality in depicting the threat (Kolaković-Bojović & Paraušić, 2020). These contrasting public perceptions are not a new phenomenon in the context of emerging mobility technologies, as similar perspectives could be observed in the beginning of the 20th century, when emergence of private automobiles happened (Norton, 2011). Besides these aspects, we have to recognize that built environment, especially as it is still dominated by the automobile and its incumbents, represents also an actor in the (need of) transformation (Birtchnell et al., 2018).

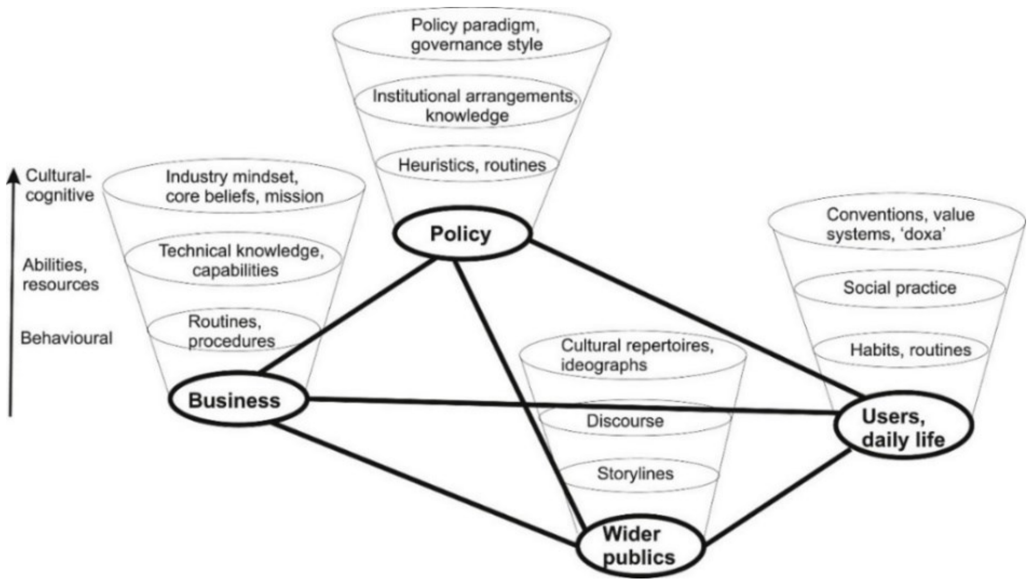


Figure 15: Depiction of different actor groups and their constitutive elements (Geels, 2021)

A crucial aspect of institutional adaptation and transition management (Patterson, 2021; Van Poeck et al., 2020; Van Poeck & Östman, 2021) is organizational learning, which goes all the way to the level of managerial capabilities (Tawse & Tabesh, 2021). Figure 16 below depicts the interplay of levels that should be considered in order to achieve the so-called triple-loop organizational learning (Schmidt-Thomé & Mäntysalo, 2014; Tosey et al. 2012). On the right-most side of this Figure 16, positive and negative impacts of actions in Helsinki urban mobility system are distributed over spatial and temporal scales but are also essentially related to behavioural and cultural change as part of wider societal learning during the transition (de Vries et al., 2021; Dibaj et al., 2021; Kaufman et al., 2021). For steering this behavioural change, choosing the right actions requires understanding human behaviour (as explained under domain A above) and understanding the relationships between actions and their effectiveness on behavioural change. However, decisions on these actions and their implementation must originate from practices and processes of decision-making, which are done in communication between a plethora of actors mentioned above.

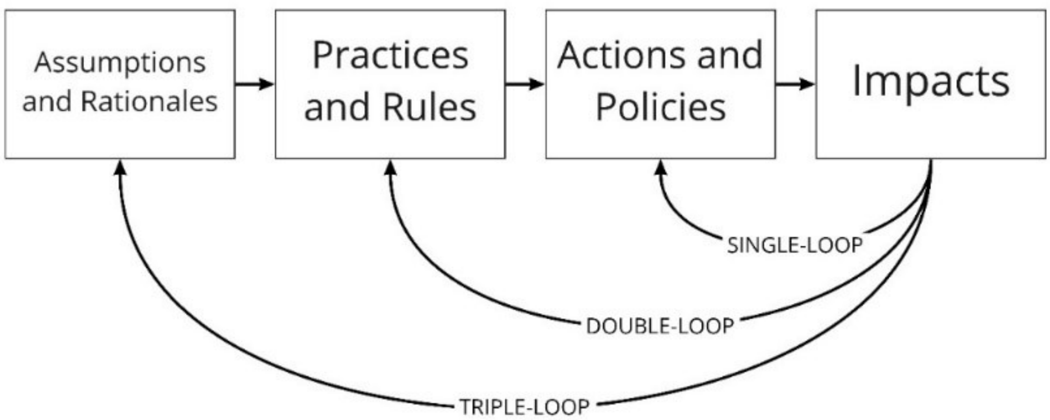


Figure 16: A conceptual depiction of triple-loop organizational learning

In urban planning theory, the multi-actor communication and collaboration challenge aspect has been defined as a challenge of knowledge integration through communicative planning (Eräranta & Mladenović, 2021a,b; Healey, 2009), while in the field of technology management, this aspect has been referred to as the problem of many hands (Van de Poel, 2015). Both of these fields agree on a common point of importance of agency and agent's power in the transitional dynamics (Kok et al., 2021). Such governance challenge of distributed actions across different actors in different sectors (Liimatainen & Mladenović, 2021; Mladenović et al., 2020b), has been identified in other urban environments experiencing the deployment of e-scooters (Fearnley, 2020; Field & Jon, 2021; Kim, 2019; Sareen et al., 2021). Similarly, in the case of Helsinki, events of 2021 happened in an institutional void, exemplified in the lack of rules and responsibilities for steering the technological trajectory – which as a response requires innovation in governance rules and instruments for communicative decision-making.

Finally, besides innovation in practices and rules, the third loop of learning has to be addressed as well, focusing on evolving governance culture with its underlying assumptions and rationales. Such change management culture has to face some of the traditional challenges also observed in urban planning in general. These include, but are not limited to, change aversion, conflict aversion, avoiding discussion on the meaning of technology, and illusion of comprehensive rationality – all also identified in previous research on governance of e-scooters (Field & Jon, 2021; Kim, 2019; Sareen et al., 2021). Moreover, developing a responsible culture of governance has to be rooted in principles of responsibility. Thus, decision-making cannot only be evidence-based but has to rely on adequate foresight procedures, reflective about path dependence and uncertainties, hand in hand with wider deliberation and explicit development of roles and responsibilities (Stilgoe et al., 2013; Mladenović, 2019). The fundamental uncertainty, which goes hand in hand with the above premise on technological determinisms, is that sociotechnical trajectories are non-linear, even if we assume they usually match the traditional S-curve of technology diffusion (Figure 17).

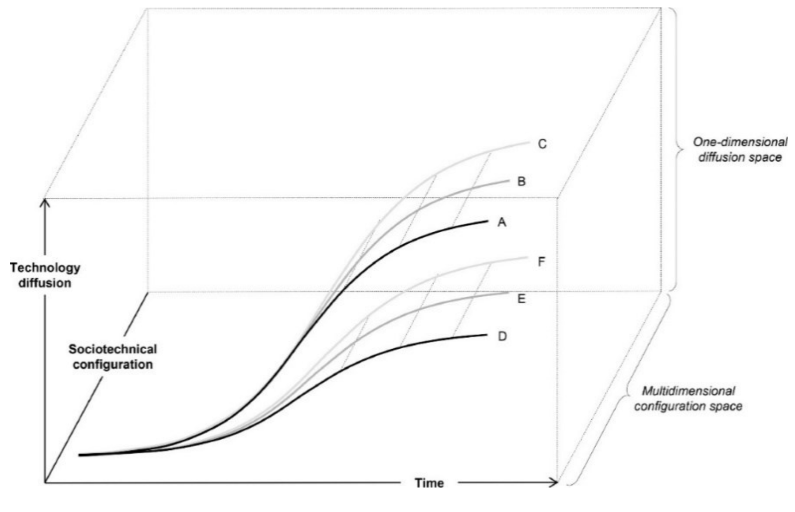


Figure 17: Six potential development trajectories (A-F) for an emerging technology, resulting in different sociotechnical configurations and/or different levels of diffusion (Andersson et al., 2020)

Ultimately, the same notions that can be found in the state-of-the-art of (transport) planning theory pertain here. A single future is not something we should try to predict, but rather we should anticipate different futures (Sustar et al., 2020; Mäntysalo et al., 2022). This anticipation can be based on speculative foresight methods, such as scenarios, but also provide a better starting point through structured organizational learning. Thus, as depicted in Figure 18, we challenge the fundamental assumption of Collingridge, where knowledge of impacts is rather low at the stage when we have greatest flexibility of technology (red line on Figure 18) – if we assume not having knowledge of urban mobility impacts (blue line on Figure 18). However, we cannot pretend that we do not have knowledge of various urban mobility impacts, and that we cannot anticipate desired and undesired consequences of emerging mobility technologies, such as e-scooters. So, we assume that 21st century organizations should have by default improve knowledge of impacts (green line on Figure 18). Thus, a modern dilemma of technological trajectory would focus also on the path, not just the end state of technology over its waves of development (Figure 19). If we assume that technological performance, in any way we measure it (e.g., number of injured, perceived well-being, CO_2 emissions, etc.) will end up a better state in the future, are we also willing to accept Path Z depicted in Figure 19. This path describes the possibility for a non-linear socio-technical transition that goes through worse level of performance, at least for some amount of time, before reaching an improved and desired state (State 2). This moral question remains a central dilemma for adaptive governance. Further details of different disciplinary perspectives on emerging technologies and sociotechnical trajectories can be found in (Mladenović et al., 2021a).

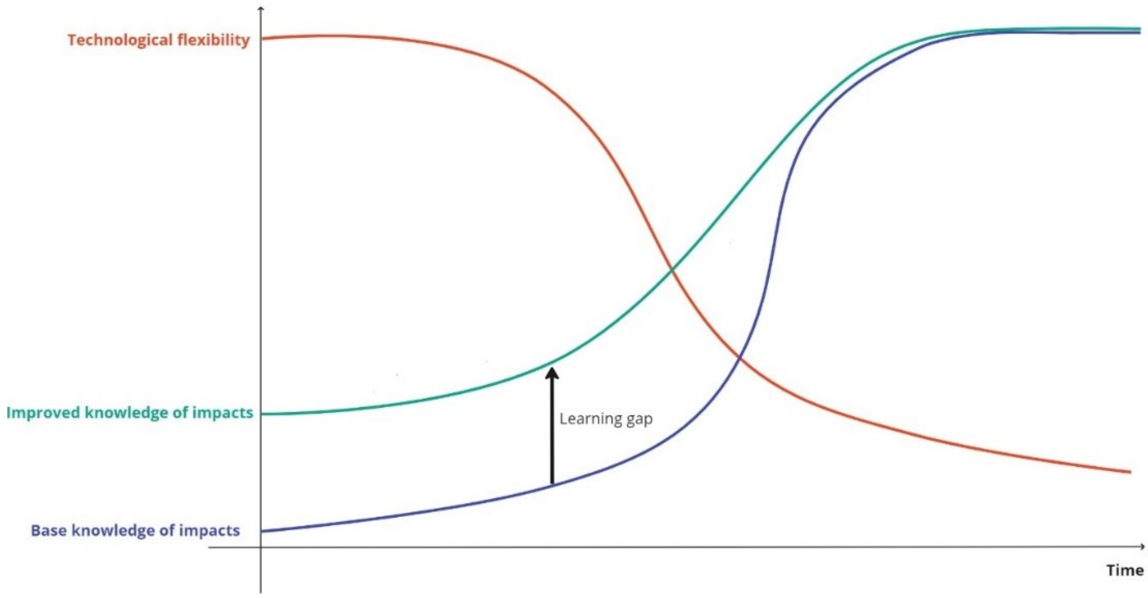


Figure 18: Revised depiction of Collingridge dilemma to account for improved anticipation from organizational learning

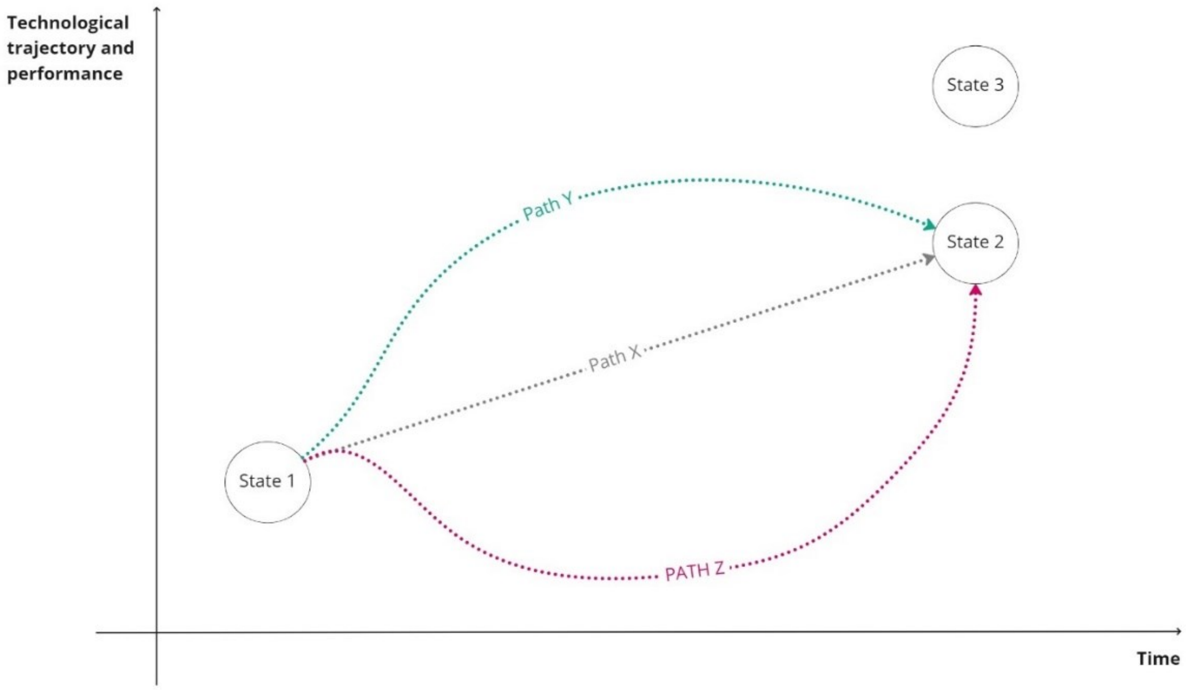


Figure 19: Nonlinear technological trajectory paths and states

Research questions

Based on the A and B domains elaborated above, the following four questions are used to guide research aims and specific methodological development for this project.

RQ1: What are the spatio-temporal changes in the occurrence and severity of standing shared e-scooter related emergency cases in the City of Helsinki?
RQ2: What are the types of observed riding competences and behaviours of standing shared e-scooter users in the City of Helsinki?
RQ3: What are the user and non-user perspectives on the usage and restrictions of standing shared e-scooter in the City of Helsinki?
RQ4: What are implications and directions for developing responsible and adaptive governance processes of emerging e-scooter technology, including future data collection and analysis needs?

2. Methodology

2.1 Spatio-temporal analysis of emergency case data

In order to address RQ 1, the emergency data analysis framework is developed, having five components, as depicted on Figure 20. In general, a retrospective analysis (Kweon, 2011) was implemented in order to identify changes in injury types and severity of e-scooter related emergency cases (Cicchino et al., 2021) in the Helsinki region, including descriptive statistics before and after the restrictions. Since the restrictions were implemented from September 3^{rd}, 2021, this date is a threshold for before-after analysis, including years 2021 and 2022. On the one hand, analysis is intended to identify risk groups based on socio-demographic characteristics of injured people, as well as spatial and temporal distribution of e-scooter crash locations before and after the restrictions. On the other hand, the analysis aims to compare exposure between bicycles and e-scooters in the city of Helsinki, where incidence rate can be estimated as a ratio of incidences and some unit of exposure (Vanparijs et al., 2015).

Sociodemographic characteristics of the injured people	• Age and gender distribution of injured people in 2021 and 2022 • Intoxication based on age and gender distribution in 2021 and 2022
Crash characteristics	• Crash type quantity • Crash reason categories • Distribution of different e-scooter crash reasons
Cycling and e-scooter trips and crash comparison	• Cycling exposure ratio • Comparison of cycling and shared e-scooter exposure ratio
Temporal distribution of shared e-scooter crashes before and after the restrictions	• Monthly, weekly, daily and hourly distribution of crashes and proportional crashes of shared e-scooters in 2021 and 2022 • Proportional number of e-scooter related emergency cases before the restrictions • Comparative analysis of proportional e-scooter crashes during weekends and weekdays before and after the restrictions • Injury severity during weekends and weekdays before and after the restrictions
Spatial distribution of shared e-scooter crashes before and after the restrictions	• Heatmap of e-scooter related crashes arrived by ambulance in 2021 and 2022, non-weighted • Heatmap of e-scooter related crashes arrived by ambulance in 2021 and 2022, weighted by injury severity

Figure 20: Emergency case data analysis framework

Data on e-scooter related injury has been collected and compiled by the Helsinki University Hospital (HUS), and includes the same dataset as in (Vasara et al., 2022). When referring to emergency room data from HUS, we have used the word “injuries” in the whole report. This data includes cases where injuries led to a hospital treatment. In particular, the dataset delivered by HUS includes 460 and 148 data points from 2021 (whole year) and 2022 (from January until August), respectively. After processing as explained below, 432 cases from 2021 and 130 cases from 2022 remained in the sample. The data included the following columns:

- ID
- Primary Hospital (0 = Haartman, 1 = Malmi, 2 = Töölö)
- Patient required special medical care (Töölö hospital/Meilahti tower hospital)

- Gender (0 = Male, 1 = Female)
- Age, years
- Emergency room (ER) arrival date
- ER arrival time
- Crash date, (if differs from ER arrival date)
- Crash time, (if differs from ER arrival time)
- Method of arrival (0=Self, 1=By ambulance, 2=Referral, on-call (another unit is directing) 3= Referral, tensionless)
- The address of the crash (from ambulance records, if available)
- Breath alcohol (‰) (Highest value)
- Left the ER before examination (binary)
- Injury severity score expressed using Abbreviated Injury Scale (AIS) (AAAM, 2015)
- Accident mechanism (0 =The rider fell, 1=The rider crashed, 2= Pedestrian hit by a e-scooter, 3 = Two riders on the same e-scooter, fell or crashed, 4 = Other)
- Whose e-scooter (0 = rental, 1 = Privately owned, blank = N/A)
- The rental company (if available)
- Alcohol (0 = no, 1 = yes, blank = N/A)
- More accurate crash mechanism (if available)
- Helmet use (0 = no, 1 =yes, blank = N/A)
- Surgery (0 = no, 1 = yes, if more than one, the amount is shown)
- Hospital ward treatment (0 = no, 1 = yes, basic level hospital ward, 2 = ICU)
- Length of hospital ward stay (days)

Since the data entry was not a systematic process and it depended on the medical personnel's attention to details as well as the crowdedness of the ER, the available dataset was not perfect. For example, being intoxicated was either assessed by the medical personnel without the test or by the breath alcohol level test. Records are classified based on the following criteria presented in columns of Table 1. Accordingly, only about 27% of the data has semi-perfect, perfect and pure quality in 2021. The data quality is similar for 2022 dataset.

Table 1: Injury data quality assessment in 2021

	Breath alcohol (‰)	**Injury severity score**	**Accident severity**	**Accident mechanism**	**Method of arrival**	**Crash description**	**Crash address**	**Helmet use**	**Owner of e-scooter**	**Quantity (percent)**
Pure	x	x	x	x	x	x	x	x	x	5 (1.2%)
Perfect	x	x	x	x	x	x	x	x	-	33 (7.6%)
Semi-perfect	-	x	x	x	x	x	-	-	-	77 (17.8%)
Semi-messy	x	x	x	x	x*		-	-	-	150 (34.7%)
Messy	-	-	-	-	-	-	-	-	-	167 (38.7)

*Column "Method of arrival" or "Crash description" is not blank.

In addition to data described above, the dataset had a column named "accident description", which included the medical personnel's written description in Finnish about the crash based on patient's narration. 199 out of 432 (46%) of the data in 2021 and 116 out of 148 (78%) in 2022 had some information in this column. This part of the data for 2021 was categorized and analysed based on the following information:

- Detailed crash type
- Place of crash (e.g., intersection, sidewalk, street, cobblestones, sand road, tram rails or near tram station etc.)
- Multiple riders on the same e-scooter
- Speed estimate
- Performing tricks with the e-scooter
- Low competence in using e-scooter
- Weather condition
- Vehicle issues (e.g., break malfunction, steering malfunction, front tire malfunction, fading battery)
- Infrastructural issue (e.g., gravel, pothole, parking)
- Hitting an external object

According to the location of crashes, some of the crashes did not happen in Helsinki (Table 2). However, the injured was either brought to Helsinki hospitals by an ambulance for treatment or the injured persons went to the Helsinki hospitals for a check-up. The total number of cases outside Helsinki in 2021 and 2022 is 13 and 14 records, respectively which are excluded in our analysis. However, we assume that all the other cases with no crash locations happened in Helsinki. Explicit exclusion of crashes happening outside of Helsinki was done because of the research scope, where both restrictions and street infrastructure, especially in the Helsinki city centre, are differing from other Finnish cities.

Table 2: Number of crashes per city in 2021 (whole year) and 2022 (Jan-Aug)

City	2021	2022
Not stated	267	91
Helsinki	180	43
Vantaa	4	4
Järvenpää	3	0
Espoo	2	1
Hyvinkää	1	1
Kerava	1	0
Oulu	1	0
Tuusula	1	0
Hanko	0	1
Kouvola	0	2
Lahti	0	1
Turku	0	1
Estonia	0	2

The dataset also included 15 crashes in 2021 and 4 crashes in 2022 while using private e-scooters in Helsinki. These cases are treated separately, under the premise that use behaviour of shared and private usage differs. For private e-scooter crashes in 2021, average age was 32.3 and 80% of them were male, while the blood alcohol level test showed that 20% of them were intoxicated. While in 2022 (Jan-Aug), average age was 51.6 and 75% of them were male, while the blood alcohol level test showed that 25% of them were intoxicated. After filtering based on municipality and e-scooter ownership, the final injury dataset ends up having 432 cases from 2021 and 130 cases from 2022 (Jan-Aug).

E-scooter trip data is obtained as an output from Vianova CityScope platform which collates data from different operators' interfaces[1], and is under the purview of the City of Helsinki. The total number of e-scooter trips in 2021 is 4,040,467, while the same number for January to August 2022 is 3,412,674. This number corresponds in scale to numbers in Helsinki and other cities, from previous research, which indicates there have been 1,128,507 trips in Helsinki between May 25 and July 25, 2021 (Li et al., 2022). The hourly e-scooter trip data on weekend and weekdays, 2021 and 2022 is plotted in Figure 21 to Figure 25.

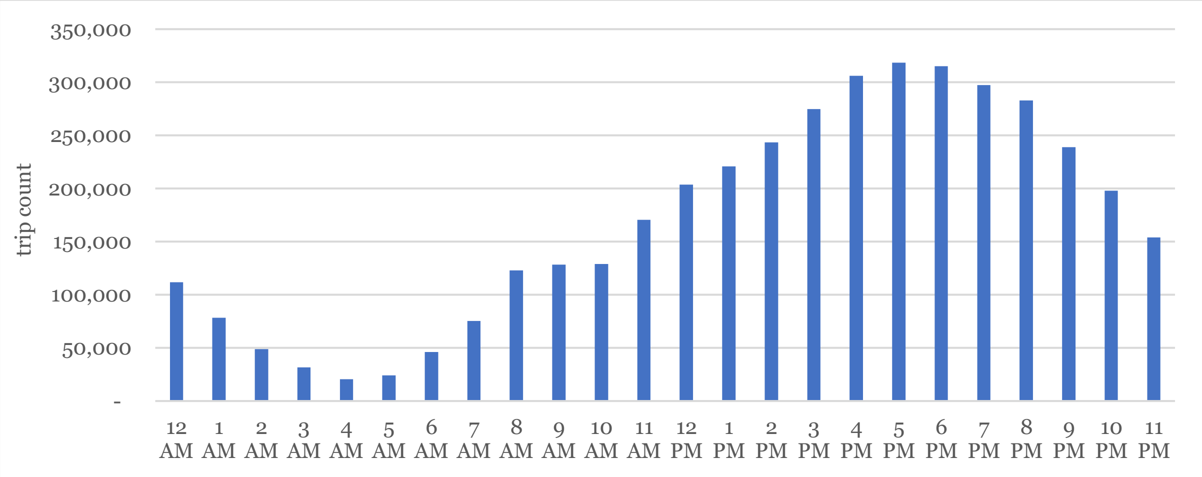


Figure 21: Shared e-scooter trip data in 2021

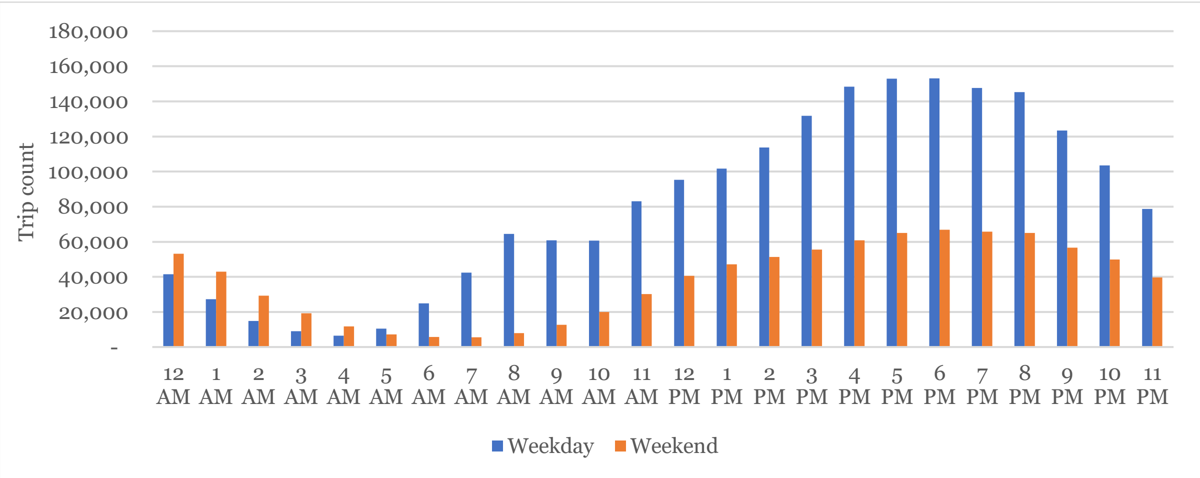


Figure 22: Shared e-scooter trip data from January until August 2021 per day of week

[1] https://github.com/openmobilityfoundation/mobility-data-specification/blob/main/provider/README.md

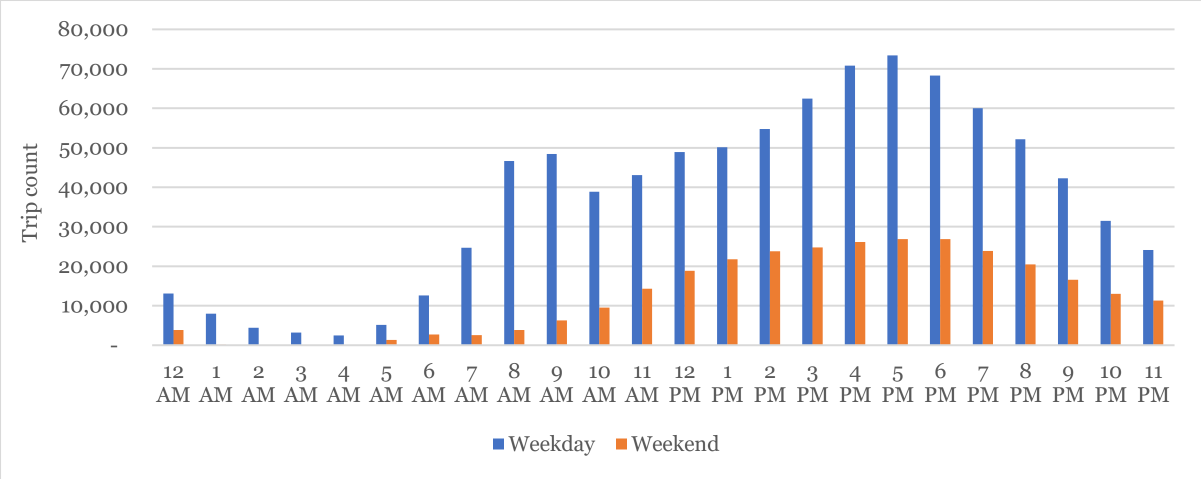


Figure 23: Shared e-scooter trip data from September until December 2021 per day of week

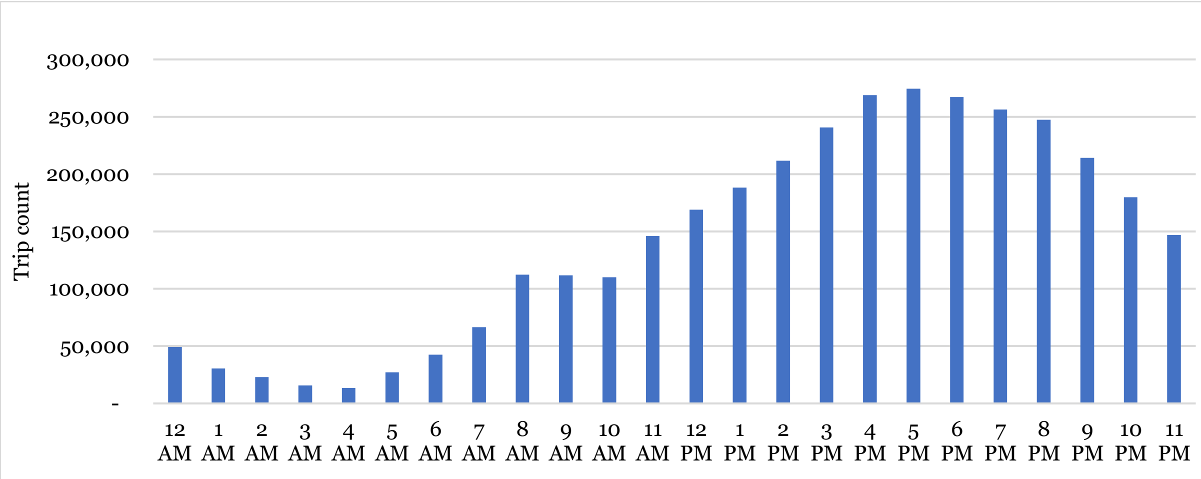


Figure 24: Shared e-scooter trip data in 2022 (January-August)

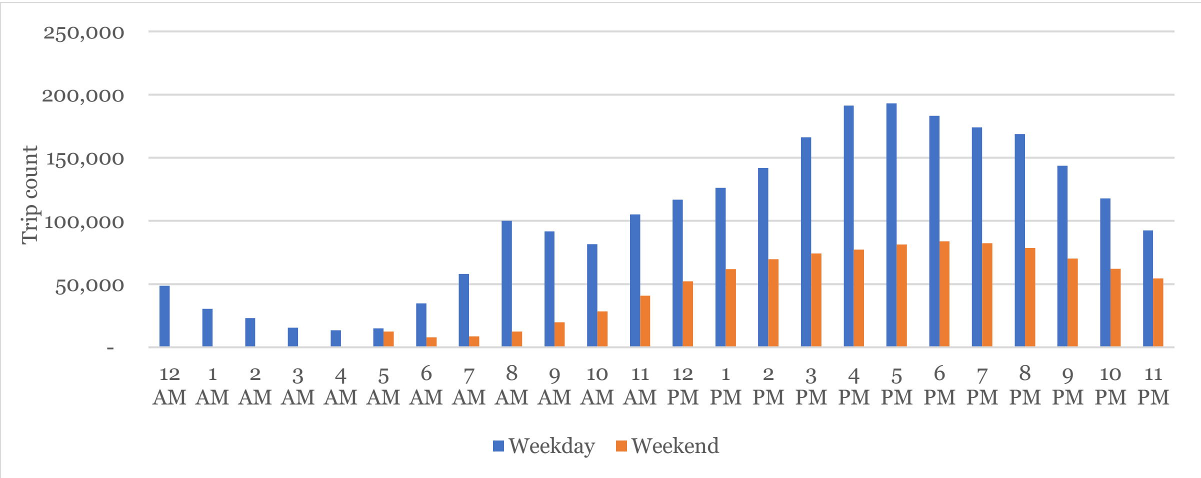


Figure 25: Shared e-scooter trip data from January until August 2022 per day of week

Due to data limitations, the analysis framework could not implement state-of-the-art methodology for comparing e-scooter and cycling safety, such as (Shah, 2021). Data issues were both on the side of exposure data and incidence data. In particular, although kilometres are an optimal measure for exposure, often used in state-of-the-art studies such as (Malin et al., 2020), obtaining such data in adequate quality for both e-scooters and cycling would require substantial efforts beyond this research project. In particular, estimating number of cycling trips within a part of Helsinki is a challenging problem since such data is not comprehensively and longitudinally gathered using both traditional travel surveys and automatic data collection methods (Livingston et al., 2021; Nordback et al., 2017). As a trade-off with effort needed to precisely-enough estimate the number of cycling trips within the same geographic boundary as e-scooter operating area (Figure 26), a scenario-based estimation is implemented. The operational area of shared e-scooters is presented in Figure 26, with the top layer marked in red, while orange layer depicts the extra area of geofenced area that does not include Helsinki area or population. The shared e-scooter operational boundary map has been plotted based on estimated geofence coordinates, compared across different shared e-scooter applications.

The cycling trips in 2021 have been estimated as following. The average number of cycling trips per day per person is 0.3 according to "Mobility survey 2018, Use of transport modes, in the Helsinki Region" report[1]. Therefore, total number of cycling trips for the population of Helsinki (641,155 in 2021) is as follow:

$$Total\ annual\ cycling\ trips\ in\ whole\ Helsinki = 365 \times 641{,}155 \times 0.3 = 70{,}206{,}473$$

This value of approximately 70 million trips is taken as the upper overestimation boundary. Furthermore, based on cycling barometer study in Helsinki[2] in 2020, 58% of adults in Helsinki cycle at least once per week (11%, once per week, 22%, two to three times per week, 25%, daily or almost daily). On the other hand, 13% rarely cycle and 29% of residence in Helsinki never cycle (42%) (Helsinki, 2020). We can consider that, 58% of adults in Helsinki cycle actively throughout the year. Rationing the previously mentioned 70 million trips with 58%, the upper estimation boundary for annual cycling trips in Helsinki is rounded to 40 million trips. This number of 40 million also includes cycling trips outside the operational area of the e-scooters. In order to further scale the number of cycling trips, the operational area presented in Figure 26 is estimated to be about 29.5% of the whole Helsinki's area (in total 213,8 km^2) and to have about 50% of the population of the whole Helsinki (in total 641,155). Taking the 29.5% as the condition for the lower boundary, which when multiplied with 40 million results in approximately 10 million cycling trips, estimation scenarios have been categorized as 10, 20, and 30 million of cycling trips within the e-scooter operational area in 2021. The same set of scenarios for cycling trips is assumed for January-August 2022 as well, as operating area for e-scooters is larger, while time is shorter than a full year. The new 2022 operating area has increased by about 12% in

[1]https://hslfi.azureedge.net/globalassets/hsl/tutkimukset/liikkumistutkimus/kulkutapojen_kaytto_helsingin_seudulla_liikkumistutkimus_2018.pdf
[2]https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/julkaisu-29-20.pdf

area and about 15% in population coverage. Therefore, in 2022, 41.5% of the area of Helsinki and 65% of the population is covered by the operators.

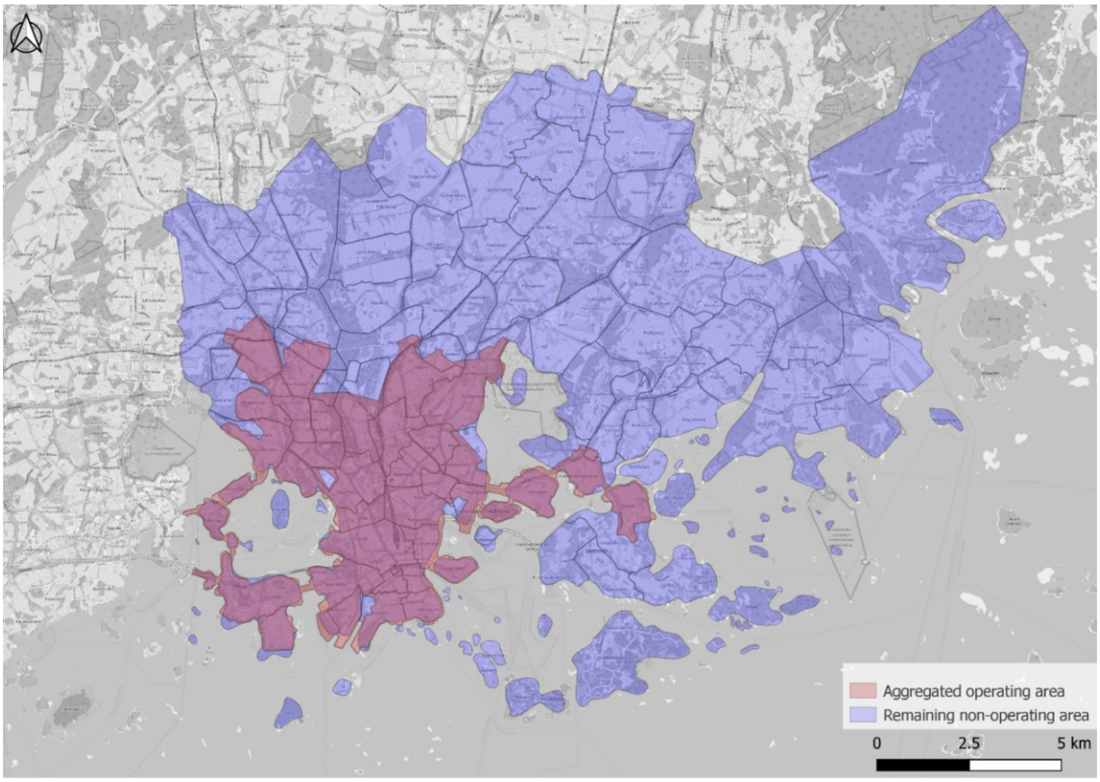


Figure 26: Estimated shared e-scooter operational area in 2021

The data on distinct injured people from cycling incidents have been received from The Finnish Institute for Health and Welfare (THL)[1] for the City of Helsinki for 2021 and for 2022 (Jan-Aug). According to this data, there might be different visits from the same patient to health centres. Therefore, after discussing the issue with an expert in THL, the duplicate visits were excluded. Based on Table 3, we have considered two approaches to estimate the number of cycling crashes in the operational area in Helsinki. The first one is based on the area and the other one is based on the population living inside that area, using the percentages explained above.

Table 3: Estimated number of cycling injuries inside e-scooter operating area of Helsinki in 2021 (whole year) and 2022 (Jan-Aug)

Date \ **Injuries**		**Injuries in the whole Helsinki**	**Injuries based on area**	**Injuries based on population**
2021	Before the restrictions (Jan-Aug)	998	294	499
	After the restrictions (Sep-Dec)	460	136	230
	Whole 2021	**1,458**	**430**	**729**
2022	After the restrictions (Jan-Aug)	**1009**	418	655

[1] https://thl.fi/fi/tilastot-ja-data/tilastot-aiheittain/sairastavuus-ja-tapaturmat/tapaturmat

2.2 Video recording, coding and clustering analysis of revealed e-scooter riding behaviour

In order to further understand actual behaviour of users in the urban space related to RQ2, a video recording and analysis methodology has been developed, drawing from similar previous research (Eby, 2011; Casello et al., 2017; Hong et al., 2022; Huemer et al., 2022; Lyons et al., 2020). This method has an inherent trade-off between wider field of vision, and resolution for specific part in the field of vision, due to lens constraints (Dibaj et al., 2022b). Video recording has been conducted on selected four locations in Helsinki, during daylight and night-time conditions. First, a larger set of suggestions for locations was compiled based on emergency case data and input from the city and operators. Ten locations were visited for a closer inspection of the site, to be able to assess the site features (e.g., scooter parking locations and amount, scooter traffic volume being medium or high, surrounding land use, etc.). In addition, site visits include assessing the location for the camera that would account for height and visual angle constraints, since objects of interest might block each other less than they would from a lower position. Besides maximizing the visible area in trade-off with visibility of details due to lens distance, camera location choice included assessing possible glare issues (e.g., lighting, sunshine) and potential for theft or vandalism of the equipment, while also avoiding drawing excessive attention of the street users that could affect their behaviour. After approval from the city to use lighting or signage poles, a written privacy notice on video recording was attached on the pole. Following four figures show recording locations and camera placement position.

Viiskulma location was selected as complex, five leg uncontrolled intersection, with interrupted bike lane, narrow sidewalks, and cobblestone street surface, including proximity to diverse land use (Figure 27). Ruoholahti/Jätkäsaari underpass location was selected as shared space, and beginning of Baana cycling street, including unclear space for routes and conflict points of intersecting traffic flows (Figure 28). Keskuskatu/Aleksanterinkatu location was selected as shared space with street furniture and terraces, including high pedestrian and micromobility volume, as well as tramlines (Figure 29). Erottajan aukio location was selected as a larger signalized intersection, including motorized traffic and discontinuous bike lane (Figure 30).

Viiskulma, Ruoholahti, and Keskuskatu recordings started on Friday, October 29, 2021. Weather conditions were partly cloudy, no rain, with temperature between 9 and 13 C, while sunrise and sunset were at 08:36 and 17:32, respectively. Recoding on Viiskulma started at 14:02 and ended at 06:03 on the next day, October 30. Recoding on Ruoholahti started at 14:17 and ended at 06:25 on the next day. Recording on Keskuskatu started at 13:47 and ended at 05:48 on the next day. Recording on Erottaja started on Friday, November 5, 2021, at 14:08 and ended at 06:09 on the next day. Weather conditions were light rain until late evening, with temperatures between 6 and 8 C, while sunrise started at 08:54 and sunset started at 17:13. Friday was chosen as critical day for recording, based on a combination of factors, including micromobility traffic volume, number of emergency cases, and the day for beginning of night-time restrictions.

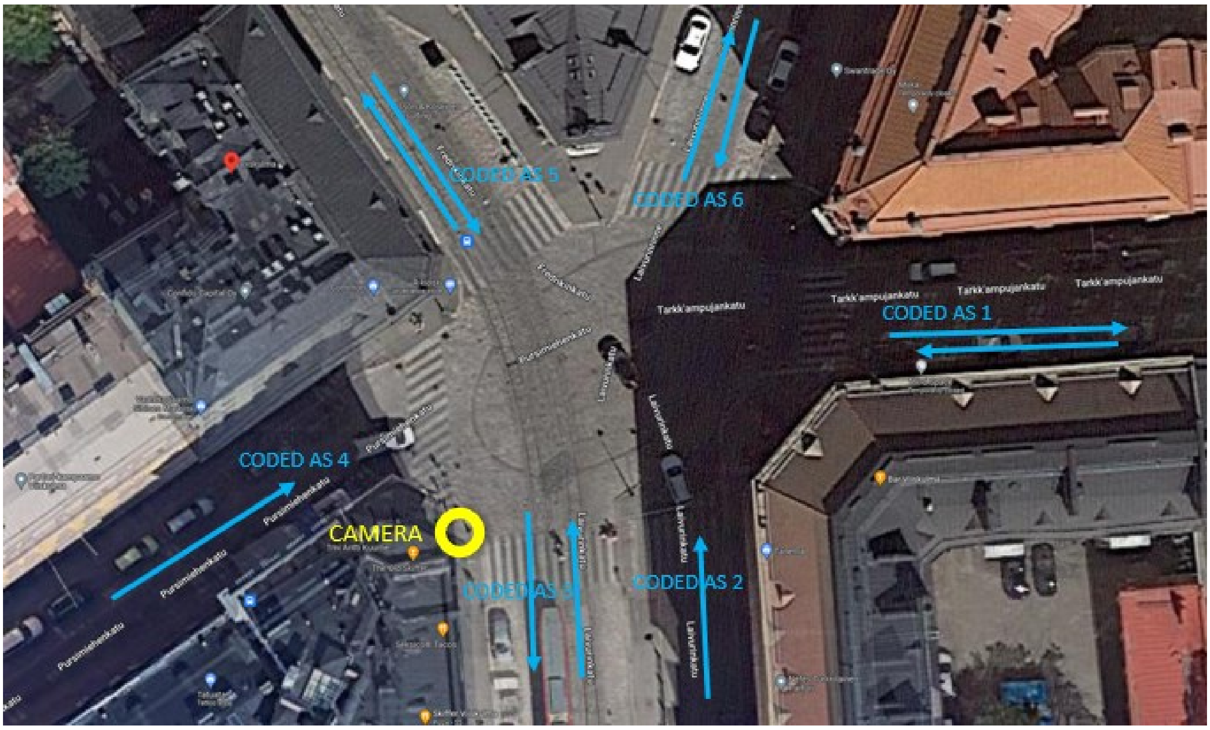


Figure 27: Viiskulma camera location and coding directions

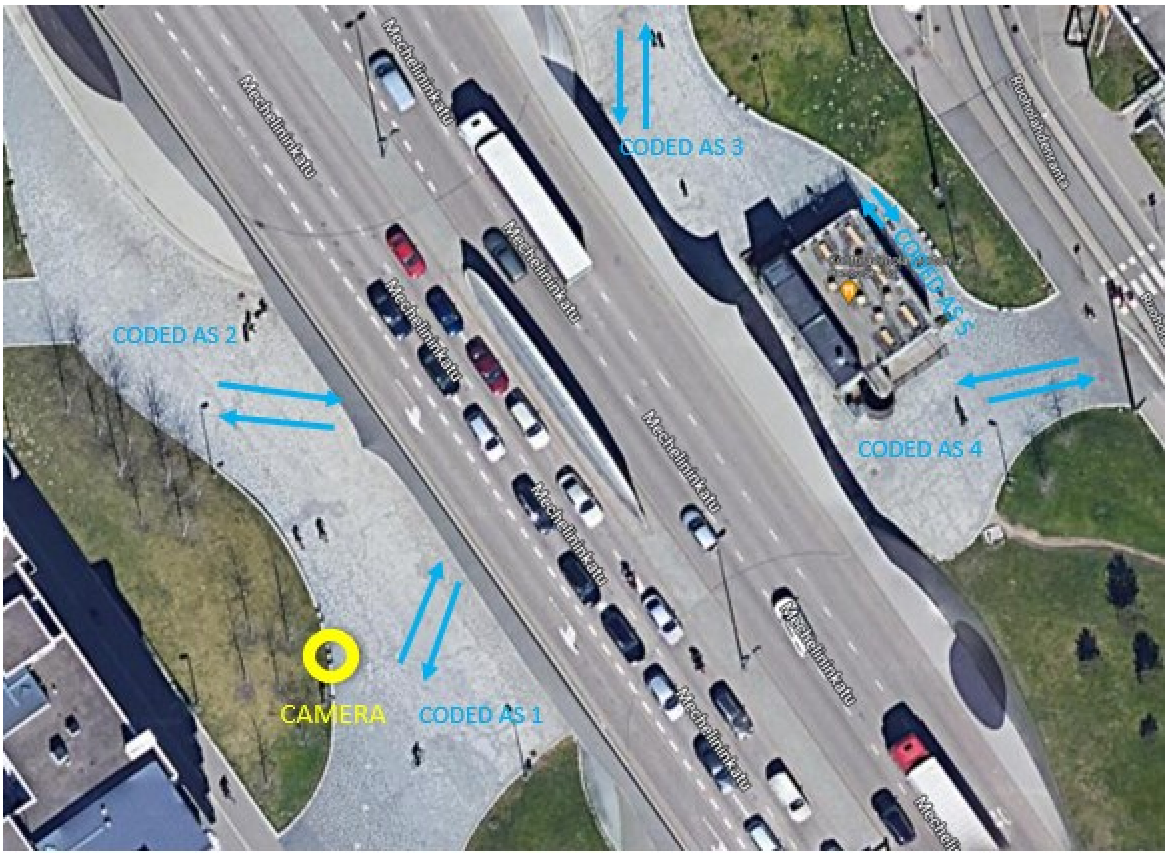


Figure 28: Ruoholahti camera location and coding directions

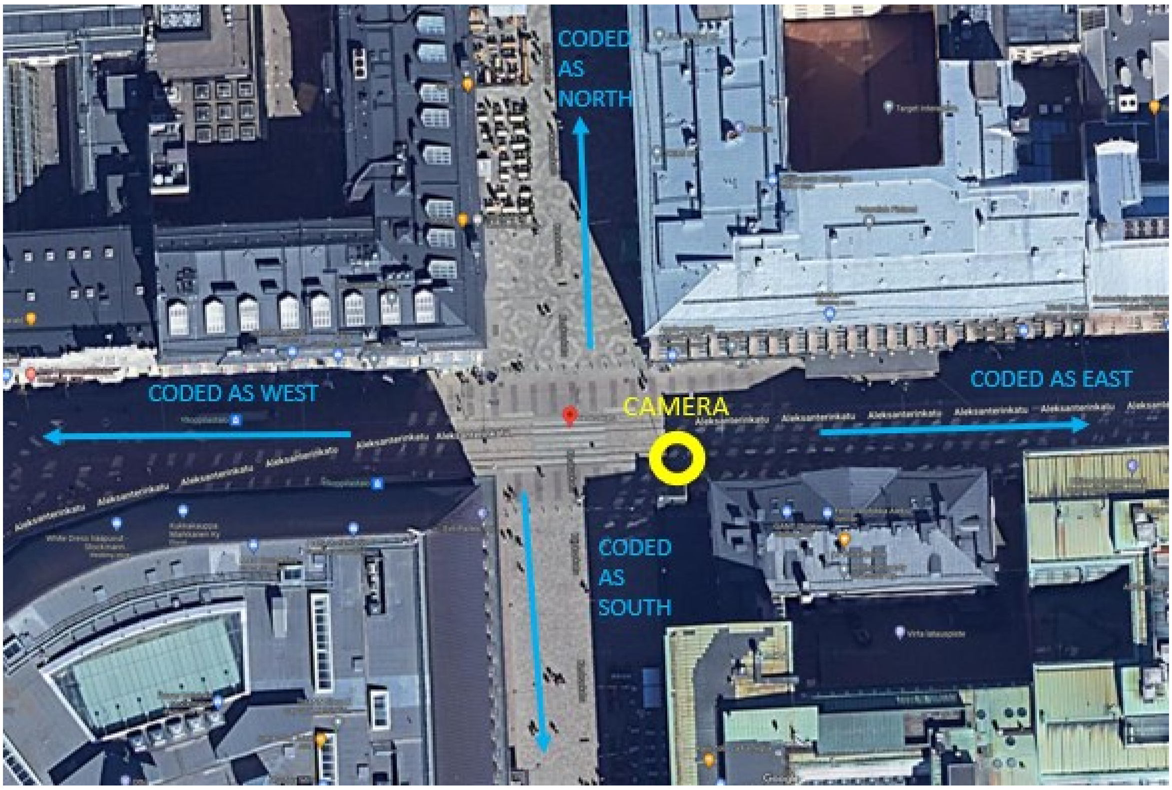


Figure 29: Keskuskatu camera location and coding directions

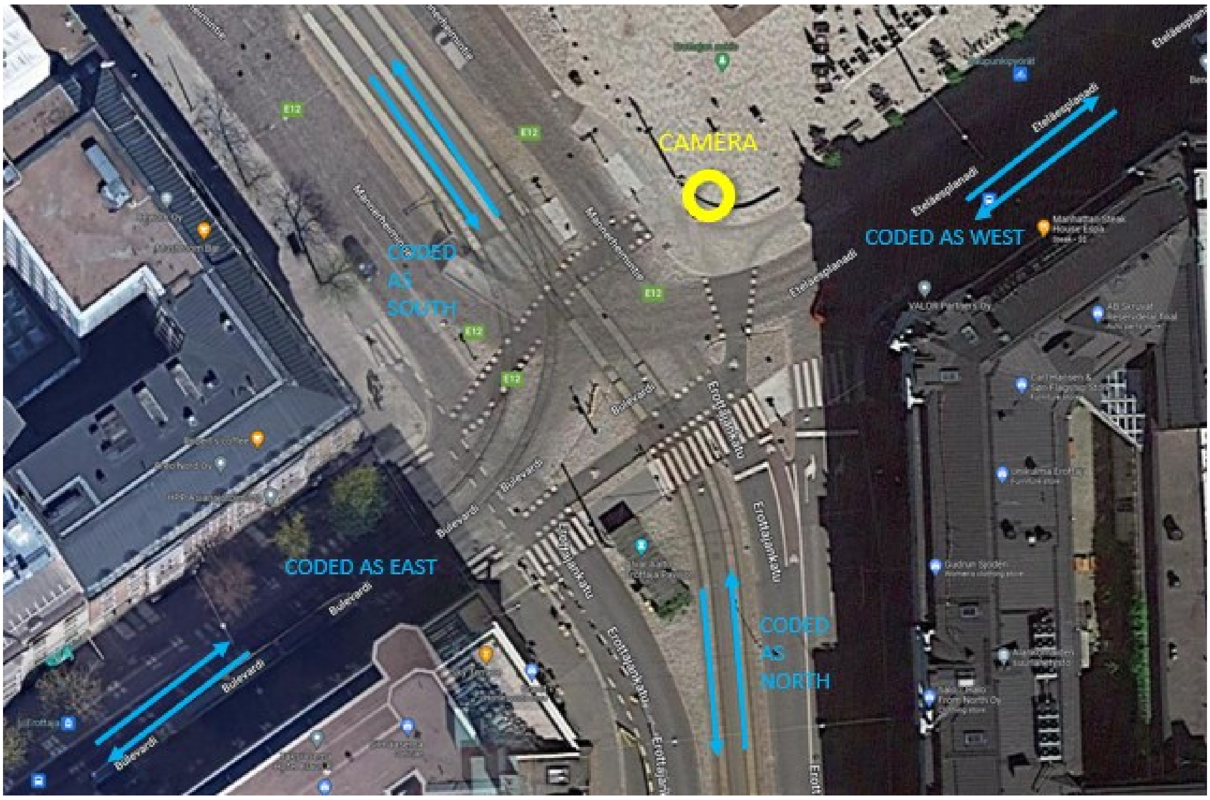


Figure 30: Erottaja camera location and coding directions

Video coding procedure was developed by first coding done by coder 1, followed by coder 2 independently coding the same location. Afterwards, two coding schemes were compared, and after re-evaluation which included an external review by two other experts, the final coding procedure was applied to all locations. Although coding is very similar in the four locations, it is not exactly the same, since each location has specific characteristics. For example, in Ruoholahti location, using coding items such as use of car road or bike lane does not make sense since these surfaces do not exist at that location. Coding order was Viiskulma, Ruoholahti, Keskuskatu, and Erottaja, respectively. Below is the list of coding items with their details.

- Observation No (1 observation = 1 e-scooter). Due to the phenomenon of multiple users on one e-scooter, there are more riders than number of observations.
- Time of arrival/ time of leaving: When rider/s enter and exit the recorded view.
- Trajectory: Describes the position where rider/s enter and exit the recorded view, depending on the location, with point of reference depicted in figures above.
- Riding surface and order: Describing the riding surface as sidewalk, bike lane, carriageway, etc., while also coding these usages in order over time.
- Inconsistent use of infrastructure: Coding item for diverse usage of infrastructure, such as a rider who uses a bike lane and then sidewalk. Inconsistency does not apply to justified mixing, such as switching from bike lane to carriageway because bike lane is no longer available.
- Infrastructure problems: Separate code just for Erottaja location, for events that involve behavioural adaptation to infrastructural problems, such as incomplete and disconnected bike lane.
- Headphones: When visible, descriptive comment on type of headphones an e-scooter rider is wearing (e.g., small, big, cable, etc.).
- Mobile phone: A code when checking phones attached to handlebar vs when checking non-attached phones, which implies one-hand riding.
- Age: When possible to determine, the categories involved child (younger than teenager), teenager (13 to 19), young adult (20s and early 30s), middle-aged (late 30s, 40s, early 50s), and old (late 50s and over).
- Flock riding: Code that includes a number of riders riding in a group, on separate e-scooters, or mixed riding with other vehicles (e.g., bicycle) or with pedestrians.
- Multi-riding: Code for multiple users on one e-scooter, where the user steering the e-scooter and non-steering rider/s also identified, in term of their position on the e-scooter, i.e., front or back.
- Food delivery: Coded if user is clearly wearing clothes or equipment from a food delivery service.
- Objects carried: Coded as object and position, such as handbag (e.g., small purse), shoulder bag (e.g., bigger bag, carried as backpack), bag on handlebar (e.g., shopping bag in different positions on a handlebar).
- Speed: Estimated as rider’s speed during the visible trajectory and when not breaking.

- Speed reduction: Coded as levels of speed reduction when approaching a conflict zone, as no reduction, slight or large reduction.
- Weaving: Coded when user is not driving in a straight-enough line.
- Distance with pedestrians: Coded as approximate distance. When approximate distance is under one meter, coded as unsafe distance.
- Dismounting: Coded as dismounting e-scooter before crossing, when rider dismounts before, but then crosses while riding, and coded as dismounting to cross, when rider dismounts before and then crosses while walking.
- Checking sides: Coded when rider turns head to look left or right.
- Turning signal light: Coded when turning signal lights are turned on. In comments, added whether apparently intentional or not, as some riders did not use them intentionally or had forgotten they are turned on.
- Spontaneous interactions: Coded when riders interact with other riders, drivers or pedestrians that were not part of their moving group, as in group riding.
- Doing tricks: Coded when a user is clearly performing activities that are fun and excitement seeking, such as vehicle acrobatics.
- Red light (Erottaja): Rider has not stopped at red traffic light.
- Comments: Additional explanations and information.

Table 4 shows the distribution of age and gender in the sample, which are in line with previous research and questionnaire sample. Total sample included 1,378 observed users in four locations, out of which 273 were food delivery workers, which are analysed separately. After coding, qualitative analysis focuses on two aspects. One key aspect is clustering behaviours into distinct categories that can inform about aggregate patterns in behaviour and competences. Four categories used in clustering include highly non-cooperative, moderately non-cooperative, moderately cooperative, and highly cooperative. Each observed user is classified with the focus on the most negative aspect during video observation. For example, rider who is using one scooter together with another user in the form of multi-riding is labelled as highly non-cooperative even if they are using turning lights or checking both sides while crossing conflict areas. The second aspect of analysis is focused on identifying diverse types of behaviours and competences, without the explicit focus on categorization. The intention with diversity analysis is to complement aggregate categories and identify potential points for campaigning or changes in the streetscape infrastructure.

Table 4: Observed distribution of age and gender in the video recoding sample

	Child	**Teenager**	**Young adult**	**Middle aged**	**Old**	**Not clear**
Female	1.22%	17.48%	61.79%	10.98%	0.00%	8.54%
Male	1.94%	9.27%	60.99%	19.28%	0.60%	7.92%
Not clear	2.08%	10.94%	13.54%	2.60%	0.00%	70.83%
Total	**1.81%**	**11.38%**	**52.94%**	**14.54%**	**0.36%**	**18.97%**

2.3 Analysis of questionnaire data for users and non-users

Online questionnaire design is presented in Table 5. The survey was opened on 20.06.2022 and was closed on 12.07.2022, having 7,724 respondents. By excluding those who do not live, work, study, or regularly visit Helsinki, the sample was reduced to 5,586 responses. Furthermore, based on the last open-ended question and the email addresses, the repeated responses and those who did not adequately fill in the questionnaire have been removed. Therefore, 5,342 respondents are included in the final sample. Analysis details, answering to RQ3, are presented in section 3.3, focusing on different user and non-user respondents' categories, with a specific focus on age and gender, as well on summary statistics on mode substitution and group riding. Drawing from experiences in past questionnaires on emerging mobility technologies (Weckström et al., 2018), some aspects of the analysis are based on categorizing users into groups, based on their frequency of use, in relation to 2021 and 2022:

- One time user – those who have tried e-scooter only once
- Curious user – those who have tried e-scooter couple times a year
- Occasional user – those who use e-scooters few times (3-5) per month
- Frequent user – those who use e-scooters few times (3-5) per week
- Weekend user – those who use e-scooter dominantly during weekends
- Power user – those who use e-scooters on a daily basis
- Previous user – those who have used e-scooters in 2021 but not in 2022
- New user – those who have not used e-scooters in 2021 but have or will in 2022

There were two questions in the questionnaire about group riding, since it is one of the special behaviours that was observed frequently in the video recordings. These behaviours were divided into:

- Multi-riding: Have ridden the same shared e-scooter with more than one person on the top.
- Flock-riding: Group riding of more than two e-scooters along with each other.

Table 5: Questionnaire design

Question	Answer options	Asked from.../ Mandatory or non-mandatory
Have you used a shared electric scooter (e.g., Bird, Dott, Lime, Ryde, Tier, Voi) in 2021 and before?	1 = No 2 = Yes, I have tried it once 3 = Yes, a few times per year 4 = Yes, a few times per month 5 = Yes, 3-5 times per week 6 = Yes, on weekends 7 = Yes, every day	Everybody and mandatory
Are you using or planning to use shared electric scooters in 2022?	1 = No 2 = Yes, I have tried it once 3 = Yes, a few times per year 4 = Yes, a few times per month 5 = Yes, 3-5 times per week	Everybody and mandatory

Question	Answer options	Asked from…/ Mandatory or non-mandatory
	6 = Yes, on weekends 7 = Yes, every day	
Do you own a private electric scooter?	1 = Yes 2 = No 3 = Not yet, planning to buy	Everybody and mandatory
Do/did you mostly use electric scooter as a delivery worker (e.g., Wolt, Foodora, etc.)?	1 = Yes, with a shared e-scooter 2 = Yes, with my own e-scooter 3 = No, I am not a delivery worker 4 = I am a delivery worker, but I use other means of transportation for my work.	Everybody and mandatory
Select the top three reasons on why did you choose e-scooter for delivery work? + Open text answers	1 = It is affordable 2 = I can ride it everywhere 3 = You can easily find it everywhere 4 = It is fast 5 = I can take it into public transit 6 = Unavailability of shared e-scooters at the origin or destination 7 = I am not worried about locking, parking, or steeling issues 8 = I saw it frequently and it seems like the best option 9 = It is recommended by my colleagues 10 = Other reasons	Delivery workers; non-mandatory
Approximately, how many rides on average do you make with the electric scooter as a delivery worker per day?	1 = Less than 5 2 = 5-10 3 = 10-15 4 = 15-20 5 = More than 20	Delivery workers; non-mandatory
What are your most common reasons for using an e-scooter other than delivery work? Select all that apply+ Open text answers	1 = Being in a hurry (e.g., catching the train, appointment, etc.) 2 = To save money 3 = Having fun while riding e-scooter 4 = Not getting sweaty or exposed to the weather 5 = Being able to reach new locations 6 = Faster than other alternatives (public transport, walking, etc.) 7 = To be environmentally sustainable 8 = Trying to be physically active and engaged 9 = Being able to drink alcohol and avoid driving 10 = Other reasons	Delivery workers; non-mandatory
What are/were your most common purposes of e-scooter trip? Select all that apply + Open text answers	1 = Commute (usually between home and work) 2 = Business trip (work-related business trip, work lunch trip) 3 = School/study 4 = Shopping trip (groceries and running errands) 5 = Personal trip (doctor, bank, lunch) 6 = Socializing (e.g., spending time with friends) 7 = Leisure activities (exercise, hobby, culture, visits) 8 = Other purposes	Previous users, new users, frequent users; non-mandatory
What are/were your most common reasons for using a shared e-scooter? Select all that apply + Open text answers	1 = Being in a hurry (e.g., catching the train, appointment, etc.) 2 = To save money 3 = Having fun while riding e-scooter 4 = Not getting sweaty or exposed to the weather 5 = Being able to reach new locations 6 = Faster than other alternatives (public transport, walking, etc.) 7 = To be environmentally sustainable	Previous users, new users, frequent users; non-mandatory

Question	Answer options	Asked from.../ Mandatory or non-mandatory
	8 = Trying to be physically active and engaged 9 = Being able to drink alcohol and avoid driving 10 = Other reasons	
What were the reasons for stopping the usage of shared e-scooters? Select all that apply + Open text answers	1 = I terminated my job as a delivery worker 2 = It was not absolutely necessary 3 = More expensive than other transport alternatives 4 = Issues with the app or not having a bank account 5 = Unavailability of e-scooters at the origin or destination 6 = Complex rules for riding (forbidden zones, low-speed, no parking zones) 7 = Bought or planning to buy a private e-scooter 8 = Lacking bike lanes, high curbs, unsuitable road surfaces, etc. 9 = Needing to travel with children 10 = Because of my physical conditions 11 = Not feeling safe while riding it 12 = I am satisfied with my current way of transport 13 = A previous bad experience 14 = Other	Previous users; non-mandatory
What are the reasons for not using a shared e-scooters? Select all that apply.	1 = It was not absolutely necessary 2 = More expensive than other transport alternatives 3 = Not knowing how to ride e-scooter 4 = Issues with the app or not having a bank account 5 = Unavailability of e-scooters at the origin or destination 6 = Bought or planning to buy a private e-scooter 7 = Lacking bike lanes, high curbs, unsuitable road surfaces, etc. 8 = Needing to travel with children 9 = Not feeling safe using it 10 = I am satisfied with my current way of transport 11 = Other	Non-users; non-mandatory
Because of using e-scooter, I cycle/cycled ...	1 = Less 2 = Same 3 = More 4 = I do not have this option 5 = I do not know	Previous users, new users, frequent users, delivery workers; non-mandatory
Because of using e-scooter, I walk/walked ...	1 = Less 2 = Same 3 = More 4 = I barely walk even without using an e-scooter 5 = I do not know	Previous users, new users, frequent users, delivery workers; non-mandatory
Because of using e-scooter, I use/used metro or train ...	1 = Less 2 = Same 3 = More 4 = I do not have this option 5 = I do not know	Previous users, new users, frequent users, delivery workers; non-mandatory
Because of using e-scooter, I ride/rode bus or tram ...	1 = Less 2 = Same 3 = More 4 = I do not have this option 5 = I do not know	Previous users, new users, frequent users, delivery workers; non-mandatory
Because of using e-scooter, I drive/drove my car ...	1 = Less 2 = Same 3 = More 4 = I do not have this option 5 = I do not know	Previous users, new users, frequent users, delivery workers; non-mandatory

Question	Answer options	Asked from…/ Mandatory or non-mandatory
Because of using e-scooter, I use/used taxi/uber …	1 = Less 2 = Same 3 = More 4 = I do not have this option 5 = I do not know	Previous users, new users, frequent users, delivery workers; non-mandatory
As a pedestrian, what is the most frequent issue that has happened to you regarding e-scooters in the recent past? + Open text answers	1 = An e-scooter rider passed very close by me on the sidewalk. 2 = Had to move out of the way of an e-scooter rider on the sidewalk. 3 = Suffered an injury relating to an e-scooter crashing into me. 4 = Tripped over a bad-parked e-scooter. 5 = I was unable to walk easily on the sidewalk with a wheelchair, pram, carriage, etc. 6 = Other (please specify)	Non-users; non-mandatory
Riding e-scooters on the sidewalks is …	1 = Very problematic 2 = Problematic 3 = No idea 4 = Slightly problematic 5 = Not problematic	Non-users; non-mandatory
Improper parking of shared e-scooters.	1 = Very problematic 2 = Problematic 3 = No idea 4 = Slightly problematic 5 = Not problematic	Non-users; non-mandatory
Not keeping a safe distance from other road users	1 = Very problematic 2 = Problematic 3 = No idea 4 = Slightly problematic 5 = Not problematic	Non-users; non-mandatory
Teenagers and kids riding shared e-scooter	1 = Very problematic 2 = Problematic 3 = No idea 4 = Slightly problematic 5 = Not problematic	Everybody; non-mandatory
More than one rider on top of an e-scooter	1 = Very problematic 2 = Problematic 3 = No idea 4 = Slightly problematic 5 = Not problematic	Everybody; non-mandatory
Group riding of more than two e-scooters along with each other	1 = Very problematic 2 = Problematic 3 = No idea 4 = Slightly problematic 5 = Not problematic	Everybody; non-mandatory
How often have you ridden the same shared e-scooter with more than one person on the top?	1 = Never 2 = I have tried it once 3 = A few times per year 4 = A few times per month 5 = 3-5 times per week 6 = On weekends 7 = Every day	Previous users, new users, frequent users, delivery workers; non-mandatory
What were the reasons for riding together on the same e-scooter? Select all that apply + Open text answers	1 = It is more fun to travel like that 2 = Not enough e-scooters in the origin 3 = Other people are doing that and it seems normal 4 = Only one of us had the e-scooter app 5 = It is cheaper	Only from the ones who didn’t choose “never” in above question; non-mandatory

Question	Answer options	Asked from…/ Mandatory or non-mandatory
	6 = I don't have enough skills to ride an e-scooter alone 7 = To be able to have a conversation while riding 8 = Tried it out of curiosity 9 = Other reasons	
How often have you done group riding of more than two e-scooters along with each other?	1 = Never 2 = I have tried it once 3 = A few times per year 4 = A few times per month 5 = 3-5 times per week 6 = On weekends 7 = Every day	Previous users, new users, frequent users, delivery workers; non-mandatory
What were the reasons for e-scooter group riding? Select all that apply + Open text answers	1 = It is more fun to travel like that 2 = Feeling more free compared to taking public transport 3 = It feels safer compared to two riders on the same e-scooter 4 = I did not know the route to the destination 5 = Not being left out from the group of friends 6 = To be able to have a conversation while riding 7 = Other reasons (please specify)	Only from the ones who didn't choose "never" in above question; non-mandatory
Shared e-scooters are a necessary part of my mobility habits nowadays.	1 = Strongly agree 2 = Agree 3 = Neither agree nor disagree 4 = Disagree 5 = Strongly disagree	Previous users, new users, frequent users, delivery workers; non-mandatory
What should be improved related to e-scooter usage? (Choose one or more) + Open text answers	1 = Street infrastructure 2 = Improving rules for other road users (car speed, etc.) 3 = E-scooter riding rules 4 = E-scooter vehicle design 5 = Proper e-scooter parking behaviour 6 = Educate people on how to ride e-scooter properly 7 = Educate other road users on how to use the shared space 8 = Other	Everybody; non-mandatory
How often are you using or planning to use your private e-scooter in Helsinki?	1 = A few times per year 2 = a few times per month 3 = 3-5 times per week 4 = On weekends 5 = Every day	Only asked from private e-scooter owners; non-mandatory
Gender	1 = Female 2 = Male 3 = Other 4 = Prefer not to say	Everybody; non-mandatory
Age	1 = Under 18 2 = 18-24 3 = 25-34 4 = 35-44 5 = 45-54 6 = 55-64 7 = 64+	Everybody; non-mandatory
What was your personal annual income level before taxes in the previous year?	1 = 0–9,999 (less than 10,000 €) 2 = 10,000–19,999 (less than 20,000 €) 3 = 20,000–29,999 (less than 30,000 €) 4 = 30,000–39,999 (less than 40,000 €) 5 = 40,000–59,999 (less than 60,000 €) 6 = 60,000 to 79,999 (less than 80,000 €) 7 = 80,000 and more (more than 80,000 €) 8 = Don't know / Don't want to say	Everybody; non-mandatory

Question	Answer options	Asked from…/ Mandatory or non-mandatory
Occupation + Open text answers	1 = Employed 2 = Unemployed or laid off 3 = Student 4 = Pensioner 5 = On parental or care leave 6 = Other	Everybody; non-mandatory
What is the postal code of your living address? If you do not know the postal code, please select the city + Open text answers	1 = I know the postal code of my living address (please write) 2 = Helsinki 3 = Espoo 4 = Vantaa 5 = Kauniainen 6 = Other	Everybody; non-mandatory
What is the postal code of your working/studying address? If you do not know the postal code, please select the city + Open text answers	1 = I know the postal code of my working/studying address (please write) 2 = Helsinki 3 = Espoo 4 = Vantaa 5 = Kauniainen 6 = Other	Everybody; non-mandatory
What is the highest degree or level of school you have completed?	1 = High school 2 = Bachelor's degree 3 = Master's degree 4 = Doctoral degree	Everybody; non-mandatory
How do you rate your cycling experience?	1 = Very high 2 = High 3 = Moderate 4 = Beginner 5 = No experience	Everybody; non-mandatory
How does the introduction of the shared e-scooter in Helsinki affect your personal everyday mobility?	1 = Completely beneficial 2 = Beneficial 3 = No change 4 = Damaging 5 = Completely damaging	Everybody; non-mandatory
How does the introduction of the shared e-scooter in Helsinki affected society and people's everyday traveling?	1 = Completely beneficial 2 = Beneficial 3 = No change 4 = Damaging 5 = Completely damaging	Everybody; non-mandatory
Please elaborate what do e-scooters mean for you or if you have any suggestions for improvements in the city related to e-scooter usage?	Open text comment	Everybody; non-mandatory

2.4 Analysis of implications and directions for developing responsible and adaptive governance processes

In order to respond to RQ4, a collaborative research framework has been developed, focusing on two main components. The first component is organized site visits. In order to identify implications for street design improvements, two organized site visits including city and operator representatives have been conducted on May 18 and May 25, 2022. Figure 31 shows the area for the first site visit in the black ellipse, and area for the second site visit in the blue ellipse. The first criteria for selecting sites was their crash severity, the second was diversity of location in terms of infrastructure, and the third was route planning for walking withing the feasible time of three hours and approximate distance of 10 km – which is a reasonable distance to cover at once. Besides these group site visits, individual site visits have been conducted by the research team members at the locations that could not be included in the coherent route within an area or that have not been included in the site visits for determining video recording locations.

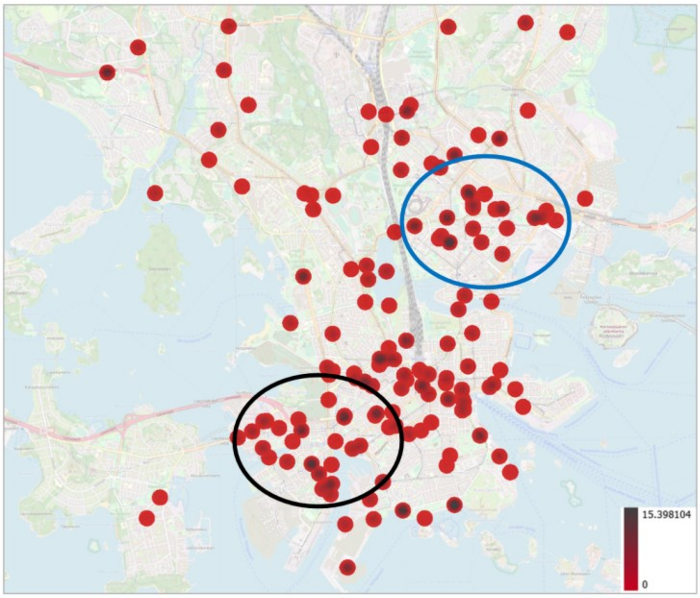


Figure 31: Areas for group crash site visits

At the start of the site visit, all the experts were provided with identical input form, consisting of the following input fields.

1. Location name
2. General site features
3. Conflict points between traffic flows or queuing
4. Challenging design details
5. Other safety challenges

In total, 163 expert comments for all the locations during group site visits were collected. In addition, several of the experts have provided pictures from the locations, complementing written descriptions. Analysis included coding of qualitative material and qualitative clustering of issues in the streetscape design.

The second component was focused even further on multi-stakeholder collaboration, and development of policy design. To this aim, a Miro[1] web-based collaboration platform was established, with open access to all the interested stakeholders (Figure 32). In addition, regular monthly or bi-monthly steering group meetings of approximately 90-120 minutes were held. This activity has been synchronized with meetings between the City of Helsinki and shared e-scooter operators. Although the interaction had to suffer due to online work caused by COVID-19 pandemic, which did not allow for more creative in-person discussion, the Miro platform enabled iterative development and explicating complexities of the issue at hand. Besides this communicative setting, expert interviews with city and operator representatives have been conducted at the beginning of the project, aiming to understand sociotechnical transition trajectory that has led to the introduction of regulation in September 2021.

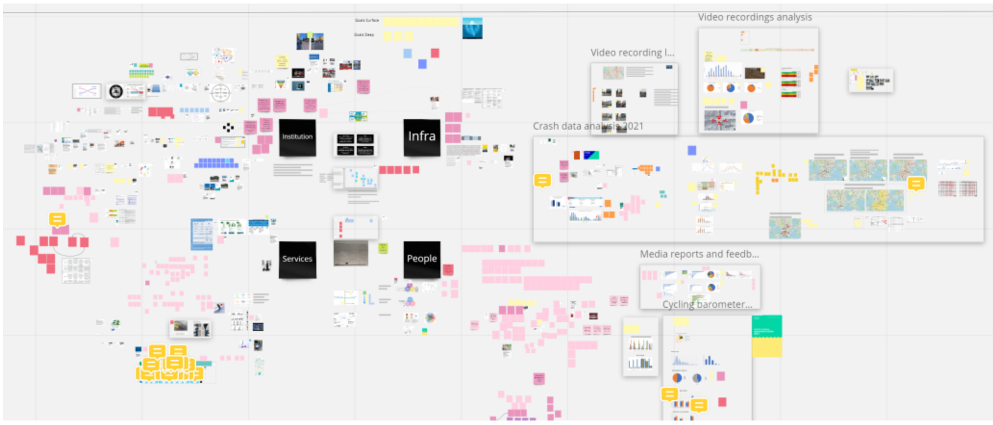


Figure 32: Snapshot from web-based collaboration platform

Finally, following best practices in action research (Bartels & Wittmayer, 2019; Mladenović, & Eräranta, 2020) this project part focuses on policy design suggestions (Howlett, 2019). Optimal policy design includes suggestions for stages of analysis and ranking of policy measures, as depicted in Figure 33. The need for integrated development of policy packages for steering Finnish mobility system has already been recognized before (Mladenović et al., 2021a). However, the attempt here is to go a step further in providing practical recommendations for policy design, as the basis for collaborative and responsible institution of governance – not only of e-scooter technology, but of all the other emerging mobility modes in Helsinki and Finland. As part of policy design suggestions, recommendations for development of policy design culture, processes and tools also relied on scanning literature focused on analysis of e-scooter regulation across the world.

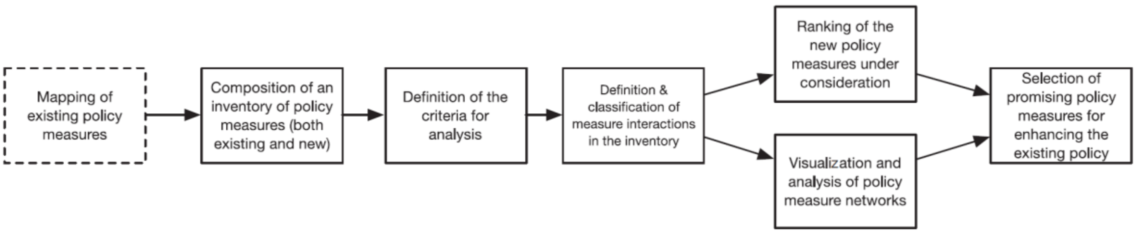


Figure 33: Stages for analysis and ranking of policy measures (Taeihagh, 2018)

[1] https://miro.com/

3. Results

3.1 Spatio-temporal changes of shared e-scooter related injuries

For all 2021, average age was 28.7, while the median was 25.6 years old. For 2022, January-August, the average age was 31.2, while the median was 27.9. For the same period, January-August, in 2021, the average age was 27.9, while the median age was 25.3 years. Based on Figure 34, the injured are mostly aged between 19-25 years old in 2021.

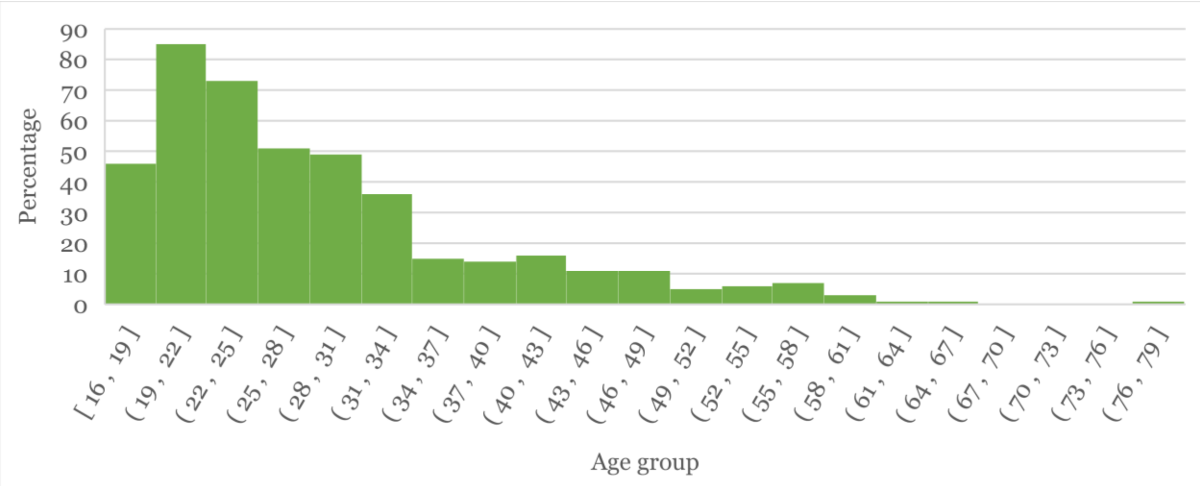


Figure 34: Age distribution of e-scooter related injured people in 2021

Out of 432 cases of shared e-scooter injuries in Helsinki in 2021, 248 of them (57%) are male and 43% are female. Figure 35 depicts the percentage of each age group based on the gender. The injured females are higher in percentage for the ages of 18-32, while the injured males are higher percentagewise for the age groups of 32-50.

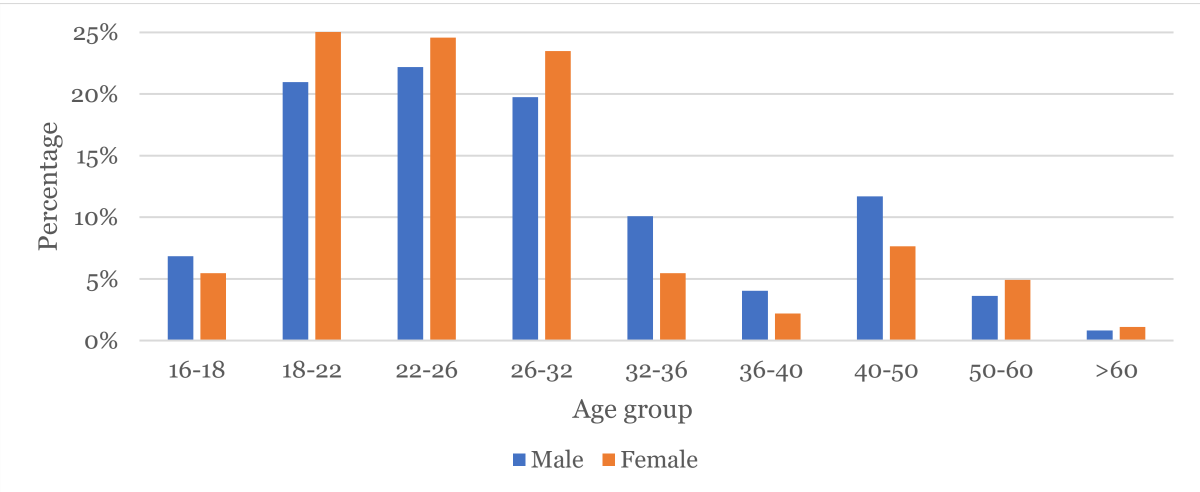


Figure 35: Age distribution of e-scooter related injuries based on gender in 2021

The breath alcohol level was analysed in 165 of cases in 2021. The mean value for breath alcohol of those 2021 cases was 1.44‰ while it was 1.47‰ in 2022. In addition, data contained a non-numeric assessment if the patient was intoxicated. In total, 191 cases (about 44%) were identified as intoxicated in 2021, while this number is about 35% in 2022. Focusing only on the period from January until August 2021, that percentage is 46%. Figure 36 shows the distribution of intoxicated injuries based on age and gender. The proportion of intoxicated injured females in the age group of 16-26 is higher than in the same group for males.

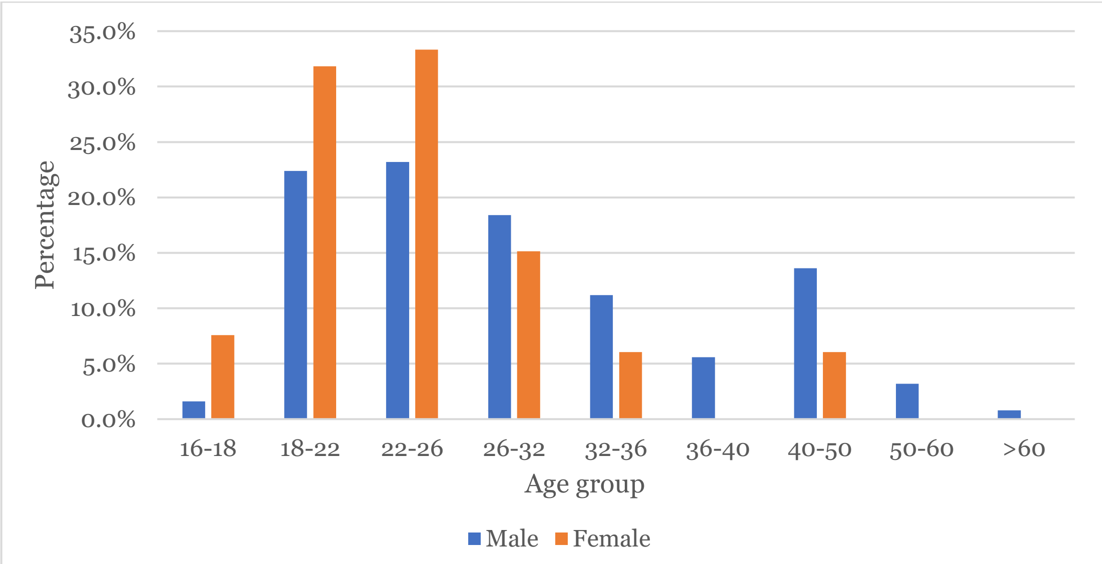


Figure 36: Intoxication based on age distribution and gender in 2021

Gender and age distribution of injuries from January until August in 2021 and 2022 is presented in Figure 37. Based on this figure, the proportion of 35-54 years old males has significantly increased in 2022.

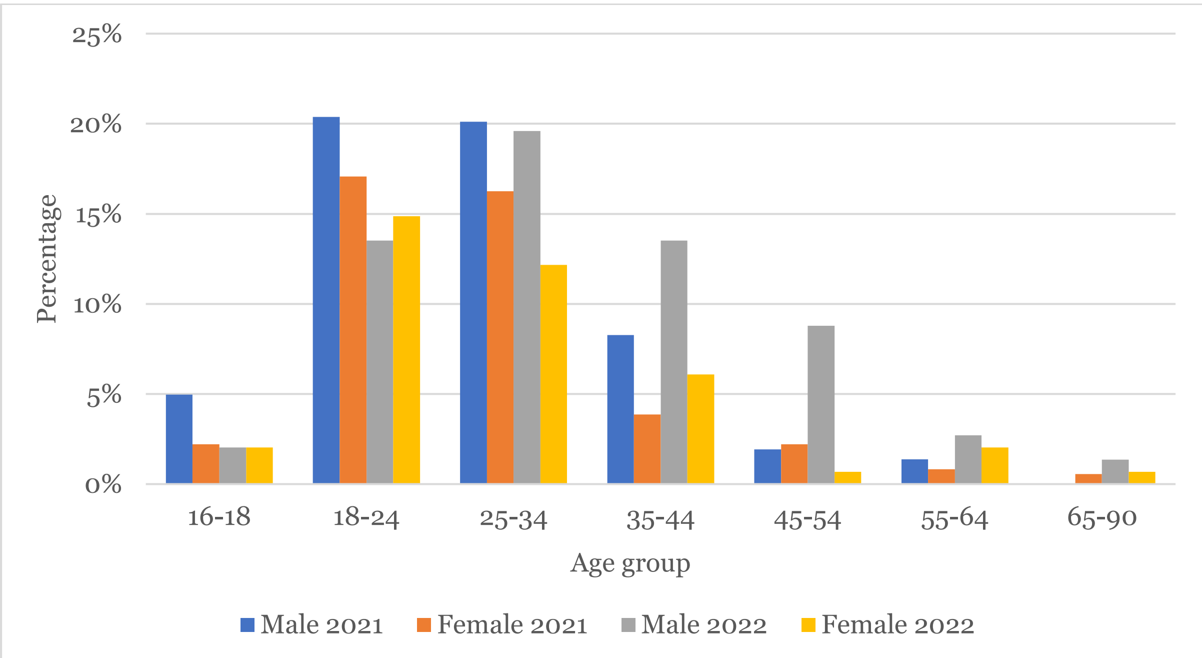


Figure 37: Age distribution of e-scooter related injuries based on gender in Jan-Aug 2021 and Jan-Aug 2022

Based on the data, 349 (80.8%) of all the 432 e-scooter crashes happen because the rider fell (Table 6).

Table 6: Crash type quantity and percentage in 2021

Crash type	Quantity (percent)
The rider fell	346 (80.1%)
The rider crashed	30 (6.9%)
Pedestrian hit by an e-scooter	8 (1.9%)
Multi-user or flock riding crash/fall	20 (4.6%)
E-scooter crashed into a car	13 (3.0%)
E-scooter crashed into a bike	6 (1.4%)
Two e-scooters crashed	3 (0.7%)
A cyclist crashed with an e-scooter	3 (0.7%))
Fallen/crashed because of dodging other road users	3 (0.7%)
Other reasons	4 (0.9%)
Sum	**29 (6.7%)**
Not stated	7 (1.6%)

Table 7 shows categorization of crash types based on crash reasons. According to this table, being intoxicated does not have a clear relationship with rider falling. However, in multi-riding or flock-riding crashes/falls, the majority of riders were intoxicated (64.3%). A higher speed mostly related to the rider crashing into objects such as wall, tree, signs, etc., while higher speed was not related to the rider falling. Other factors cannot be analysed properly because of the quality of gathered data.

Table 7: Categorization of crash type based on crash reasons in 2021 (column-based)

Crash/fall reasons \ Crash type Quantity (percent)		The rider fell (%)	The rider crashed (%)	Pedestrian hit by an e-scooter (%)	Multi-riding or flock riding crash/fall (%)	Other crash types (%)	Not stated (%)
Alcohol usage	Intoxicated (1)	163 (47.1)	11 (36.7)	2 (25.0)	9 **(64.3)**	5 (17.2)	1 (14.3)
	Sober (0)	183 (52.9)	19 **(63.3)**	6 **(75.0)**	5 (35.7)	24 **(82.8)**	6 (87.7)
Speed	High (>=15 km/h) (1)	26 (7.5)	7 **(23.3)**	0 (0.0)	1 (7.1)	1 (3.4)	0 (0.0)
	Low (<15 km/h) (0)	20 (5.8)	1 (3.3)	1 (12.5)	1 (7.1)	4 (13.8)	0 (0.0)
	Not stated (N/A)	300 (86.7)	22 (73.3)	7 (87.5)	12 (85.7)	24 (82.8)	7 (100.0)
Low competence in riding	Yes (1)	32 (9.2)	7 (23.3)	0 (0.0)	1 (7.1)	2 (6.9)	0 (0.0)
	Not stated (N/A)	314 (90.8)	23 (76.7)	8 (100.0)	13 (92.9)	27 (93.1)	7 (100)
Infrastructure faults or hitting an external object	Yes (1)	16 (4.6)	2 (6.7)	0 (0.0)	0 (0.0)	3 (10.3)	0 (0.0)
	Not stated (N/A)	330 (95.4)	28 (93.3)	8 (100.0)	14 (100.0)	26 (89.7)	7 (100.0)
Vehicle dynamic issues/ weather condition	Yes (1)	16 (4.6)	2 (6.7)	0 (0.0)	0 (0.0)	3 (10.3)	0 (0.0)
	Not stated (N/A)	330 (95.4)	28 (93.3)	8 (100.0)	14 (100.0)	26 (89.7)	7 (100.0)
The place of fall/crash	Intersection or turning point based	20 (5.8)	4 (12.9)	0 (0.0)	2 (14.3)	10 (32.3)	1 (14.3)
	Tram rails or near tram station	6 (1.7)	0 (0.0)	1 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)
	Street	1 (0.3)	1 (3.2)	0 (0.0)	0 (0.0)	5 (16.1)	0 (0.0)
	Steep (up or downhill)	2 (0.6)	1 (3.2)	0 (0.0)	0 (0.0)	1 (3.2)	0 (0.0)

Crash type Quantity (percent) / Crash/fall reasons		The rider fell (%)	The rider crashed (%)	Pedestrian hit by an e-scooter (%)	Multi-riding or flock riding crash/fall (%)	Other crash types (%)	Not stated (%)
	Sand road	2 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Sidewalk or fallen from sidewalk to street	2 (0.6)	1 (3.2)	1 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)
	Not stated (N/A)	314 (90.5)	24 (77.4)	6 (75.0)	12 (85.7)	15 (48.4)	6 (85.7)

Table 8 shows the relationship between different e-scooter crash reasons. Based on this table, 26.9% of intoxicated-related crashes happened on weekend, while 25.7% at night-time. Furthermore, 22% of the crashes that happened on weekends were at night-time. From this table, there is no clear relationship between speed and low competency with other crash reasons.

Table 8: Relationship between different e-scooter crash reasons in 2021

Crash reasons	Intoxicated (1)	High speed (1)	Low competence (1)	Weekend (1)	Night-time (1)	Night-time weekend	Night-time weekdays
Intoxicated (1)	-	17 (3.9%)	14 (3.2%)	116 **(26.9%)**	111 **(25.7%)**	70 (16.2%)	41 (9.5%)
High speed (1)	-	-	3 (0.7%)	18 (4.2%)	9 (2.1%)	4 (0.9%)	5 (1.2%)
Low competence (1)	-	-	-	15 (3.5%)	7 (1.6%)	4 (0.9%)	3 (0.7%)
Weekend (1)	-	-	-	-	95 **(22.0%)**	-	-
Night-time (1)	-	-	-	-	-	-	-
Night-time weekend	-	-	-	-	-	-	-
Night-time weekdays	-	-	-	-	-	-	-

In Table 9, the proportional number of cycling injuries has been calculated based on three different cycling trips scenarios in 2021 and 2022 (Jan-Aug).

Table 9: Average number of proportional cycling injuries for 2021 and 2022 in Helsinki operating area, based on three scenarios

Year	Cycling trips scenarios	Proportional cycling injuries	
		Based on the area	Based on the population
2021	10 Mil cycling trips	$\frac{430}{10,000000} = 0.004\%$	$\frac{729}{10,000000} = 0.007\%$
	20 Mil cycling trips	$\frac{430}{20,000000} = 0.002\%$	$\frac{729}{20,000000} = 0.004\%$
	30 Mil cycling trips	$\frac{430}{30,000000} = 0.001\%$	$\frac{729}{30,000000} = 0.002\%$
2022	10 Mil cycling trips	$\frac{418}{10,000000} = 0.004\%$	$\frac{655}{10,000000} = 0.007\%$
	20 Mil cycling trips	$\frac{418}{20,000000} = 0.002\%$	$\frac{655}{20,000000} = 0.003\%$
	30 Mil cycling trips	$\frac{418}{30,000000} = 0.001\%$	$\frac{655}{30,000000} = 0.002\%$

Table 10 shows the proportional number of e-scooter and cycling injuries in Helsinki operating area for different scenarios in 2021. Based on this table, in all the scenarios the proportional number of injuries in e-scooters is higher than the same number in cycling except only in the case after the restrictions in 2021 (from September until December) and in the first cycling trips scenario (10M). Table 11 shows the proportional number of e-scooter and cycling injuries in Helsinki operating area for different scenarios in 2022 (Jan-Aug). This table is also compatible with Table 10 and it shows that in all the scenarios the proportional number of injuries in e-scooters is higher than the same number in cycling, except for the first 10 million cycling trip scenario which is the lower estimation boundary. This informs that even though both cycling, and e-scooters are still not at desired target level zero in Helsinki, and safety level of e-scooters have been improving over time, the estimated values are still different.

Table 10: Percentage difference between shared e-scooter and cycling crashes in Helsinki for 2021

Based on the area ratio	Proportional number of e-scooter crashes	Cycling with 10M	Cycling with 20M	Cycling with 30M
		0.004%	**0.002%**	**0.001%**
Shared e-scooters before restrictions in 2021	**0.013%**	202%	504%	807%
Shared e-scooters after restrictions in 2021	**0.005%**	16%	132%	249%
Shared e-scooters in 2021 total	**0.011%**	156%	411%	667%

Based on the population ratio	Proportional number of e-scooter crashes	Cycling with 10M	Cycling with 20M	Cycling with 30M
		0.007%	**0.004%**	**0.002%**
Shared e-scooters before restrictions in 2021	**0.013%**	78%	257%	435%
Shared e-scooters after restrictions in 2021	**0.005%**	-31%	37%	106%
Shared e-scooters in 2021 total	**0.011%**	51%	202%	353%

Table 11: Percentage difference between shared e-scooter and cycling crashes in Helsinki for 2022

Based on the area ratio	Proportional number of e-scooter crashes	Cycling with 10M	Cycling with 20M	Cycling with 30M
		0.007%	**0.003%**	**0.002%**
Shared e-scooters after restrictions in 2022	**0.004%**	-64%	18%	45%

Based on the population ratio	Proportional number of e-scooter crashes	Cycling with 10M	Cycling with 20M	Cycling with 30M
		0.004%	**0.002%**	**0.001%**
Shared e-scooters after restrictions in 2022	**0.004%**	-4%	48%	65%

Figure 38 depicts the monthly distribution of e-scooter related injuries in 2021. Based on this figure, about 69% of the e-scooter related injuries happened from June to August 2021. Similar temporal clustering can be seen also in 2022 data, where 83% of the e-scooter related injuries happened from June to August 2022, even if that data set is only January to August 2022.

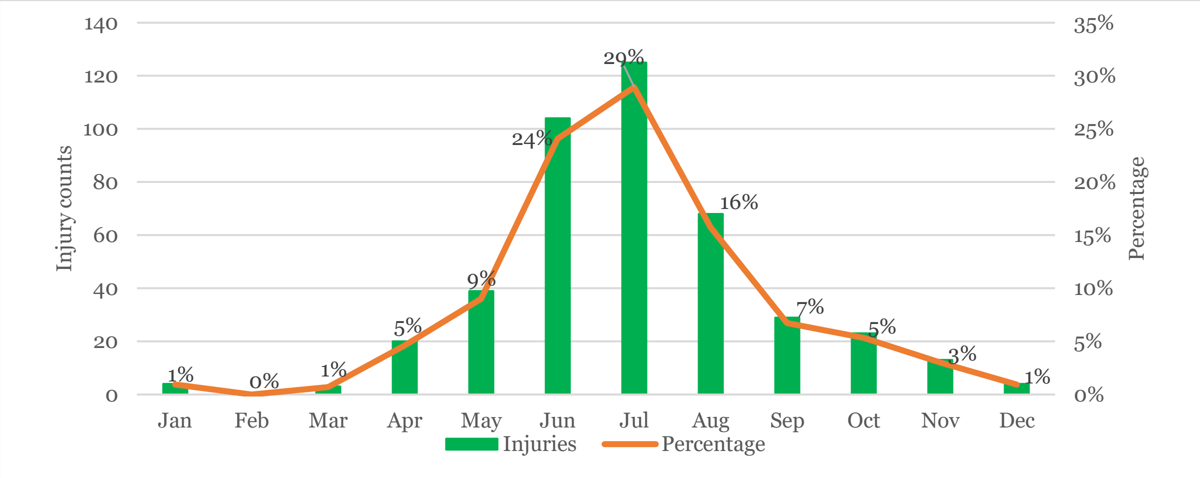
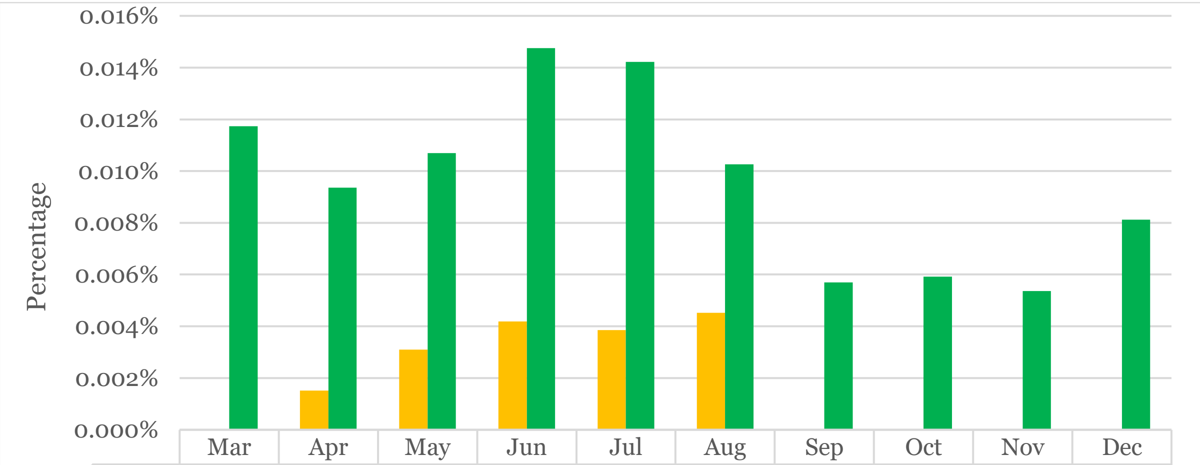


Figure 38: Monthly distribution of e-scooter related injuries in 2021

In order to analyse the injuries proportional to the number of e-scooter trips, Figure 39 shows the proportional monthly distribution of injuries in 2021 and 2022. Here, it worth mentioning that the proportional number for January 2021 was very high because of the very small number of trips (1,468) comparing to four e-scooter related injuries (0.272%). Furthermore, the proportional number for February 2021 was zero, since there was no crash and only 8 trips. Similarly, the number of trips in January and February 2022 is zero. Therefore, this figure only depicts data from March to December. From this figure, one can conclude that the proportional number of injuries in 2022 has decreased after the restrictions compared to the same numbers before the restrictions in 2021.



	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	0.000%	0.002%	0.003%	0.004%	0.004%	0.005%				
2021	0.012%	0.009%	0.011%	0.015%	0.014%	0.010%	0.006%	0.006%	0.005%	0.008%

Figure 39: Proportional monthly distribution of e-scooter related injuries in 2021 and 2022

The daily distribution of e-scooter related injuries for the whole 2021 has been plotted in Figure 40. Based on this figure, almost half (49%) of all cases happened on weekends.

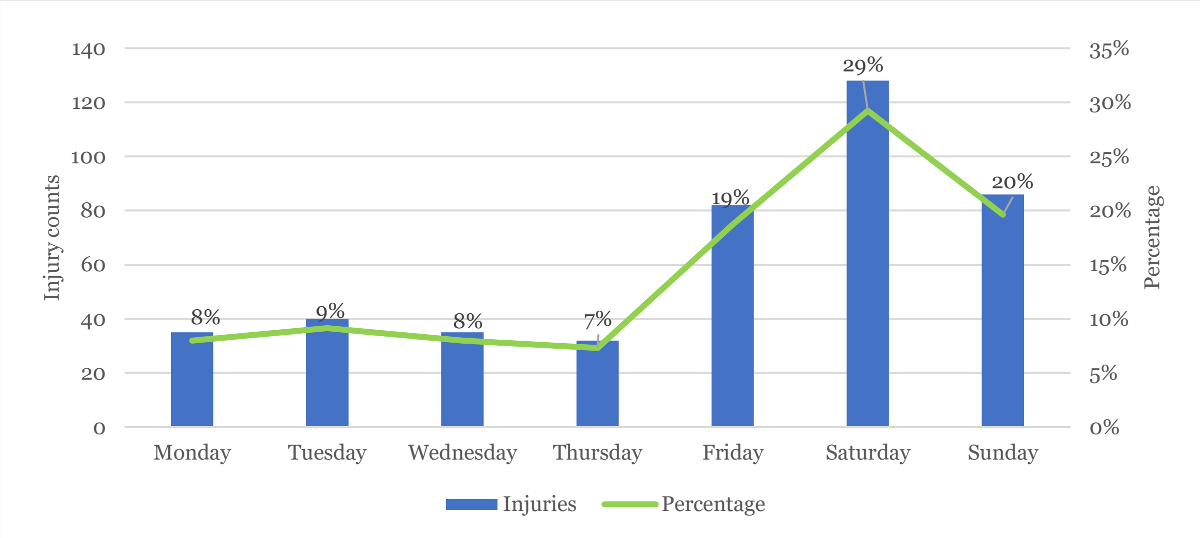


Figure 40: Daily distribution of e-scooter related injuries in 2021

Figure 41 shows the comparative daily distribution of injuries in 2021 and 2022 from January until August. Based on this figure, the quantity and percentage of injuries has decreased on Saturday and Sunday after the restrictions in 2022. The percentage of injuries on Friday has remained 18% in both 2021 and 2022.

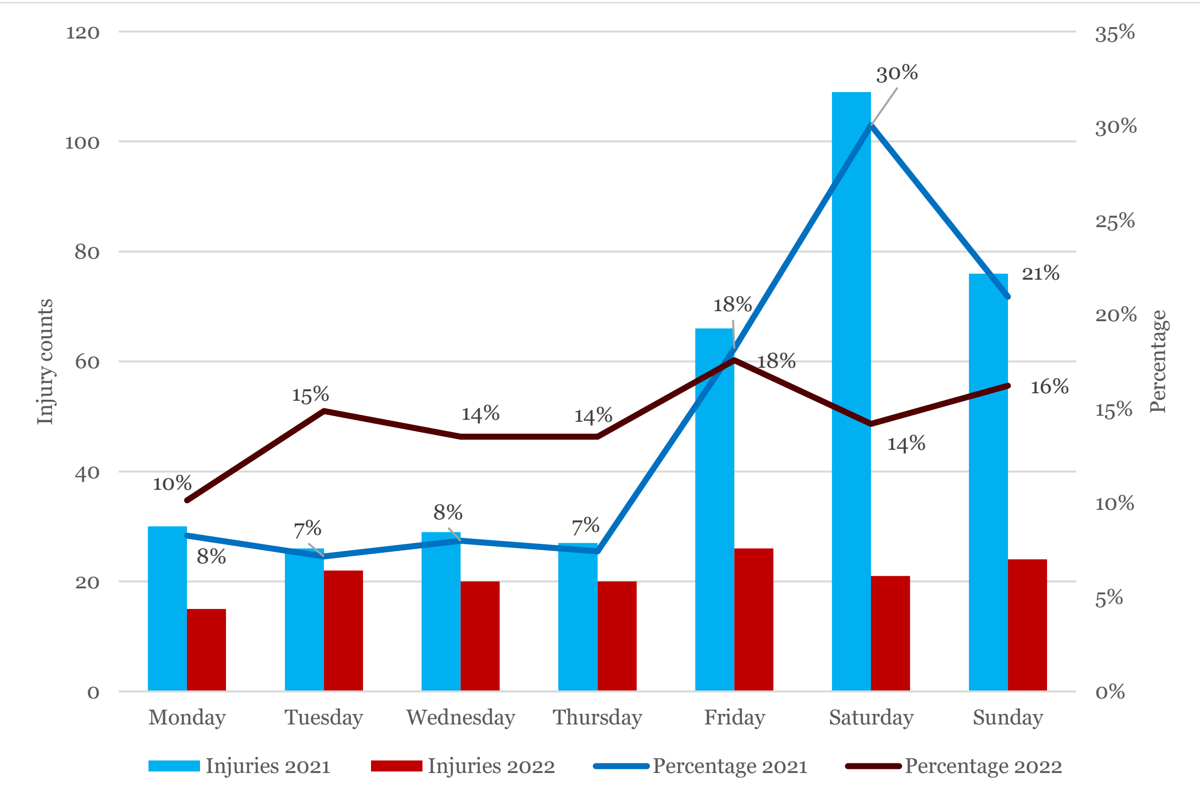
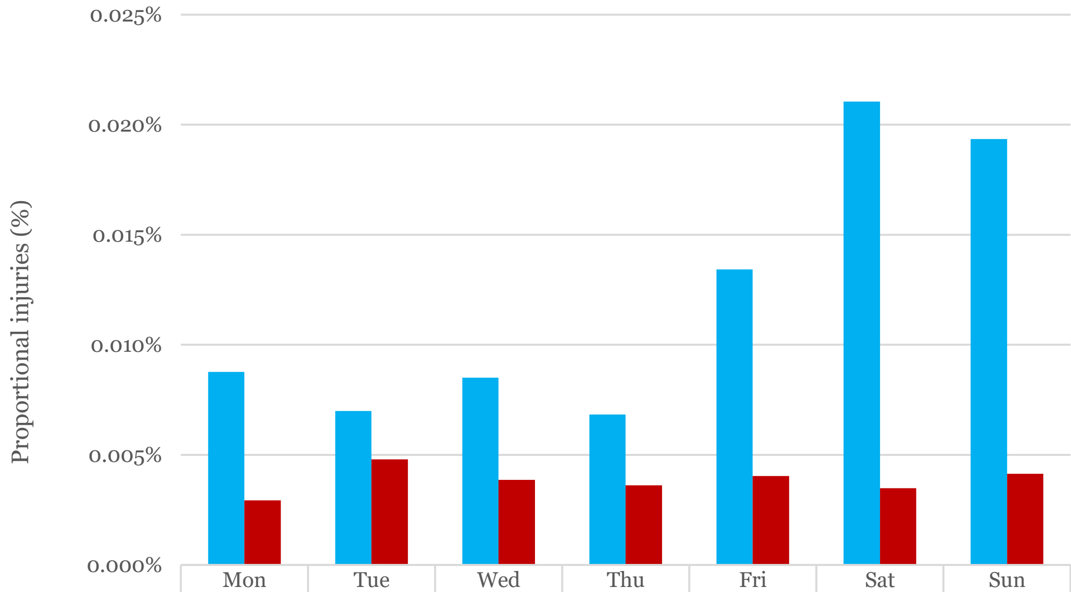


Figure 41: Daily distribution of e-scooter related injuries for Jan-Aug in 2021 and 2022

Figure 42 shows the daily distribution of proportional e-scooter related injuries in 2021 and 2022 from January to August, in proportion to trips. Based on this figure, the percentage of injuries has significantly decreased after the restrictions in 2022, especially during the weekend.



	Mon	Tue	Wed	Thu	Fri	Sat	Sun
2021 before restrictions	0.009%	0.007%	0.009%	0.007%	0.013%	0.021%	0.019%
2022 after restrictions	0.003%	0.005%	0.004%	0.004%	0.004%	0.003%	0.004%

Figure 42: Daily distribution of proportional e-scooter injuries for Jan-Aug in 2021 and 2022

Figure 43 Shows the hourly distribution of e-scooter related injuries in 2021. Based on this figure, 35% of cases happened between 00:00 and 05:00, while 51% happened between 22:00 and 05:00. In contrast, for January to August 2022, 18% happened between 00:00 and 05:00, and 30% between 22:00 and 05:00.

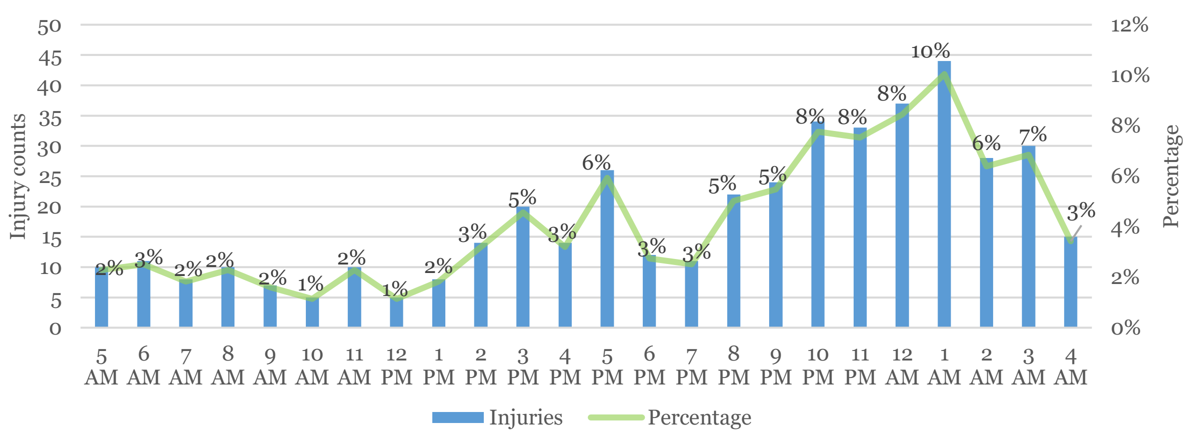


Figure 43: Hourly distribution of e-scooter related injuries in 2021

Figure 44 depicts the comparative hourly distribution of injuries in 2021 and 2022 from January until August. Based on this figure, the percentage and number of injuries has significantly decreased between 8 pm and 6 am after the restrictions in 2022. However, in 2022, the number of emergency cases have spikes at noon and 7 pm.

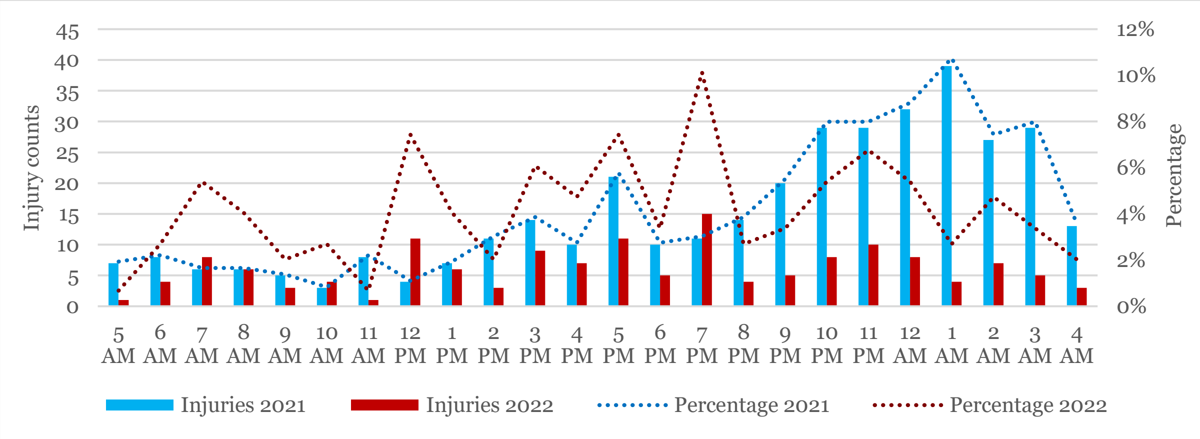


Figure 44: Hourly distribution of e-scooter related injuries for Jan-Aug in 2021 and 2022

Figure 45 depicts the e-scooter trip count and proportional number of injuries based on trip count data before the restrictions in 2021. According to this figure, the proportional number of injuries is the highest between 23:00 and 06:00.

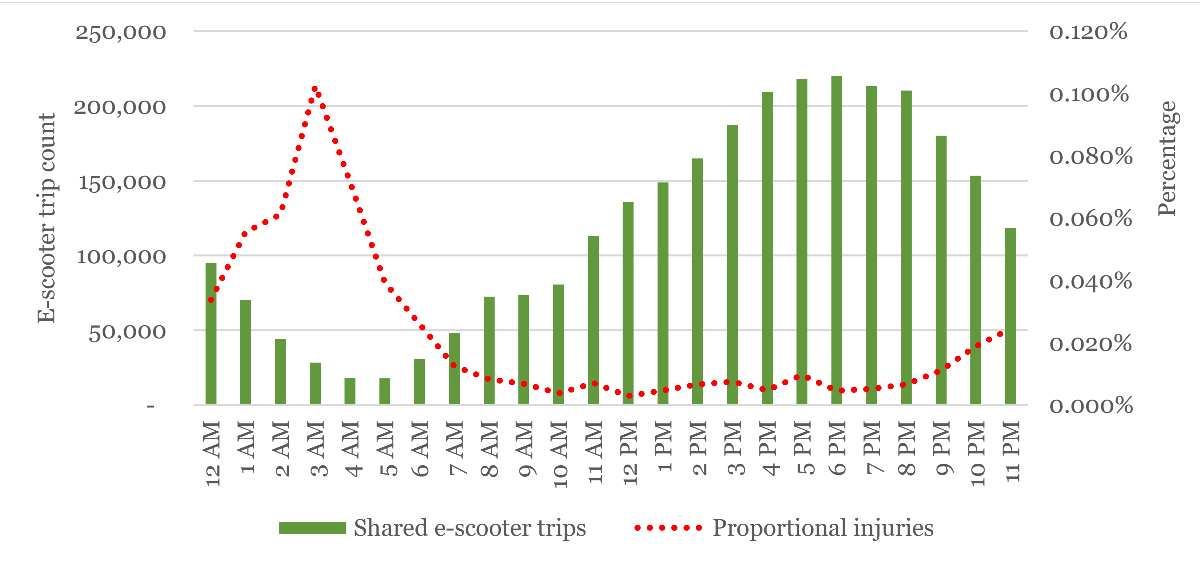


Figure 45: E-scooter trip count and proportional number of injuries before the restrictions (Jan-Aug) in 2021

Figure 46 depicts the e-scooter trip count and proportional number of injuries based on trip count data after the restrictions in 2021. Based on this figure, the proportional number of injuries is high at 00:00-01:00, because part of the trips which started before midnight continued after midnight. The average proportional number of injuries has decreased from 0.013% to 0.005% which is about 60% decrease after restrictions in 2021.

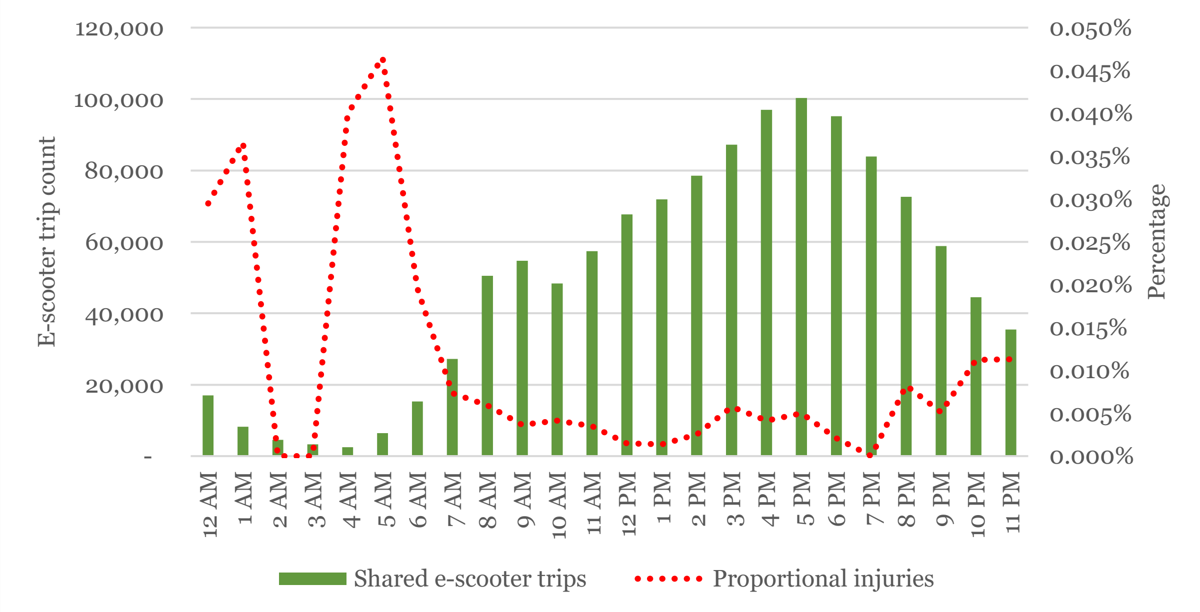


Figure 46: E-scooter trip count and proportional number of injuries after the restrictions in 2021 (Sep-Dec)

Figure 47 shows the e-scooter trip count and proportional number of injuries based on trip count data in 2021 before the restrictions and in 2022 after the restrictions, from January until August. Based on this figure, the proportional number of injuries in 2021 is very high between 00:00 and 06:00. After the restrictions, the proportional number of crashes has significantly decreased in the mentioned hours. The average proportional number of injuries has decreased from 0.013% to 0.004% which is about 70% decrease in 2022 compared to 2021.

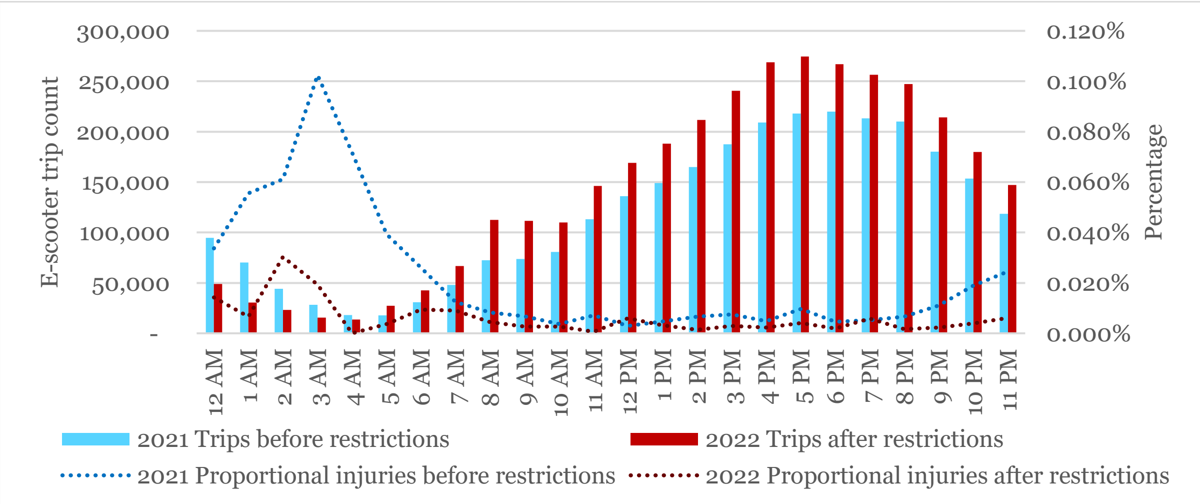


Figure 47: *E-scooter trip count and proportional number of injuries in 2021 and 2022 (Jan-Aug)*

In the following parts, the proportional number of injuries before and after restrictions has been categorized based on days of week and time of day. Table 12 and Table 13 show the proportional number of e-scooter related injuries before and after the restrictions in 2021, respectively. The values that are higher than the average have been highlighted in red cells. Based on Table 12, there is a clear increase in early hours of the day specially on weekends from midnight until 07:00. The number of injuries is also higher than average in all days of week at 23:00. However, based on Table 13, there is no clear concentration of crashes in some clustered time of day. Still, the number of proportional injuries is higher on Friday and Saturday. The average proportional number of injuries has decreased from 0.013% to 0.005% which is about 60% decrease after the restrictions. Table 14 shows the proportional number of e-scooter related injuries after the restrictions in 2022 from January to August. Based on this table, the average proportional number of injuries has decreased from 0.005% in September-December 2021 to 0.004% in 2022 which is about 30% decrease in 2022. It is worth mentioning that the number of proportional injuries in Table 13 and Table 14 between 00:00-05:00 on weekends should be zero. However, they might belong to private e-scooter incidents or error in injury date and time reporting.

Table 12: Proportional number of e-scooter related injuries per time of day and day of week before the restrictions in 2021 (Jan-Aug)

Day / Hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Avg.
12 AM	0.027%	0.058%	0.013%	0.022%	0.068%	0.034%	0.026%	0.034%
1 AM	0.038%	0.098%	0.020%	0.049%	0.029%	0.060%	0.065%	0.056%
2 AM	0.116%	0.045%	0.000%	0.028%	0.154%	0.052%	0.057%	0.061%
3 AM	0.000%	0.073%	0.266%	0.000%	0.214%	0.127%	0.076%	0.102%
4 AM	0.080%	0.000%	0.101%	0.000%	0.121%	0.097%	0.061%	0.072%
5 AM	0.000%	0.000%	0.051%	0.000%	0.000%	0.090%	0.077%	0.039%
6 AM	0.000%	0.000%	0.000%	0.019%	0.060%	0.069%	0.069%	0.026%
7 AM	0.000%	0.000%	0.000%	0.012%	0.000%	0.063%	0.123%	0.013%
8 AM	0.000%	0.015%	0.000%	0.000%	0.008%	0.042%	0.032%	0.008%
9 AM	0.000%	0.000%	0.017%	0.000%	0.016%	0.000%	0.021%	0.007%
10 AM	0.000%	0.000%	0.000%	0.008%	0.007%	0.009%	0.000%	0.004%
11 AM	0.013%	0.000%	0.000%	0.006%	0.016%	0.006%	0.007%	0.007%
12 PM	0.017%	0.000%	0.000%	0.000%	0.005%	0.000%	0.000%	0.003%
1 PM	0.000%	0.000%	0.005%	0.000%	0.004%	0.016%	0.005%	0.005%
2 PM	0.000%	0.004%	0.005%	0.004%	0.004%	0.014%	0.013%	0.007%
3 PM	0.008%	0.004%	0.004%	0.004%	0.013%	0.013%	0.004%	0.007%
4 PM	0.000%	0.010%	0.004%	0.000%	0.006%	0.006%	0.008%	0.005%
5 PM	0.015%	0.007%	0.012%	0.003%	0.003%	0.011%	0.022%	0.010%
6 PM	0.007%	0.000%	0.008%	0.003%	0.003%	0.011%	0.000%	0.005%
7 PM	0.000%	0.004%	0.004%	0.007%	0.003%	0.013%	0.004%	0.005%
8 PM	0.013%	0.007%	0.000%	0.007%	0.007%	0.008%	0.004%	0.007%
9 PM	0.015%	0.005%	0.000%	0.004%	0.008%	0.025%	0.014%	0.011%
10 PM	0.007%	0.000%	0.035%	0.020%	0.020%	0.026%	0.013%	0.019%
11 PM	0.020%	0.025%	0.024%	0.028%	0.030%	0.021%	0.018%	0.024%
Avg.	0.009%	0.007%	0.009%	0.007%	0.013%	0.021%	0.019%	0.013%

Table 13: Proportional number of e-scooter related injuries per time of day and day of week after the restrictions in 2021 (Sep-Dec)

Day / Hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Avg.
12 AM	0.000%	0.000%	0.000%	0.032%	0.031%	0.048%	0.113%	0.029%
1 AM	0.094%	0.000%	0.000%	0.000%	0.101%	0.518%	11.111%	0.037%
2 AM	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
3 AM	0.000%	0.000%	0.000%	0.000%	0.000%	0.952%	0.000%	0.000%
4 AM	0.000%	0.000%	0.000%	0.000%	0.141%	1.695%	0.000%	0.040%
5 AM	0.000%	0.000%	0.000%	0.243%	0.000%	0.000%	0.000%	0.047%
6 AM	0.000%	0.043%	0.000%	0.000%	0.000%	0.000%	0.143%	0.020%
7 AM	0.000%	0.022%	0.000%	0.018%	0.000%	0.000%	0.000%	0.007%
8 AM	0.000%	0.000%	0.000%	0.000%	0.011%	0.084%	0.000%	0.006%
9 AM	0.000%	0.000%	0.010%	0.000%	0.000%	0.025%	0.000%	0.004%
10 AM	0.000%	0.000%	0.000%	0.000%	0.012%	0.017%	0.000%	0.004%
11 AM	0.000%	0.000%	0.000%	0.000%	0.000%	0.012%	0.017%	0.003%
12 PM	0.000%	0.000%	0.010%	0.000%	0.000%	0.000%	0.000%	0.001%
1 PM	0.000%	0.000%	0.000%	0.000%	0.008%	0.000%	0.000%	0.001%
2 PM	0.000%	0.011%	0.000%	0.000%	0.000%	0.000%	0.010%	0.003%
3 PM	0.009%	0.000%	0.000%	0.000%	0.013%	0.007%	0.010%	0.006%
4 PM	0.008%	0.008%	0.000%	0.000%	0.000%	0.013%	0.000%	0.004%
5 PM	0.000%	0.000%	0.007%	0.000%	0.012%	0.012%	0.000%	0.005%
6 PM	0.000%	0.000%	0.000%	0.000%	0.006%	0.006%	0.000%	0.002%
7 PM	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
8 PM	0.000%	0.045%	0.000%	0.000%	0.015%	0.000%	0.000%	0.008%
9 PM	0.000%	0.027%	0.000%	0.000%	0.000%	0.009%	0.000%	0.005%
10 PM	0.043%	0.000%	0.000%	0.000%	0.000%	0.034%	0.000%	0.011%
11 PM	0.000%	0.029%	0.022%	0.000%	0.024%	0.000%	0.000%	0.011%
Avg.	0.003%	0.007%	0.002%	0.003%	0.008%	0.009%	0.006%	0.005%

Table 14: Proportional number of e-scooter related injuries per time of day and day of week after the restrictions in 2022 (Jan-Aug)

Day / Hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Avg.
12 AM	0.000%	0.014%	0.012%	0.016%	0.000%	0.746%	0.467%	0.014%
1 AM	0.000%	0.000%	0.000%	0.000%	0.013%	0.000%	8.333%	0.007%
2 AM	0.020%	0.032%	0.027%	0.000%	0.036%	7.692%	12.500%	0.030%
3 AM	0.059%	0.000%	0.000%	0.027%	0.000%	0.000%	0.000%	0.019%
4 AM	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
5 AM	0.000%	0.000%	0.000%	0.033%	0.000%	0.000%	0.000%	0.004%
6 AM	0.000%	0.014%	0.000%	0.015%	0.030%	0.000%	0.000%	0.009%
7 AM	0.018%	0.008%	0.016%	0.000%	0.000%	0.000%	0.027%	0.009%
8 AM	0.000%	0.000%	0.000%	0.000%	0.016%	0.013%	0.021%	0.004%
9 AM	0.006%	0.005%	0.000%	0.000%	0.006%	0.000%	0.000%	0.003%
10 AM	0.007%	0.006%	0.000%	0.000%	0.006%	0.000%	0.000%	0.003%
11 AM	0.000%	0.000%	0.000%	0.000%	0.005%	0.000%	0.000%	0.001%
12 PM	0.000%	0.004%	0.017%	0.004%	0.000%	0.007%	0.008%	0.006%
1 PM	0.004%	0.000%	0.012%	0.000%	0.000%	0.003%	0.003%	0.003%
2 PM	0.000%	0.004%	0.000%	0.000%	0.000%	0.005%	0.000%	0.001%
3 PM	0.000%	0.009%	0.000%	0.009%	0.003%	0.000%	0.000%	0.003%
4 PM	0.000%	0.003%	0.000%	0.003%	0.000%	0.005%	0.006%	0.002%
5 PM	0.000%	0.010%	0.005%	0.005%	0.007%	0.000%	0.000%	0.004%
6 PM	0.000%	0.003%	0.000%	0.006%	0.002%	0.002%	0.000%	0.002%
7 PM	0.003%	0.012%	0.003%	0.003%	0.007%	0.004%	0.008%	0.006%
8 PM	0.000%	0.000%	0.000%	0.000%	0.000%	0.005%	0.006%	0.002%
9 PM	0.004%	0.000%	0.000%	0.000%	0.003%	0.002%	0.007%	0.002%
10 PM	0.010%	0.000%	0.005%	0.009%	0.003%	0.000%	0.004%	0.004%
11 PM	0.008%	0.007%	0.023%	0.000%	0.006%	0.003%	0.000%	0.006%
Avg.	0.003%	0.005%	0.004%	0.004%	0.004%	0.003%	0.004%	0.004%

Figure 48 shows a comparative analysis of proportional e-scooter injuries during weekends before and after the restrictions. The overall proportional number of injuries has decreased by 62% after restrictions. The reason of existing injuries in the restricted time interval could be because of inaccurate time of crash in the reporting or private e-scooter incidents. Furthermore, there are some e-scooter trips during 00:00-05:00, which could be generated because of e-scooter rebalancing or trips started just before midnight.

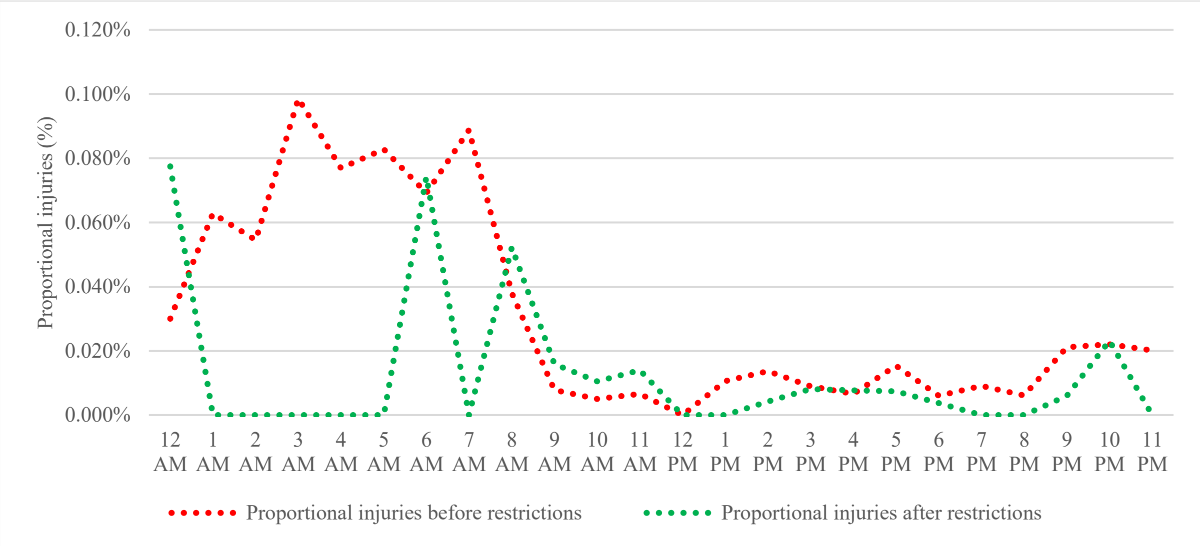


Figure 48: Comparison of proportional e-scooter injuries during weekends before and after the restrictions

Figure 49 shows a comparative analysis of proportional e-scooter injuries during weekdays, before and after the restrictions. The overall proportional number of crashes has decreased by 50% after restrictions.

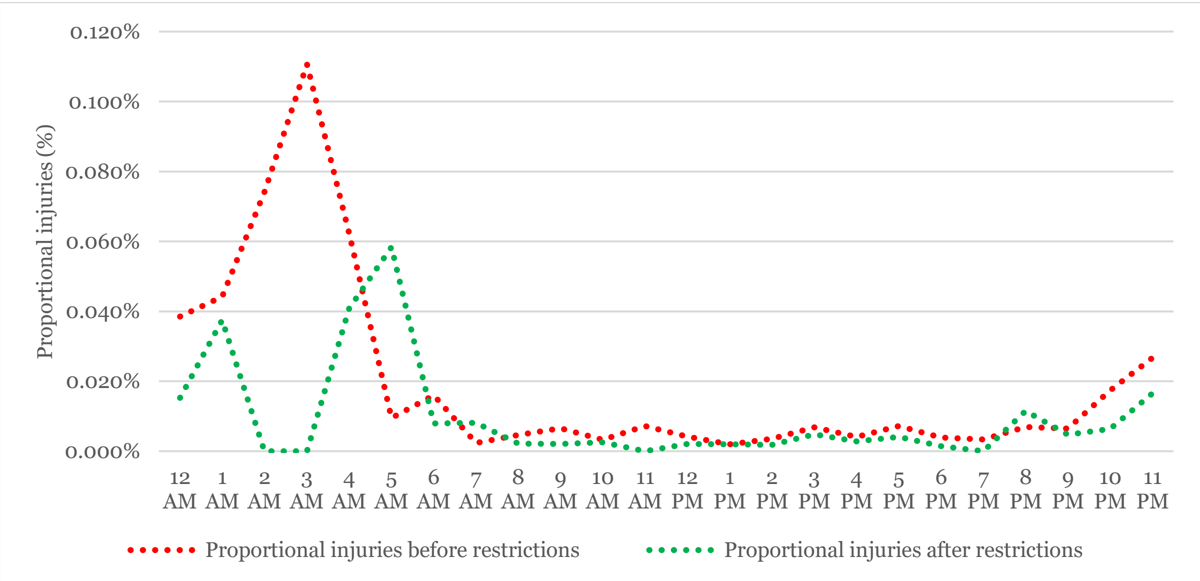


Figure 49: Comparison of proportional e-scooter injuries during weekdays before and after the restrictions

Figure 50 shows the proportional e-scooter injuries during weekdays and weekends in 2021 and 2022, separated by injury severity. By cross-comparing Figure 50-a and Figure 50-b, we can see that the injury severity score has reduced, with 86% decrease in average on weekends. The important aspect is that the injury severity of levels 3 and 4 which are serious injuries, has decreased by 83% and 100% in 2022 after restrictions on weekends. On the other hand, Figure 50-c and Figure 50-d show that the injury severity score has reduced, with 59% decrease in average on weekdays. Similarly, the important aspect is that the injury severity of 3 and 4 on weekdays has decreased by 56% and 100% in 2022 after restrictions. There is no injury severity level 5 in 2021 and 2022.

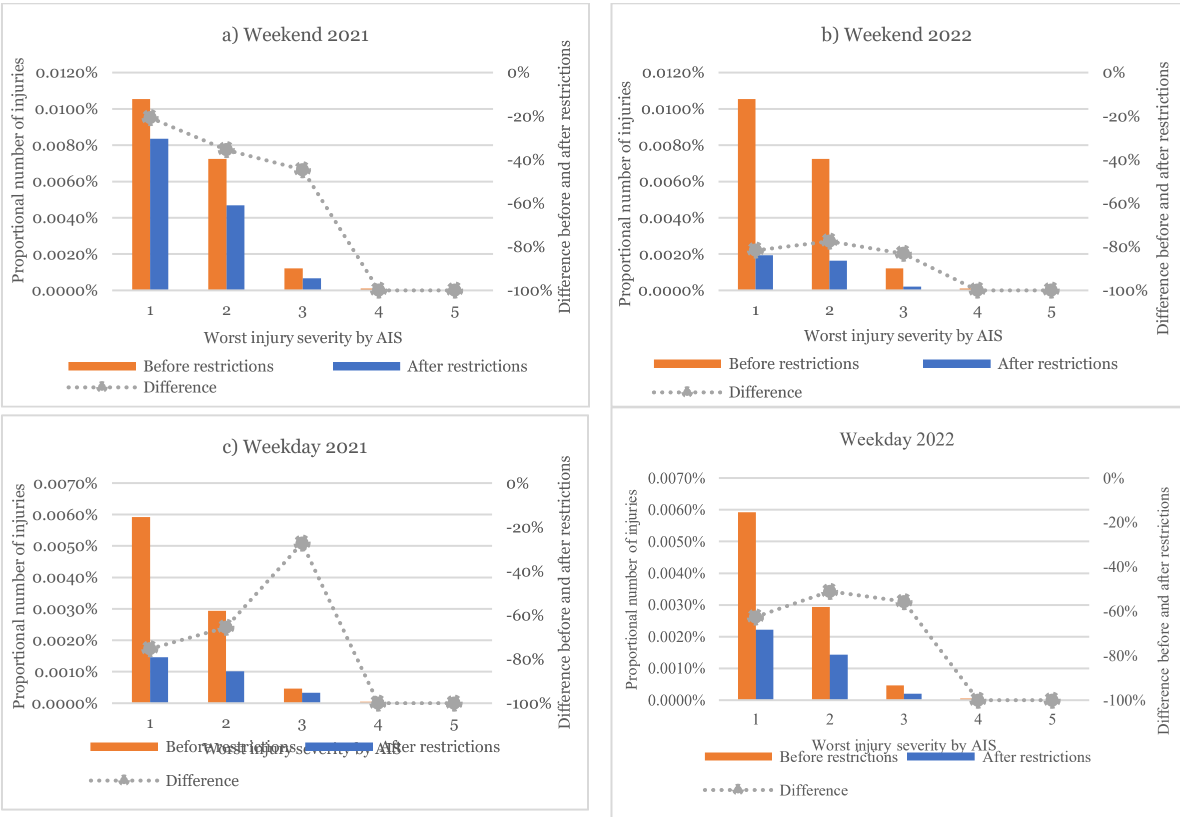


Figure 50: Proportional e-scooter injuries during weekdays and weekends 2021 and 2022, based on AIS injury severity

Table 15 shows the number of injuries separated by AIS injury severity score on weekdays and weekends before and after restrictions, for period January to August in both 2021 and 2022. These numbers are the weighted average based on injury severity score as the weight. Based on these results, the severity of injuries has decreased by 78% and 47% on weekends and weekdays after the restrictions in 2022, respectively.

Table 15: Number of injuries categorized by Abbreviate Injury Scale score on weekdays and weekends before and after restrictions during January – August

Weekend vs. weekday / Abbreviated Injury Scale (AIS)	Weekday (January-August)		Weekend (January-August)	
	2021	2022	2021	2022
1	96	19	115	54
2	66	16	57	35
3	11	2	9	5
4	1	0	1	0
5	0	0	0	0
N/A	4	0	3	0
Weighted average	**17.7**	**3.8**	**17.3**	**9.3**
Difference	**-78%**		**-47%**	

Figure 51 below shows the heatmap of e-scooter related crash location distribution in the whole 2021, plotted based on their described location. The geolocation of these crashes has been extracted from the injury data provided by HUS. It is worth mentioning that only 179 out of 447 of them have location data based on the ambulance location that was called for or by the injured person, and this set includes both rental and private e-scooters. Based on this figure, some locations are out of the city centre and rental e-scooters' operational areas, which could relate to private e-scooters. The concentration of emergency cases is high in the areas of Central Railway Station, Keskuskatu, Unioninkatu, Porkkalankatu, Tyynenmerenkatu, Fleminginkatu, Aleksis Kiven Katu and Kamppi. These areas also correspond to the largest supply and demand density for e-scooters in Helsinki.

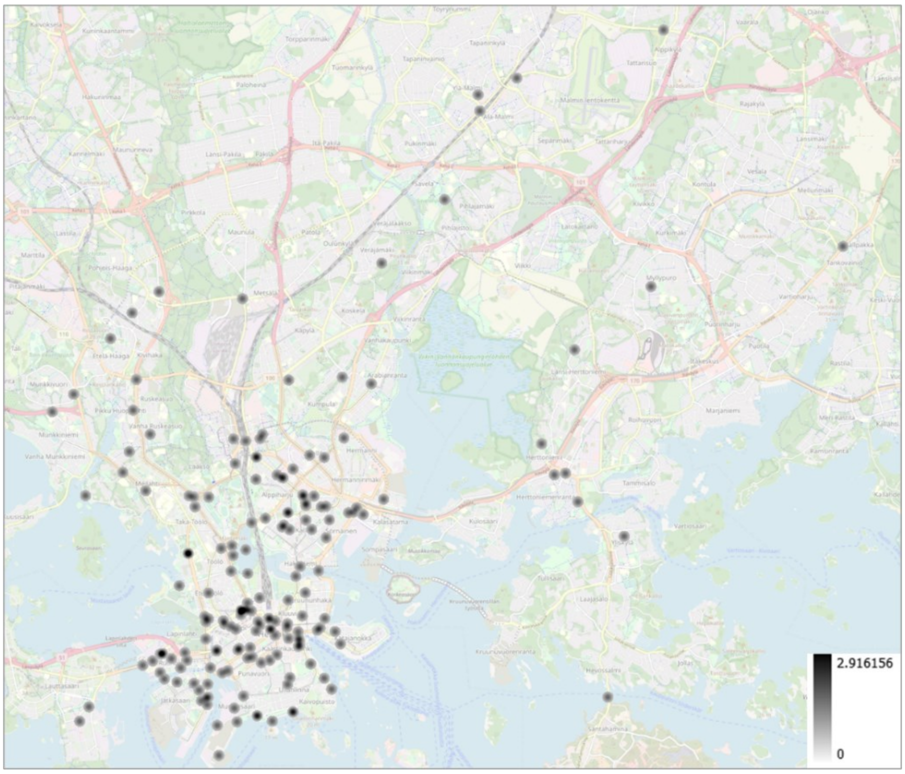


Figure 51: Heatmap of e-scooter crashes in 2021 provided in injury data, non-weighted

Figure 52 depicts the heatmap of e-scooter related crashes arrived by ambulance in 2021, before the restrictions from January until August, compared to 2022 after the restrictions, from January until August. According to this figure, some locations such as Fredrikinkatu, Bulevardi, Lönnrontinkatu, Eteläesplanadi, Runeberginkatu and Helsinginkatu are almost the same in 2022 as in 2021. However, there are some locations that are completely incident free in 2022 comparing to 2021 such as Simonkatu, Alexanderinkatu, Fleminginkatu, Tyynenmerenkatu and Ruoholahti. On the other hand, there are some new crash locations such as east of Helsinki naming Itäkeskus, Vuosaari, Aurinkolahti, Sörnäinen and Mellunmäki. Again, it worth mentioning that these locations are the crash locations that an ambulance was called for or by the injured person, and the location of other e-scooter related injuries are not available, and thus not visible in the heatmaps. Therefore, other spatial clusters might exist. The focused version of Figure 52 is presented in Figure 53.

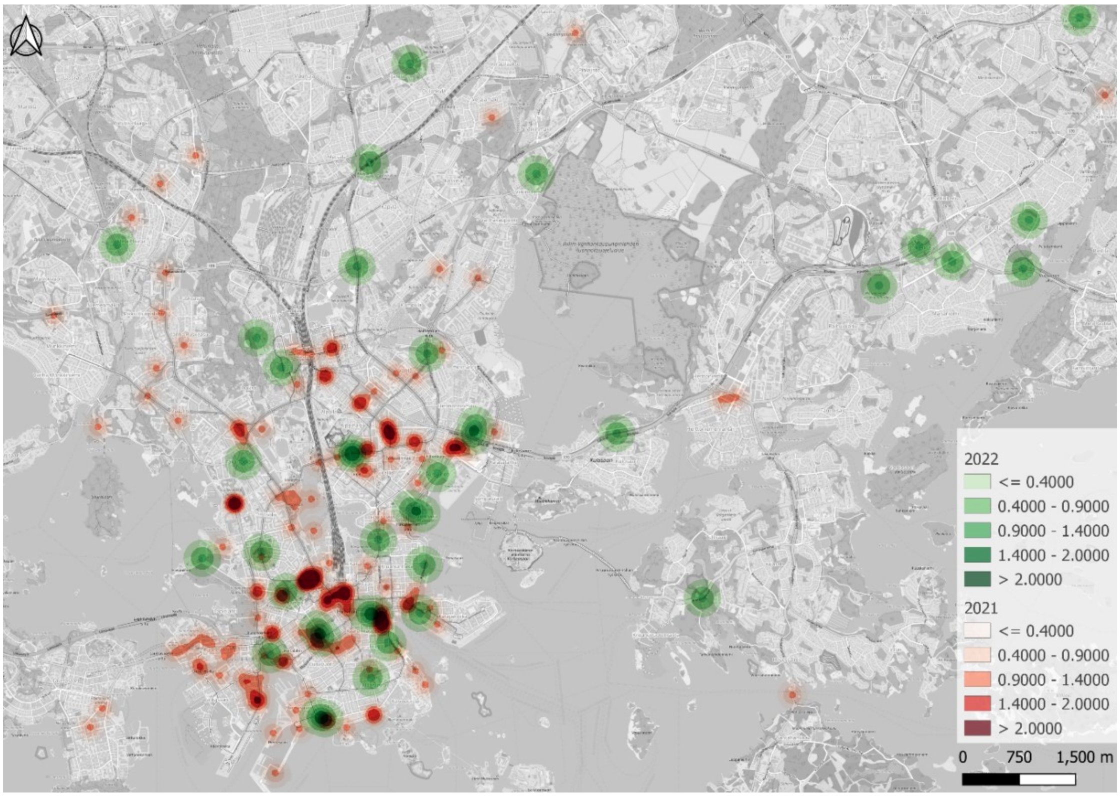


Figure 52: Heatmap of e-scooter crashes arrived by ambulance for Jan-Aug in 2021 and 2022, non-weighted

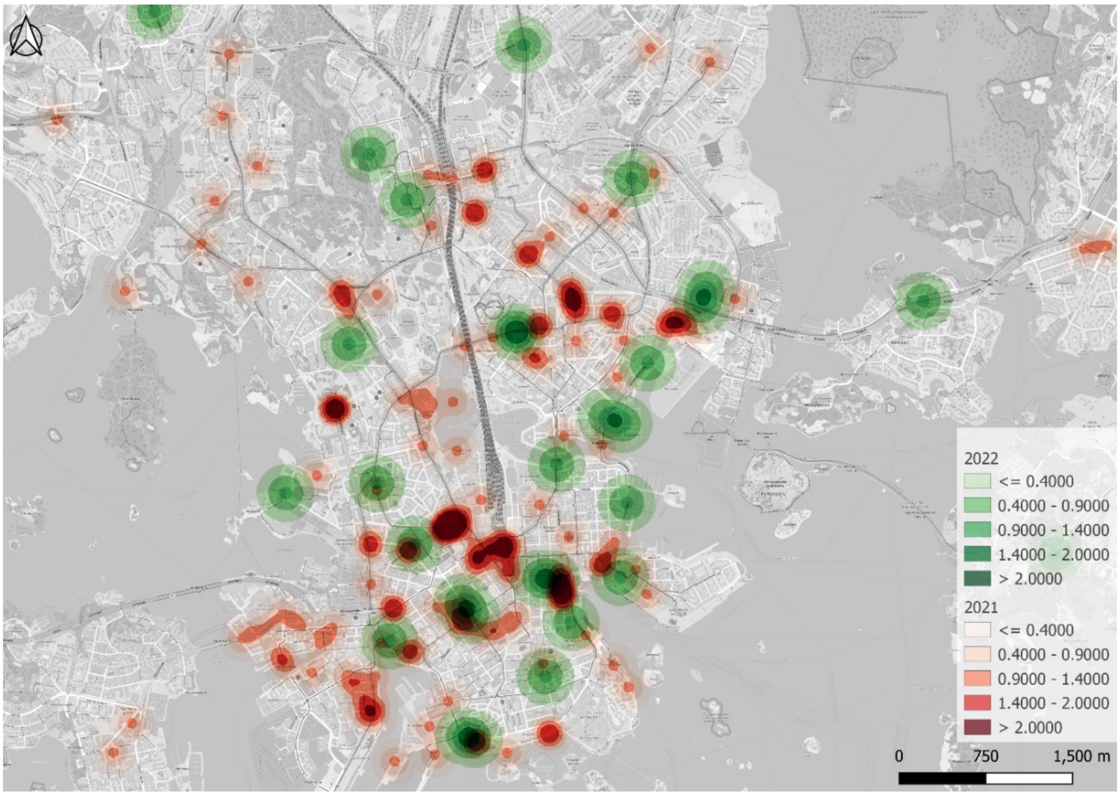


Figure 53: Focused heatmap of e-scooter crashes arrived by ambulance for Jan-Aug in 2021 and 2022, non-weighted

Figure 54 depicts the weighted heatmap of e-scooter related crash location distribution in 2021 based on AIS injury severity. According to this figure, the crashes around central railway station, Unioninkatu, Tyynenmerenkatu and Fleminginkatu not only have higher density, but also higher AIS injury severity. On the other hand, some locations such as Pasila, Teollisuuskatu and Ruoholahti have less density but higher AIS injury severity, which is further analysed during site visits.

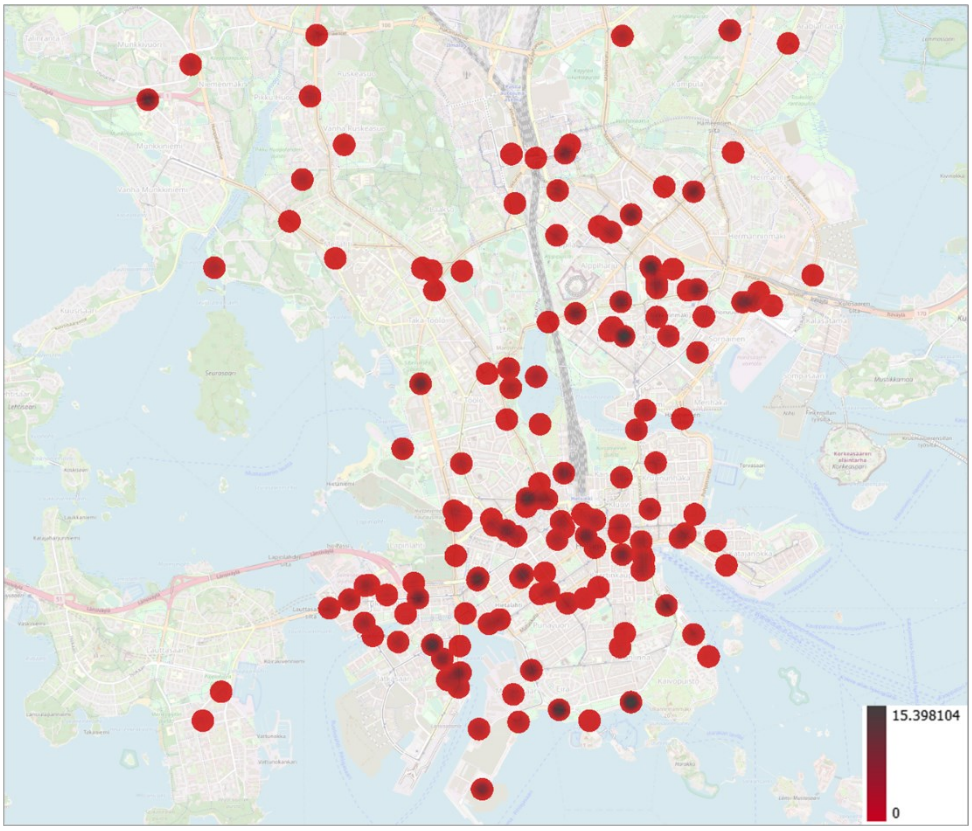


Figure 54 Heatmap of 179 e-scooter related crashes in 2021, weighted by injury severity

Figure 55 depicts the heatmap of e-scooter related crashes arrived by ambulance in 2021 before the restrictions compared to 2022 after the restrictions, from January until August, weighted by AIS injury severity. According to this figure, some locations such as Baana, Fredrikinkatu and Eiranranta have almost the same injury severity in 2022 as in 2021. There are some crash locations in 2022 with higher injury severity score such as Sörnäinen and Helsinginkatu, Merihaka and Länsi-Pasila.

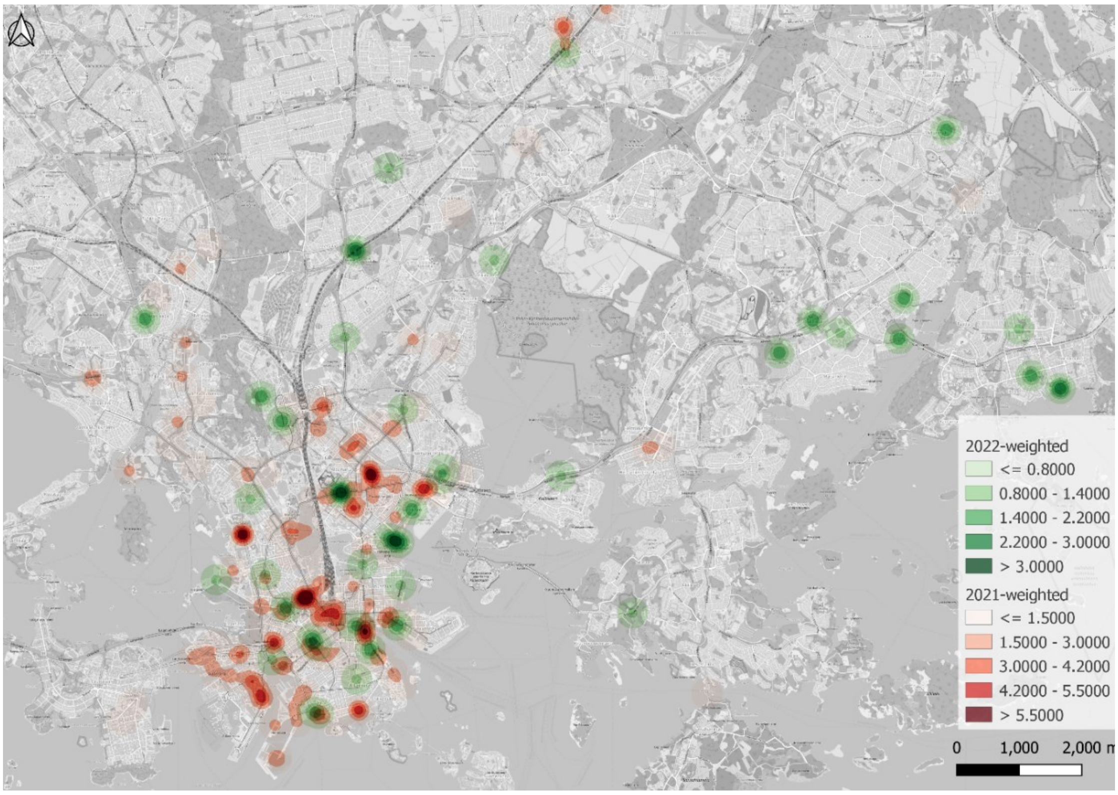


Figure 55: Heatmap of e-scooter crashes arrived by ambulance for Jan-Aug in 2021 and 2022, weighted by AIS injury severity

A focused version of Figure 55, focusing on the city centre, is presented in Figure 56.

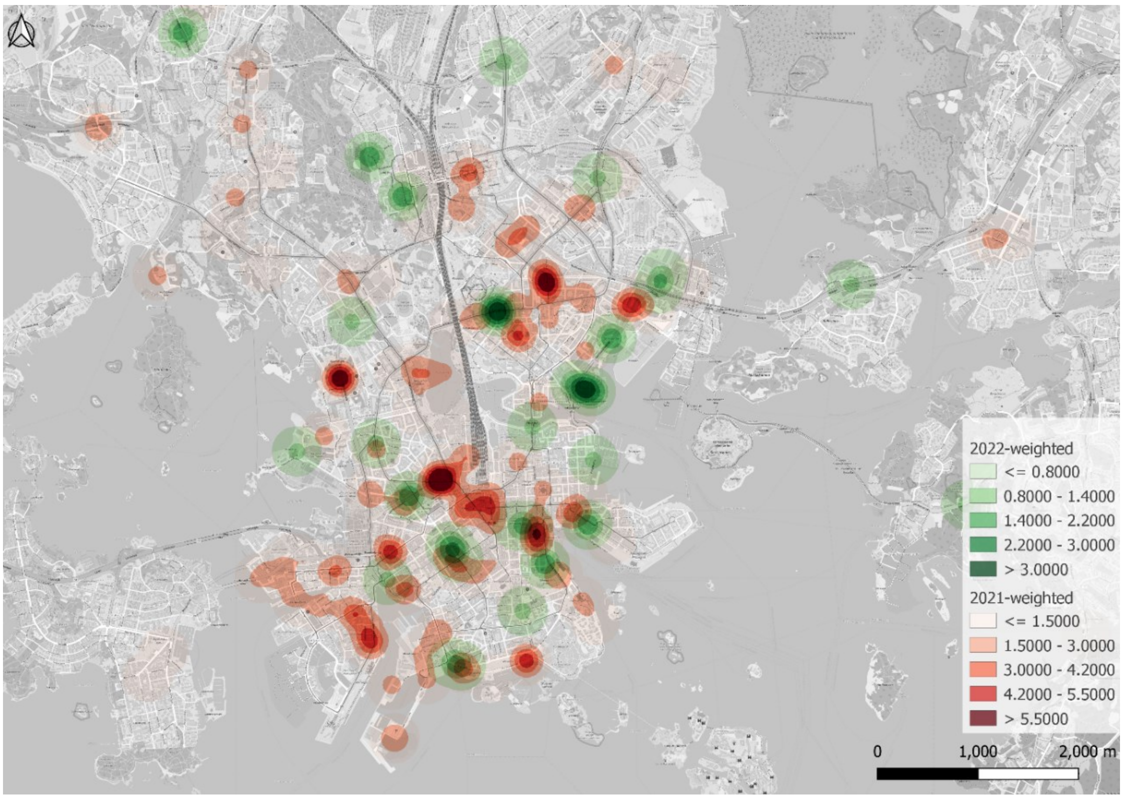


Figure 56: Zoomed heatmap of e-scooter crashes arrived by ambulance for Jan-Aug in 2021 and 2022, weighted by AIS injury severity

3.2 Types of observed riding competences and behaviours of e-scooter users

Categorization of observed user competences in four groups involves the following behavioural competences for each of the four rider categories listed below:

- Highly cooperative
    - Turning lights intentionally or using hand signalling
    - Dismounting to cross/before crossing
    - Checking both sides
    - Checking one side (both not needed)
    - Stopping to check phone
    - Wearing helmet
    - Wearing reflective vest
- Moderately cooperative
    - Flock-riders with pedestrian/s
    - Weaving among other users
    - Carrying one extra object
    - Problematic foot position on vehicle platform
    - Issues with kick-starting at initiating ride
- Moderately non-cooperative
    - Two-vehicle (e-scooter or mixed) flock-riders
    - Child-riders with adult supervision
    - Performing tricks
    - Smoking while riding
    - One-hand riding
    - Counter-flow on bike lane/cross
    - Using attached mobile phone while riding
    - Using headphones while riding
    - Carrying two objects
    - Not keeping distance when passing pedestrians
    - Losing control without interacting with other users
    - Almost crashing into other users
    - Red light running
    - No night-time light usage
- Highly non-cooperative
    - Multiple-vehicle (over two) flock-riders
    - Multi-riders on one scooter
    - Child-riders without adult supervision
    - Improper parking by blocking
    - Counter-flow on carriageway
    - Using a non-attached mobile phone while riding
    - Carrying several extra objects (3 or more)
    - Appearing drunk while riding
    - Crashing into other users or infrastructure

Based on these categories, proportions of each rider group for different video recording locations and cumulative percentages are shown in Table 16. Although these percentages should be understood as qualitative analysis, from this table, one can conclude that a) there is a significant percentage of highly dissonant users overall, and b) that number increases or decreases based on the issues in the infrastructure. For example, in dedicated shared space available in the underpass at Ruoholahti location, where only non-motorized modes are present, the percentage of highly dissonant users is 17%, while in other locations this percentage can go over 30%.

Table 16: Proportion of user categories

Viiskulma	**Count**	**Proportion**
Highly cooperative	27	13%
Moderately cooperative	61	30%
Moderately non-cooperative	43	21%
Highly non-cooperative	75	36%
Total	206	100%
Ruoholahti	**Count**	**Proportion**
Highly cooperative	160	42%
Moderately cooperative	89	23%
Moderately non-cooperative	68	18%
Highly non-cooperative	67	17%
Total	385	100%
Keskuskatu	**Count**	**Proportion**
Highly cooperative	35	12%
Moderately cooperative	77	27%
Moderately non-cooperative	75	27%
Highly non-cooperative	96	34%
Total	283	100%
Erottaja	**Count**	**Proportion**
Highly cooperative	59	25%
Moderately cooperative	50	22%
Moderately non-cooperative	62	27%
Highly non-cooperative	60	26%
Total	231	100%
All four locations	**Count**	**Proportion**
Highly cooperative	281	26%
Moderately cooperative	277	25%
Moderately non-cooperative	248	22%
Highly non-cooperative	298	27%
Total	1105	100%

From the following tables Table 17 to Table 22, one can conclude that gender is not a major factor related to highly non-cooperative behaviour, while age is. It is important to note that a substantial number of children and teenagers are using shared scooters despite age limits. Moreover, children, teenagers and young adults are most common among highly non-cooperative users, while there is also a substantial amount of middle-aged users in the same category.

Table 17: Distribution of user categories in relation to perceived age, counts

	Highly non-cooperative	Moderately non-cooperative	Moderately cooperative	Highly cooperative	Total
Child	18	2			20
Teenager	108	15	3		126
Young adult	136	161	158	131	586
Middle aged	24	34	58	44	160
Old		1		3	4
Not clear	13	35	58	103	209
Total	**299**	**248**	**277**	**281**	**1105**

Table 18: Distribution of user categories in relation to perceived age, relative percentages

	Highly non-cooperative	Moderately non-cooperative	Moderately cooperative	Highly cooperative	Total
Child	1.63%	0.18%	0.00%	0.00%	1.81%
Teenager	9.77%	1.36%	0.27%	0.00%	11.40%
Young adult	12.32%	14.58%	14.31%	11.87%	53.03%
Middle aged	2.17%	3.08%	5.25%	3.99%	14.48%
Old	0.00%	0.09%	0.00%	0.27%	0.36%
Not clear	1.18%	3.17%	5.25%	9.33%	18.91%
Total	**27.06%**	**22.44%**	**25.07%**	**25.43%**	**100.00%**

Table 19: Distribution of user categories in relation to perceived age, absolute percentages

	Highly non-cooperative	Moderately non-cooperative	Moderately cooperative	Highly cooperative	Total
Child	90.00%	10.00%	0.00%	0.00%	100.00%
Teenager	85.60%	12.00%	2.40%	0.00%	100.00%
Young adult	23.21%	27.47%	26.96%	22.35%	100.00%
Middle aged	15.00%	21.25%	36.25%	27.50%	100.00%
Old	0.00%	25.00%	0.00%	75.00%	100.00%
Not clear	6.22%	16.75%	27.75%	49.28%	100.00%
Total	**26.99%**	**22.46%**	**25.09%**	**25.45%**	**100.00%**

Table 20: Distribution of user categories in relation to perceived gender, counts

	Highly non-cooperative	**Moderately non-cooperative**	**Moderately cooperative**	**Highly cooperative**	**Total**
Female	82	60	57	47	246
Male	185	150	170	162	667
Not clear	31	39	50	72	192
Total	**298**	**249**	**277**	**281**	**1105**

Table 21: Distribution of user categories in relation to perceived gender, relative percentages

	Highly non-cooperative	**Moderately non-cooperative**	**Moderately cooperative**	**Highly cooperative**	**Total**
Female	7.42%	5.43%	5.16%	4.25%	22.26%
Male	16.74%	13.57%	15.38%	14.66%	60.36%
Not clear	2.81%	3.53%	4.52%	6.52%	17.38%
Total	**26.97%**	**22.53%**	**25.07%**	**25.43%**	**100.00%**

Table 22: Distribution of user categories in relation to perceived gender, absolute percentages

	Highly non-cooperative	**Moderately non-cooperative**	**Moderately cooperative**	**Highly cooperative**	**Total**
Female	33.33%	24.39%	23.17%	19.11%	100.00%
Male	27.74%	22.49%	25.49%	24.29%	100.00%
Not clear	16.15%	20.31%	26.04%	37.50%	100.00%
Total	**26.97%**	**22.53%**	**25.07%**	**25.43%**	**100.00%**

Overall, video observation analysis has enabled to discover a diverse set of practices while using e-scooters. One clear group of users involves carrying objects, which can be associated with shopping (e.g., grocery bag), leisure (e.g., gym bag, suitcase) or commuting (e.g., laptop bag). Similarly, trip purposes can be observed also from clothing, such as people wearing high heels or gala clothing. In addition, interesting edge cases have been observed, such as people that might have trouble using other modes, as they are carrying crutches while riding. One clear group of users are people traveling in groups, either with scooters only, or also with other modes, such as cycling or walking. This aspect emphasizes the social aspect of traveling also during the trip, since many have been observed to have conversations while moving. Here, it is important to highlight one group of users, namely children with parents/adults, who also often travel together on one scooter, which is clearly an unsafe behaviour due to potential rider kinematics on such a vehicle.

Food delivery workers have clearly been observed as a substantial group of users, as 273 in total, have been observed in the video recordings. In relation to the above-mentioned 1105 observed users, delivery workers amount to approximately 20% of the total user base. Out of those food delivery workers, 226 have used a shared e-scooter, 21 private, and 26 cases had used an unclear e-scooter type. Delivery workers have been treated as a separate user groups, with their behaviour excluded from the above categorization, as they have showed relatively high riding competences. However, given the fact that they are also using e-scooters for employment, which operates under rules of another shared service with additional objectives (e.g., maximize the number of deliveries over time), they might exhibit more complex intertwining of collaborative and competitive behaviour while riding that non-delivery users (Frey, 2022; Popan, 2021).

An analysis focused more on the actual trajectory level, clearly shows that a substantial amount of the users is not following the designed desire lines, such as available cycling infrastructure. However, in places where separate cycling infrastructure is not available, similar behaviour can be observed also from cyclists, indicating that issues are largely in the infrastructure and relative speed of motorized traffic. In addition, the effect of infrastructure has to be underlined here too, as users' trajectories have also been problematic due to unclear desire lines or inadequate surfaces for micromobility vehicles (e.g., cobblestone, tram tracks). In combination with users being in apparent rush, such trajectories can lead to undesired conflict situations with other users, and have also been observed to cause neglect in choosing a parking location (e.g., middle of the sidewalk side). Another non-cooperative type of trajectory-level behaviour worth highlighting is users doing tricks or drifting while riding. In general, turning signals are rarely used, despite their availability on most e-scooter models. Similarly, it is important to highlight simultaneous activities that users are performing while riding, such as listening to music, using the phone, smoking, and eating, which both shows evolving competences and dissonant affordances. Finally, although private e-scooter usage has been low in video recordings in 2021 than in the present 2022 situation at the time of writing this report, even from those cases it can be observed that there is a wide variety of private e-mobility devices, many of which are either of poorer quality that shared e-scooters, or have higher speeds – both of which are potential causes for safety hazards. Since video recordings were conducted also during dark conditions, it can be concluded that scooter riders do have better visibility by others in these conditions, as most of them have a front-facing light and are combined with a standing position while riding. In comparison, front-facing lights are not as common for bicycle users.

3.3 User and non-user perspectives on the usage and improvements of rules for shared e-scooters

In order to analyse the respondents, we have separate them into the following categories:

- Shared e-scooter users vs. non-users
- Private e-scooter users vs. no private e-scooter owners
- Delivery workers with shared e-scooters vs. private e-scooters

Table 23 categorizes the proportion of shared e-scooter users and frequency vs. non-users. Based on this table, 5,059 respondents were not delivery workers (93.5% of total sample), while 2,396 (47.9%) of them are absolute non-riders, which means that they have not tried e-scooter riding in 2022 and before, and they do not own a private e-scooter. The share of previous shared e-scooter users who have used e-scooter in 2021 and before but not in 2022 is about 12.7% of the sample, while 4.3% of the sample are new shared e-scooter users who have started or planning to use a shared e-scooter in 2022. About one third (35.0%) of the total sample are the shared e-scooter users who have used shared e-scooter in 2022 and before. They have been separated based on their usage frequency, as presented in the following table.

Table 23: Shared e-scooter non-users and users' frequency

Shared e-scooter non-users and user types		Quantity		Percent (%)	
Absolute non-user		2396		47.9%	
Previous shared user		636		12.7%	
New shared user		214		4.3%	
Shared e-scooter	One time user-shared	1751	106	35.0%	6.1%
	Curious user-shared		400		22.8%
	Occasional user-shared		580		33.1%
	Frequent user-shared		414		23.6%
	Weekend user-shared		79		4.5%
	Power user-shared		172		9.8%

The following Table 24 shows socio-demographic characteristics for all the respondent types. The sample has adequate distribution over all the categories.

Table 24: Shared e-scooters' users and non-users characteristics

Socio-demographic characteristic	Options	Absolute non-user	Previous shared user	New shared user	Shared e-scooter user	Total
Age	Under 18	0.7%	2.4%	8.0%	5.5%	2.9%
	18-24	3.3%	12.9%	18.3%	27.7%	13.6%
	25-34	21.2%	41.7%	30.5%	34.9%	29.0%
	35-44	31.1%	27.0%	20.7%	20.0%	26.2%
	45-54	19.9%	10.7%	16.9%	8.6%	14.7%
	55-64	15.1%	4.3%	3.8%	2.5%	8.8%
	64+	8.7%	1.0%	1.9%	0.7%	4.7%
Gender	Male	32.4%	48.6%	54.9%	61.6%	45.6%
	Female	60.1%	46.3%	39.9%	34.1%	48.5%
	Other	1.6%	1.1%	1.4%	1.3%	1.4%
	Prefer not to say	5.8%	4.0%	3.8%	3.0%	4.5%
Previous year's gross income	0–9,999 €	4.0%	9.4%	19.6%	17.3%	9.9%
	10,000–19,999 €	6.7%	12.4%	9.3%	11.4%	9.1%
	20,000–29,999 €	10.3%	10.5%	9.8%	10.7%	10.5%
	30,000–39,999 €	16.6%	18.0%	14.0%	12.6%	15.2%
	40,000–59,999 €	27.1%	23.4%	18.7%	18.3%	23.2%
	60,000 to 79,999 €	11.2%	10.5%	7.9%	9.8%	10.5%
	80,000 € and more	7.9%	8.6%	7.9%	8.9%	8.4%

	Don't know / Don't want to say	16.2%	7.3%	12.6%	11.0%	13.1%
Occupation status	Employed	74.4%	72.2%	62.1%	65.7%	70.6%
	Unemployed or laid off	1.9%	2.4%	6.5%	3.4%	2.7%
	Student	7.5%	18.7%	25.2%	26.3%	16.1%
	Pensioner	10.0%	2.2%	3.3%	0.6%	5.5%
	On parental or care leave	2.2%	1.6%	1.4%	0.9%	1.6%
	Other	4.1%	2.9%	1.4%	3.1%	3.4%
Highest completed degree	High school	19.1%	23.3%	38.5%	36.7%	26.6%
	Bachelor's degree	27.0%	30.2%	24.0%	33.0%	29.5%
	Master's degree	47.7%	42.9%	34.1%	27.8%	39.5%
	Doctoral degree	6.1%	3.5%	3.4%	2.5%	4.4%

Table 25 shows the distribution of self-perceived cycling experience, and perceptions of e-scooter effects on individual and societal level. The highlighted percentages across respondent types shows differences in perceiving e-scooters as beneficial or damaging for individuals and society.

Table 25: Shared e-scooters' users and non-users cycling experience and overall perception towards e-scooters

Experience and perceptions	Options	Absolute non-user	Previous shared user	New shared user	Shared e-scooter user	Total
Cycling experience	Very high	37.7%	39.0%	34.3%	36.0%	37.2%
	High	38.3%	37.2%	36.6%	40.5%	38.8%
	Moderate	20.2%	20.5%	22.5%	20.7%	20.5%
	Beginner	1.4%	2.7%	4.2%	2.1%	1.9%
	No experience	2.4%	0.6%	2.3%	0.7%	1.6%
Effect of shared e-scooter introduction in Helsinki on your personal everyday mobility	Completely beneficial	0.1%	1.3%	14.5%	29.0%	11.0%
	Beneficial	0.4%	2.7%	29.9%	**41.6%**	16.4%
	No change	33.8%	**36.7%**	**43.5%**	23.9%	31.1%
	Damaging	**37.6%**	35.6%	10.3%	4.0%	24.4%
	Completely damaging	28.1%	23.7%	1.9%	1.5%	17.1%
Effect of shared e-scooter introduction in Helsinki on society and people's everyday traveling	Completely beneficial	0.13%	1.44%	11.48%	16.73%	6.60%
	Beneficial	8.20%	9.58%	**40.67%**	**47.71%**	23.60%
	No change	9.26%	7.35%	20.57%	14.82%	11.45%
	Damaging	**55.14%**	**52.88%**	23.92%	18.01%	40.51%
	Completely damaging	27.27%	28.75%	3.35%	2.72%	17.84%

Out of 5,059 respondents who were not delivery workers, 443 of them have private e-scooter or are planning to buy one (8.8%). Based on Table 26, 51.0% of that sample are people willing to purchase a private e-scooter in future.

Table 26: Private e-scooter users' frequency and future users

Usage frequency	Quantity	Percent (%)
Future users-private	226	51.0%
Curious user-private	37	8.4%
Occasional user-private	56	12.6%
Frequent user-private	57	12.9%
Weekend user-private	12	2.7%
Power user-private	35	7.9%
Private user-unknown	20	4.5%

Because of the importance of possible new private e-scooter users, this user group is going to be analysed separately. Table 27 shows the shared e-scooter usage frequency of potential future private e-scooter usage.

Table 27: Potential future private e-scooter users' frequency

Usage frequency	Quantity	Percent (%)	Description
Previous shared user	8	3.5%	Have used shared e-scooter in 2021 and before and decided to buy a private e-scooter.
New shared user	20	8.8%	Used shared e-scooter in 2022 and decided to buy a private e-scooter.
Non-user	21	9.3%	Never used shared e-scooter before but decided to buy a private e-scooter.
One time user-shared	5	2.2%	Tried shared e-scooter in 2022 only once and decided to buy a private e-scooter.
Curious user-shared	17	7.5%	Used shared e-scooter couple of times in 2022 and decided to buy a private e-scooter.
Occasional user-shared	59	26.1%	Used shared e-scooter 3-5 times per month in 2022 and decided to buy a private e-scooter.
Frequent user-shared	54	23.9%	Used shared e-scooter 3-5 times per week in 2022 and decided to buy a private e-scooter.
Weekend user-shared	19	8.4%	Used shared e-scooter on weekends in 2022 and decided to buy a private e-scooter.
Power user-shared	23	10.2%	Used shared e-scooter daily in 2022 and decided to buy a private e-scooter.

Based on Table 28, about 50% of future private e-scooter users are the ones who are using shared e-scooter occasionally during year or frequently during month. About 5.3% of respondents use shared or private e-scooters for delivery work (e.g., Foodora, Wolt, etc.) and the percentage of them have been separately presented in Table 28.

Table 28: Delivery workers with shared and private e-scooters

Delivery workers	Quantity	Percent (%)
Delivery worker-private	145	51.2%
Delivery worker-shared	138	48.8%

Table 29 shows a sorted set of reasons for stopping or not using shared e-scooters, where top three reasons are satisfactory level of existing transport modes, lack of necessity, and lack of perceived safety.

Table 29: Reasons for stopping or not using shared e-scooters

Non-user types / Reasons for not using/stopping	Absolute non-user [1]	Previous shared user [1]
I am satisfied with my current way of transport	80%	43.6%
It was not absolutely necessary	61%	52.2%
Not feeling safe using it	40%	50.9%
Other	20%	16.2%
More expensive than other transport alternatives	17%	28.3%
A previous bad experience	-	16.8%
Not knowing how to ride e-scooter	14%	-
Complex rules for riding (forbidden zones, low speed, no parking zones)	-	6.3%
Lacking bike lanes, high curbs, unsuitable road surfaces, etc.	13%	16.8%
Because of my physical conditions	-	4.9%
Needing to travel with children	9%	4.2%
Unavailability of e-scooters at the origin or destination	2%	2.7%
Issues with the app or not having a bank account	1%	3.3%
Bought or planning to buy a private e-scooter	0%	1.7%
Total number of respondents in each group	2,396	635

[1] Sum of the columns is not 100% because of multiple choices that could be selected by the respondents. Therefore, percent of respondents who have selected a choice have been presented in the table.

Table 30 shows reasons for using shared e-scooters, categorized based on usage frequency, confirming previous findings that most of the reasoning comes either from a) positive activation during riding experience or from b) e-scooters providing a service that fits within constraints of daily activity spaces that could not be fulfilled by other alternatives. Similar distribution can be observed in the ranking of reasons for using private e-scooters, from Table 31. In both of these tables, it is important to highlight several user categories with different usage frequencies that have more than 10% of answers stating the reason for usage being able to drink alcohol.

Table 30: Reasons for using shared e-scooters based on usage frequency

Shared e-scooter user types / Reasons for using	One time user-shared	Curious user-shared	Occasional user-shared	Frequent user-shared	Weekend user-shared	Power user-shared
Having fun while riding e-scooter	39.4%	46.0%	59.4%	62.1%	71.6%	67.2%
Faster than other alternatives (public transport, walking, etc.)	33.5%	64.7%	66.6%	71.9%	47.7%	63.9%
Being in a hurry (e.g., catching the train, appointment, etc.)	37.1%	48.9%	59.4%	65.3%	39.8%	60.7%
Not getting sweaty or exposed to the weather	12.9%	18.1%	25.5%	27.2%	22.7%	36.6%
Being able to reach new locations	3.5%	9.8%	16.9%	21.8%	28.4%	33.3%
To be environmentally sustainable	2.9%	9.6%	17.2%	26.8%	20.5%	33.3%
To save money	7.6%	7.1%	15.0%	18.8%	19.3%	30.6%
Trying to be physically active and engaged	2.9%	2.9%	7.6%	6.3%	11.4%	12.0%
Being able to drink alcohol and avoid driving	2.4%	6.9%	6.3%	4.8%	10.2%	7.7%
Other reasons	7.1%	4.7%	3.8%	2.5%	1.1%	7.1%
Total number of respondents in each group	170	448	635	441	88	183

Table 31: Reasons for using private e-scooters based on usage frequency

Private e-scooter user types / Reasons for using	Curious user-private	Occasional user-private	Frequent user-private	Weekend user-private	Power user-private	Future users-private	Private user-unknown
Having fun while riding e-scooter	45.2%	44.7%	53.3%	63.2%	45.2%	61.1%	13.3%
Faster than other alternatives (public transport, walking, etc.)	35.5%	41.2%	48.6%	42.1%	64.3%	46.2%	13.3%
Being in a hurry (e.g., catching the train, appointment, etc.)	30.6%	24.7%	29.5%	26.3%	50.0%	37.7%	3.3%
Not getting sweaty or exposed to the weather	17.7%	23.5%	21.9%	21.1%	35.7%	19.1%	3.3%
To be environmentally sustainable	11.3%	31.8%	27.6%	21.1%	19.0%	23.1%	6.7%
To save money	8.1%	18.8%	20.0%	36.8%	26.2%	21.9%	10.0%
Being able to reach new locations	8.1%	17.6%	24.8%	42.1%	28.6%	25.5%	6.7%
Other reasons	6.5%	3.5%	1.0%	0.0%	2.4%	2.1%	10.0%
Being able to drink alcohol and avoid driving	4.8%	12.9%	7.6%	0.0%	16.7%	7.0%	0.0%
Trying to be physically active and engaged	3.2%	24.7%	11.4%	26.3%	7.1%	14.0%	3.3%
Total number of respondents in each group	62	85	105	19	42	329	30

Table 32 shows ranked reasons for using e-scooters by delivery workers, where reasons are not delivery work. Besides similar affective and utilitarian reasoning as with general user population, delivery workers are also frequently mentioning saving money as the usage reason.

Table 32: Reasons for using e-scooters for reasons other than delivery by delivery workers

Reasons for using \ Delivery worker types	Delivery worker, shared	Delivery worker, private
Having fun while riding e-scooter	47.8%	57.9%
To save money	47.1%	39.3%
Being in a hurry (e.g., catching the train, appointment, etc.)	36.2%	21.4%
Faster than other alternatives (public transport, walking, etc.)	26.8%	36.6%
Being able to reach new locations	23.2%	37.2%
Not getting sweaty or exposed to the weather	21.0%	46.2%
To be environmentally sustainable	18.8%	36.6%
Trying to be physically active and engaged	15.9%	23.4%
Being able to drink alcohol and avoid driving	5.1%	16.6%
Other reasons	0.0%	0.7%
Total Number of respondents in each category	138	145

Table 33 shows trip purpose for shared e-scooters usage, while Table 34 shows trip purpose distribution for private e-scooter usage. Similar to previous research in European cities, e-scooters are most often used for leisure and social activities.

Table 33: Trip purpose for shared e-scooter users

	One time user-shared	Curious user-shared	Occasional user-shared	Frequent user-shared	Weekend user-shared	Power user-shared	Previous shared user
Commute (usually between home and work)	18.1%	25.3%	40.4%	55.7%	31.8%	69.4%	15.5%
Business trip (work-related business trip, work lunch trip)	6.9%	13.3%	18.6%	21.6%	10.2%	31.7%	7.4%
School/study	5.6%	6.3%	16.7%	21.4%	27.3%	29.5%	2.9%
Shopping trip (groceries and running errands)	13.1%	15.4%	25.1%	32.7%	28.4%	44.8%	6.4%
Personal trip (doctor, bank, lunch)	15.6%	26.9%	29.8%	41.8%	23.9%	49.7%	8.9%
Socializing (e.g., spending time with friends)	27.5%	46.6%	55.5%	58.9%	53.4%	61.2%	30.7%
Leisure activities (exercise, hobby, culture, visits)	51.9%	62.2%	65.3%	65.9%	64.8%	68.3%	50.1%
Other purposes	9.4%	6.6%	4.3%	4.1%	4.5%	6.0%	14.8%
Sum	160	442	634	440	88	183	515

Table 34: Trip purpose for private e-scooter users

	Curious user-private	Occasional user-private	Frequent user-private	Weekend user-private	Power user-private	Future users-private	Private user-unknown
Commute (usually between home and work)	30.0%	43.8%	60.0%	36.4%	78.1%	44.1%	20.0%
Business trip (work-related business trip, work lunch trip)	20.0%	18.8%	20.0%	9.1%	37.5%	23.5%	0.0%
School/study	10.0%	22.9%	20.0%	0.0%	9.4%	29.4%	0.0%
Shopping trip (groceries and running errands)	33.3%	43.8%	44.0%	36.4%	62.5%	31.9%	20.0%
Personal trip (doctor, bank, lunch)	26.7%	41.7%	38.0%	54.5%	59.4%	38.2%	20.0%
Socializing (e.g., spending time with friends)	33.3%	52.1%	44.0%	45.5%	62.5%	57.4%	0.0%
Leisure activities (exercise, hobby, culture, visits)	56.7%	68.8%	56.0%	63.6%	75.0%	63.7%	60.0%
Other purposes	10.0%	6.3%	6.0%	0.0%	6.3%	5.4%	40.0%
Sum	30	48	50	11	32	204	5

Figure 57 and Figure 58 depict the distribution of percentages for trip purpose, for shared and private e-scooter usage, respectively. In comparison to general trend of high usage for leisure or social activities, with frequent and power-users, one can see a clear increase of usage for commuting between home and work for power and private users.

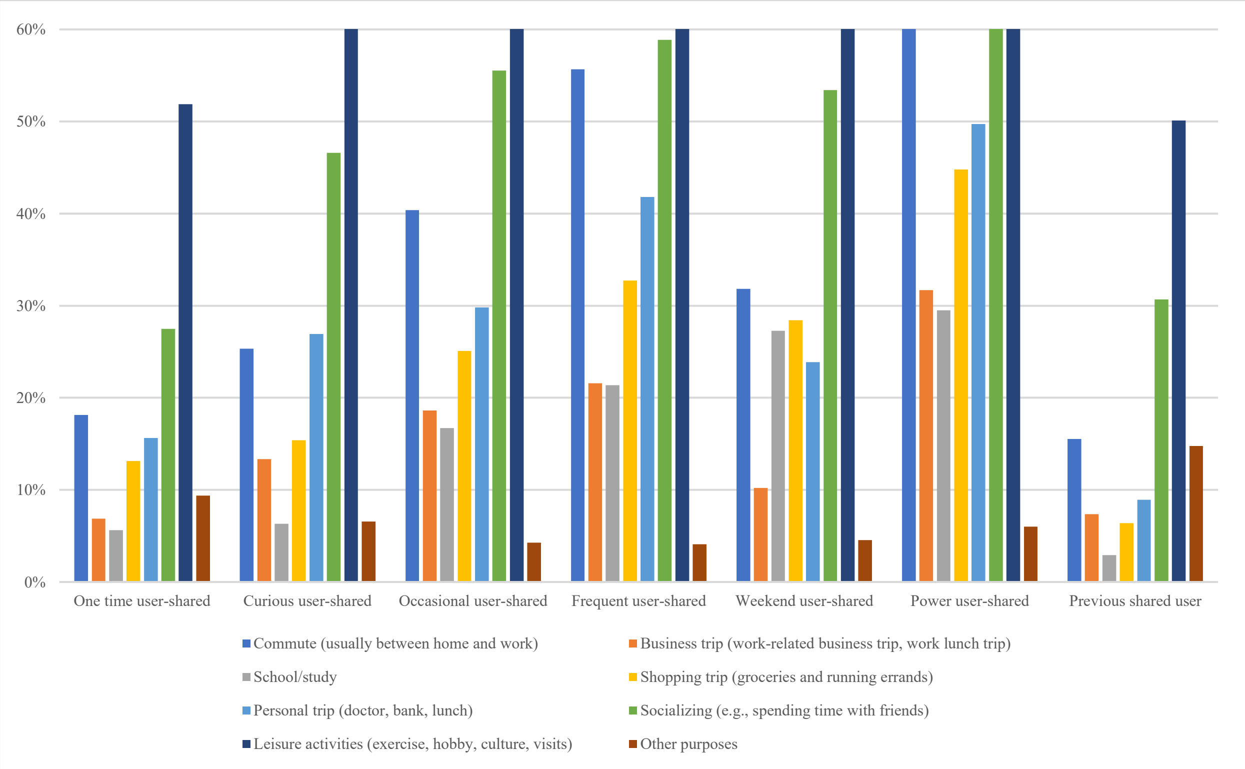


Figure 57: Trip purpose for shared e-scooter users

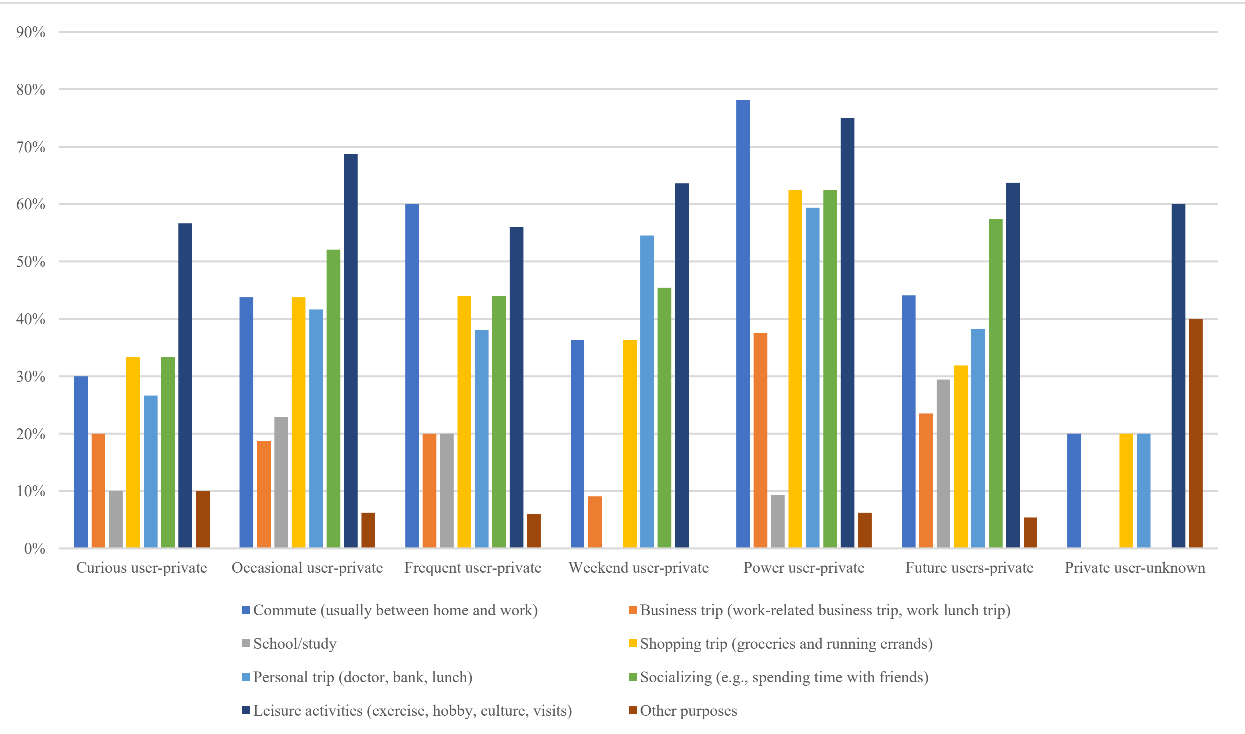


Figure 58: Trip purpose for private e-scooter users

The following Table 35 shows mode changes that have happened because of using e-scooters for non-delivery e-scooter users. Based on the details in the column "Less", one can conclude that shared e-scooter users are mostly using e-scooters to substitute bus or tram riding (41.0%), taxi or Uber riding (31.9%) and walking (31.4%). On the other hand, private e-scooter users are also using e-scooters to substitute bus or tram riding (55.7%), taxi or Uber riding (51.2%), but private car driving (42.2%) as the third option.

Table 35: Mode substitution of shared and private e-scooter users

E-scooter owner	Mode substitution	Less	Same	More	I do not have this option	I do not know
Shared e-scooter users	Walking	31.4%	53.1%	7.6%	1.3%	6.5%
	Cycling	21.4%	46.7%	5.6%	18.2%	8.2%
	Metro/train riding	24.7%	55.6%	5.0%	6.9%	7.2%
	Bus/tram riding	41.0%	45.2%	3.8%	2.7%	6.6%
	Private car driving	21.5%	29.6%	2.8%	40.7%	4.8%
	Taxi/Uber riding	31.9%	25.4%	1.9%	32.8%	7.3%
Private e-scooter users	Walking	40.3%	44.0%	10.3%	3.4%	2.1%
	Cycling	34.5%	36.6%	3.7%	19.4%	5.8%
	Metro/train riding	39.0%	44.8%	6.9%	6.9%	2.9%
	Bus/tram riding	55.7%	35.5%	2.7%	3.4%	2.1%
	Private car driving	42.2%	21.8%	2.9%	31.6%	1.6%
	Taxi/Uber riding	51.2%	16.2%	2.7%	27.1%	3.2%

Figure 59 compares the mode substitution (column "Less" in Table 35) for shared and private e-scooter users. Based on this figure, private e-scooter users are more willing to substitute each mode by e-scooters compared to shared e-scooter users, as potentially private scooter becomes the central mode of everyday traveling.

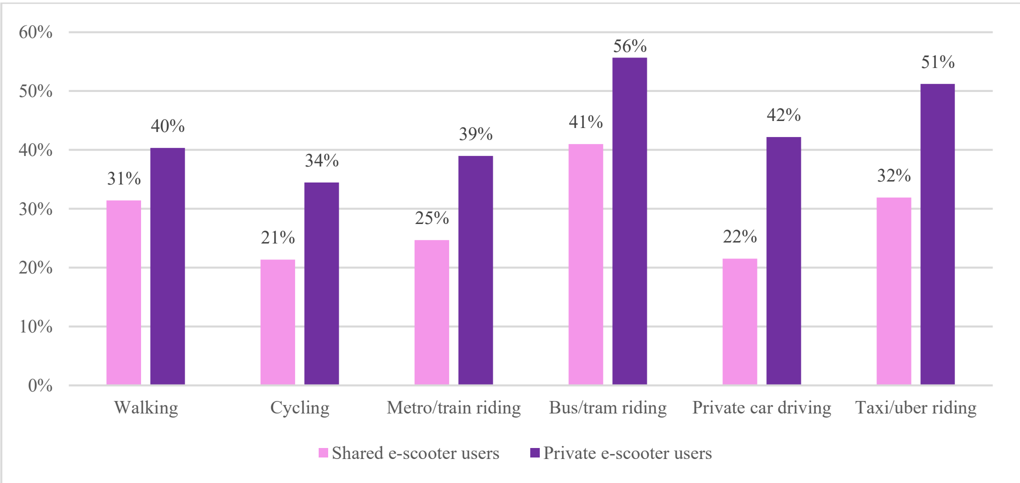


Figure 59: Mode substitution analysis separated by shared and private e-scooter users

Figure 60 shows the distribution of mode substitution based on gender, where male users are more likely to replace all modes in comparison to female users.

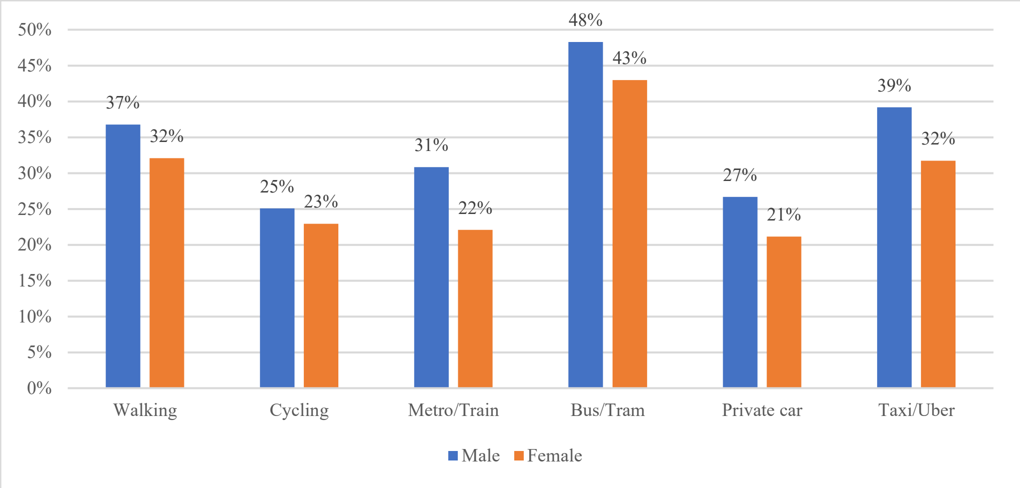


Figure 60: Mode substitution analysis for shared e-scooter users categorized by gender

If the respondent had chosen “I do not have this option”, it means that person cannot use that particular mode. In Figure 61, this option has been analysed by gender for shared e-scooter users. Based on this figure, female users have less access to private car or taxi/Uber for their transport compared to male users.

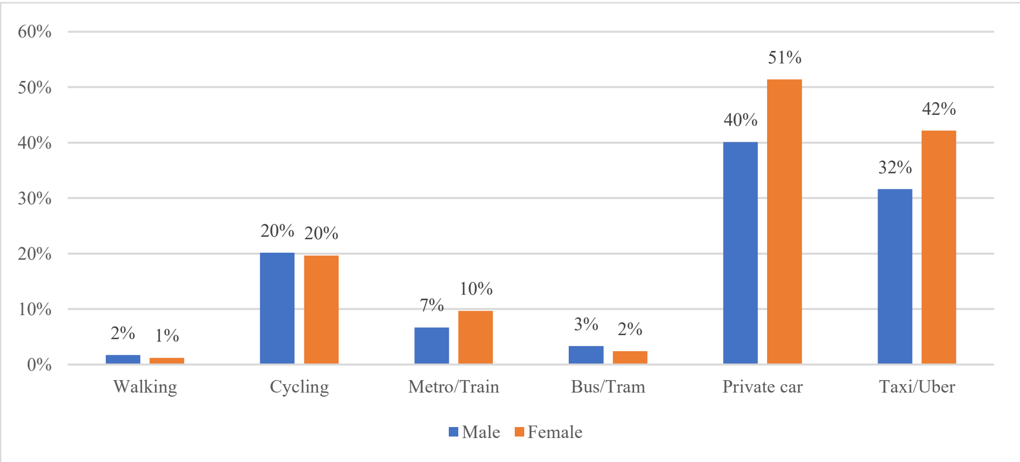


Figure 61: Analysis of not having an access an option for shared e-scooter users categorized by gender

Figure 62 shows the mode substitution analysis for shared e-scooter users categorized by age. Based on this figure, users over 64 years old are mostly substituting a walking trip with a shared e-scooter trip. On the other hand, users younger than 18 years old are mostly substituting bus or tram trips, and are less likely substituting a walking trip with a shared e-scooter trip comparing to the other age groups.

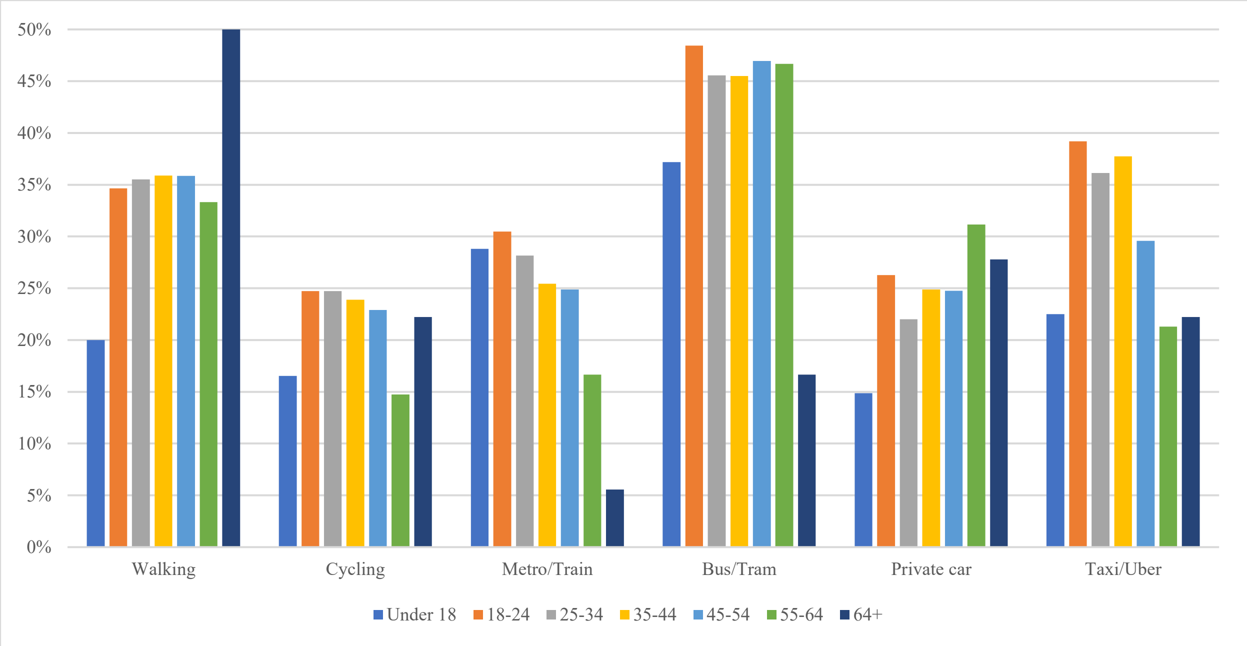


Figure 62: Mode substitution analysis for shared e-scooter users categorized by age

About 41.2% of the shared e-scooter users in Helsinki have done multi-riding at least once (1187 out of 2883). In Figure 63, the percentage of multi-riders based on frequency have been plotted in relation to gender. Based on this figure, females are more eager to try multi-riding while males are more willing to multi-riding in higher frequencies.

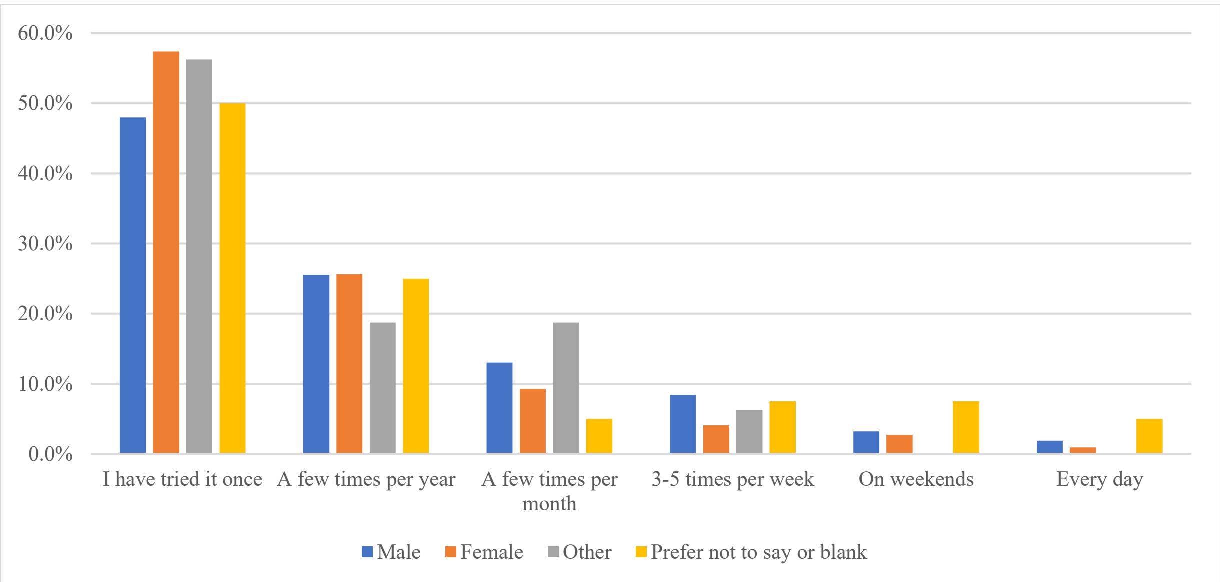


Figure 63: Multi-riding in relation to gender

Figure 64 shows the multi-riders in relation to gender and age. Based on this figure, males are relatively more willing to do multi-riding compared to females, in all age groups under 65 years.

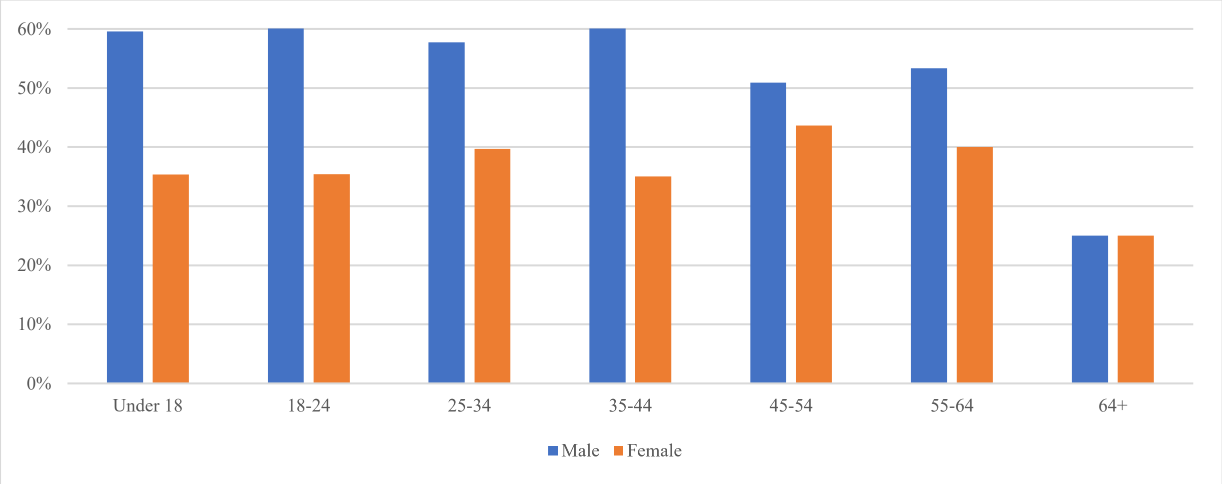


Figure 64: Multi-riding in relation to gender and age

Figure 65 shows the multi-riding reasons based on age groups. The most selected reason to do multi-riding for under 18 years old is not having an e-scooter app on the phone because it is illegal to ride e-scooters in this age. For other age groups, other frequent reasons include not enough e-scooters at the trip origin, trying to save money, or trying out of curiosity.

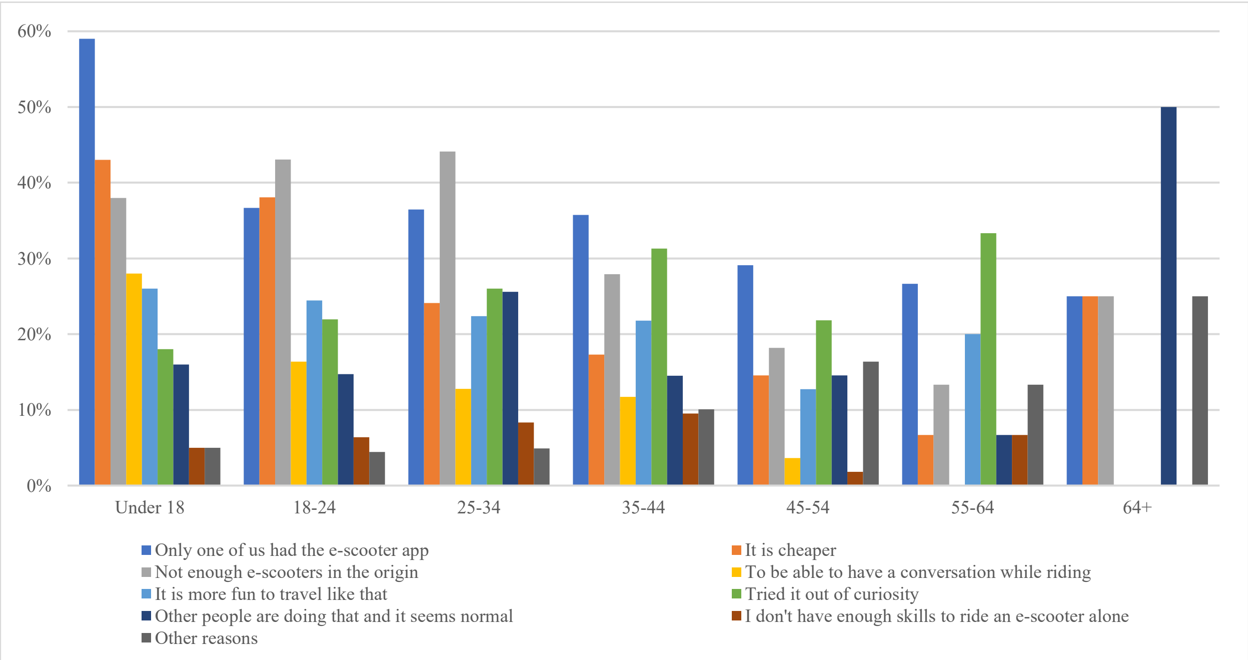


Figure 65: Multi-riding reasons based on age groups

The reasons for multi-riding based on gender are depicted in Figure 66. Based on this figure, males are more prone to do multi-riding because they notice this kind of behaviour more often in their everyday life. On the other hand, females are more often mentioning curiosity for trying multi-riding than males. Furthermore, the proportion of females who feel incompetent to ride e-scooter alone and prefer multi-riding is twice the same category in males. Males and females almost equally did multi-riding because of insufficient e-scooters in the origin and cheaper option compared to separate rides.

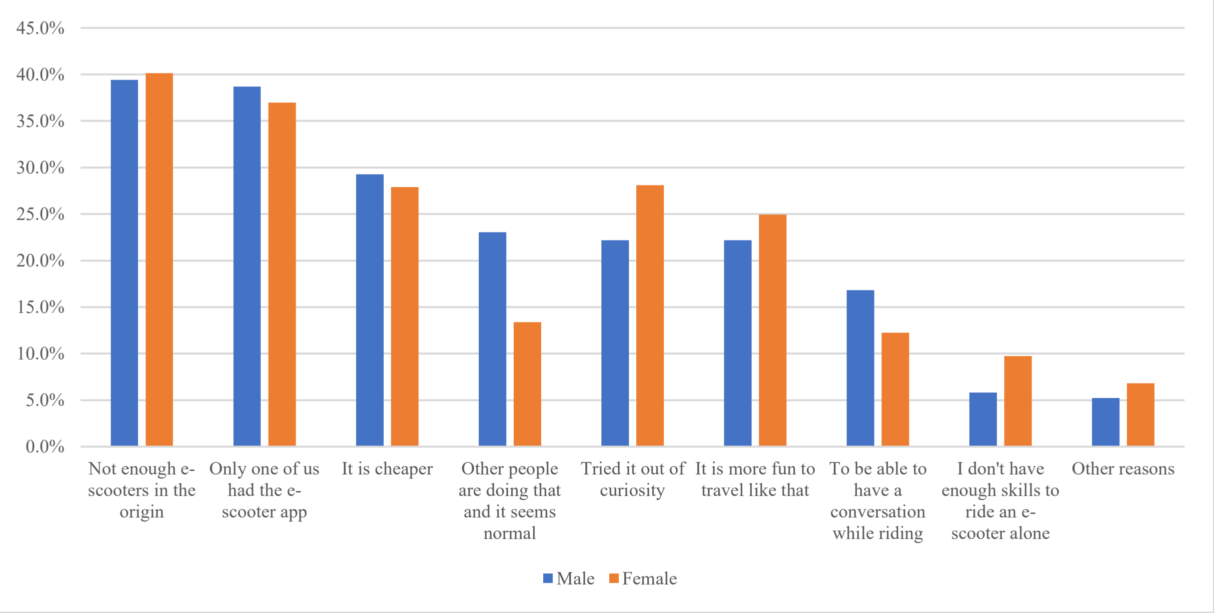


Figure 66: Multi-riding reasons for shared e-scooter users

The reasons for user group who had done multi-riding more than twice per week are plotted on Figure 67, based on gender. Based on this figure, frequent male multi-riders are doing that because of its normality in the society and insufficient e-scooters in the origin. In contrast, frequent female multi-riders find it more fun and like to do multi-riding because of their curiosity, confirming the findings above.

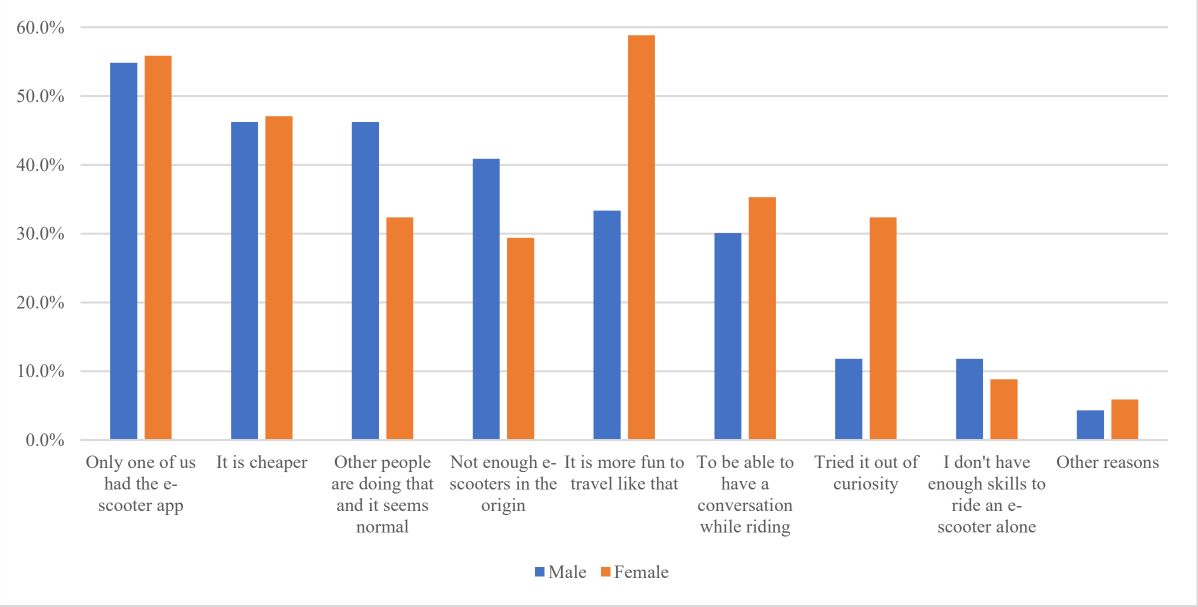


Figure 67: Reasons for multi-riding based on gender for frequent users

About 35% of shared e-scooter riders have tried flock riding at least once (998 out of 2883). In Figure 68, the percentage of flock riders based on frequency have been plotted in relation to gender. Based on this figure, just like multi riding females are more likely to try flock riding once. Interestingly, there is a high percentage of respondents who preferred to not say their gender and this group is the one that does flock riding frequently on daily basis.

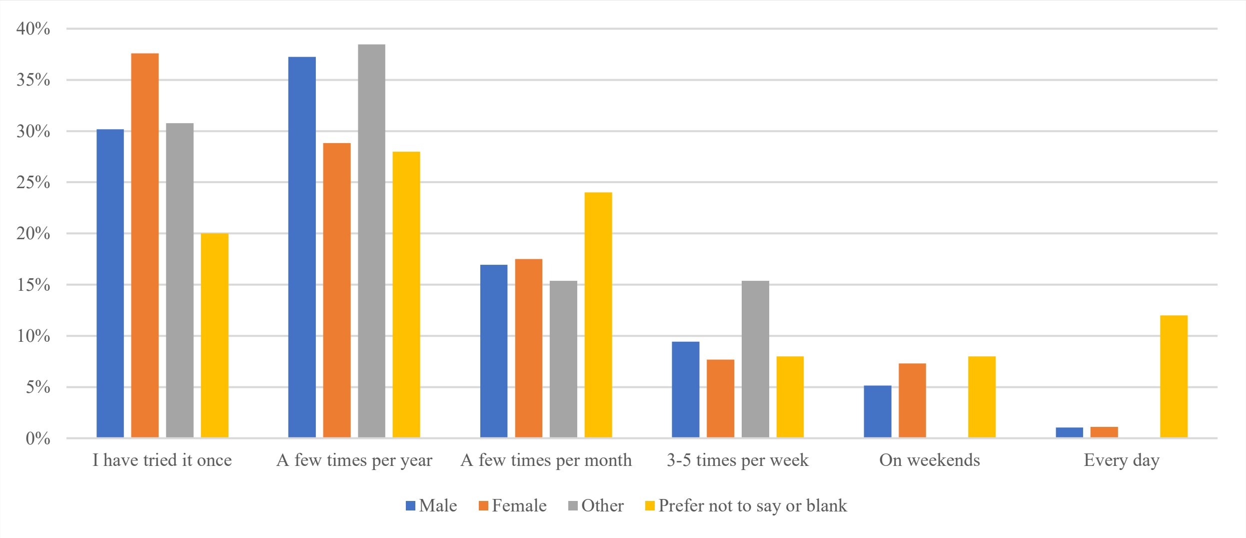


Figure 68: Flock riding in relation to gender

Figure 69 shows the flock riders in relation to gender and age. Based on this figure, males are always more willing to do flock riding compared to females in every age group and the difference is more obvious from under 18 to 55 years old.

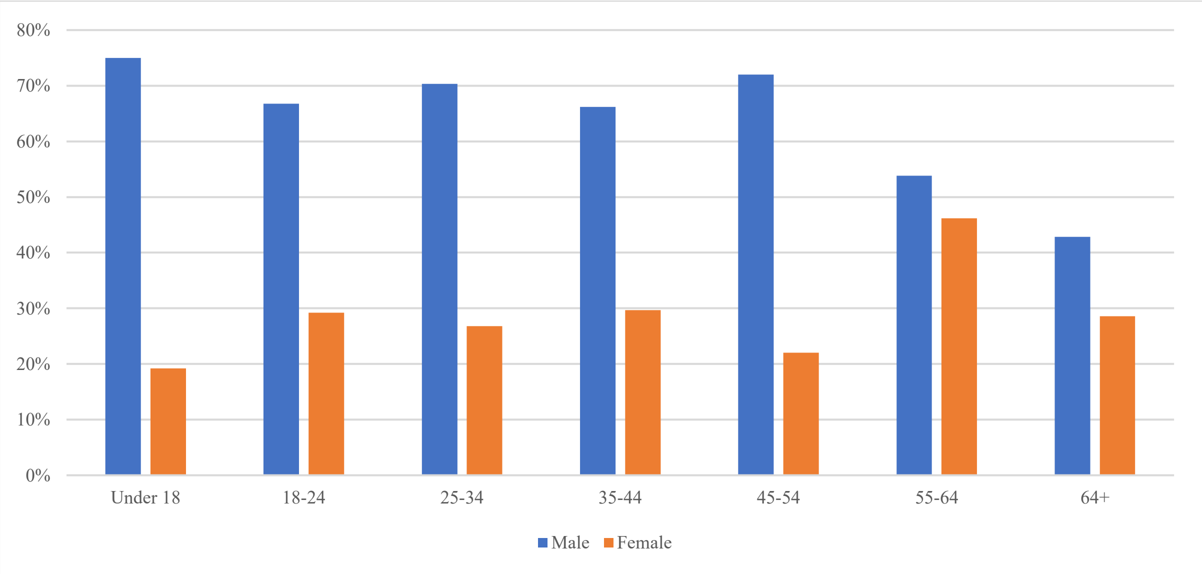


Figure 69: Flock riding in relation to gender and age

Table 36 shows the reasons of flock riding in shared e-scooter users. According to this table, 42% of the respondents have selected “feeling freer compared to taking public transport” as a reason for flock riding. They might see flock riding as a mobile public space like a bus but with more freedom and fun while riding.

Table 36: Reasons of flock riding in shared e-scooter users

Reasons	Percentage
Feeling freer compared to taking public transport	42%
It is more fun to travel like that	39%
It feels safer compared to two riders on the same e-scooter	35%
To be able to have a conversation while riding	20%
Not being left out from the group of friends	20%
I did not know the route to the destination	19%
Other reasons	10%

Figure 70 shows the flock riding reasons based on age groups. The most selected reason to do multi-riding for under 18 years old is for having more fun. However, the higher age groups mostly merit the practical reasons for flock riding.

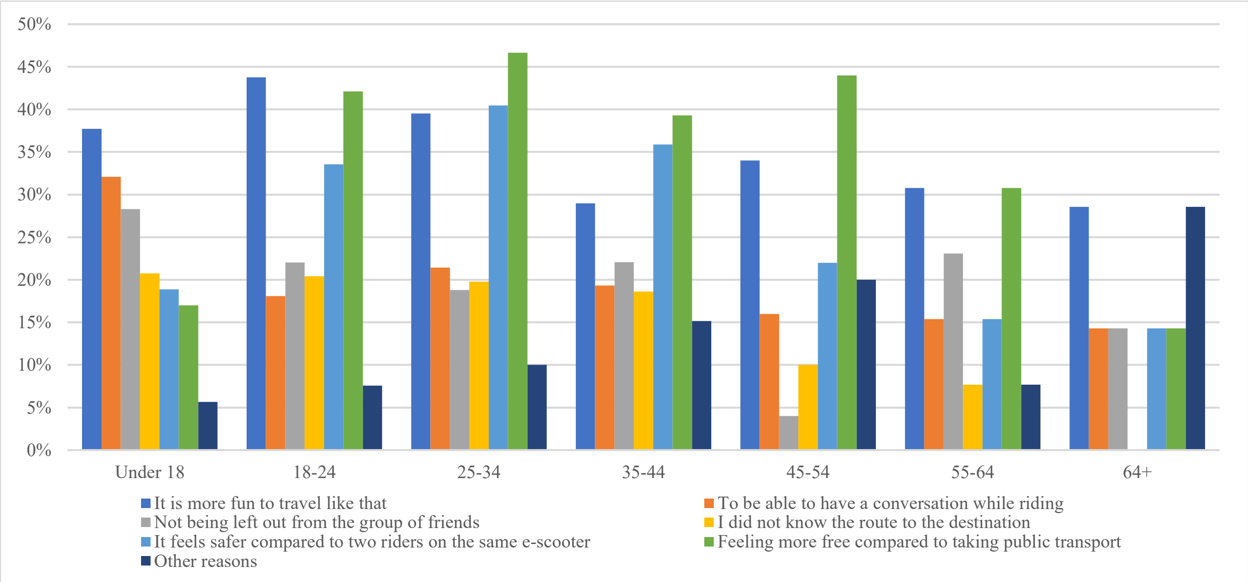


Figure 70: Flock riding reasons based on age groups

The reasons for flock riding based on gender has been depicted in Figure 71. Males and females almost equally did flock riding. Therefore, gender is not a relevant factor for flock riding reasons.

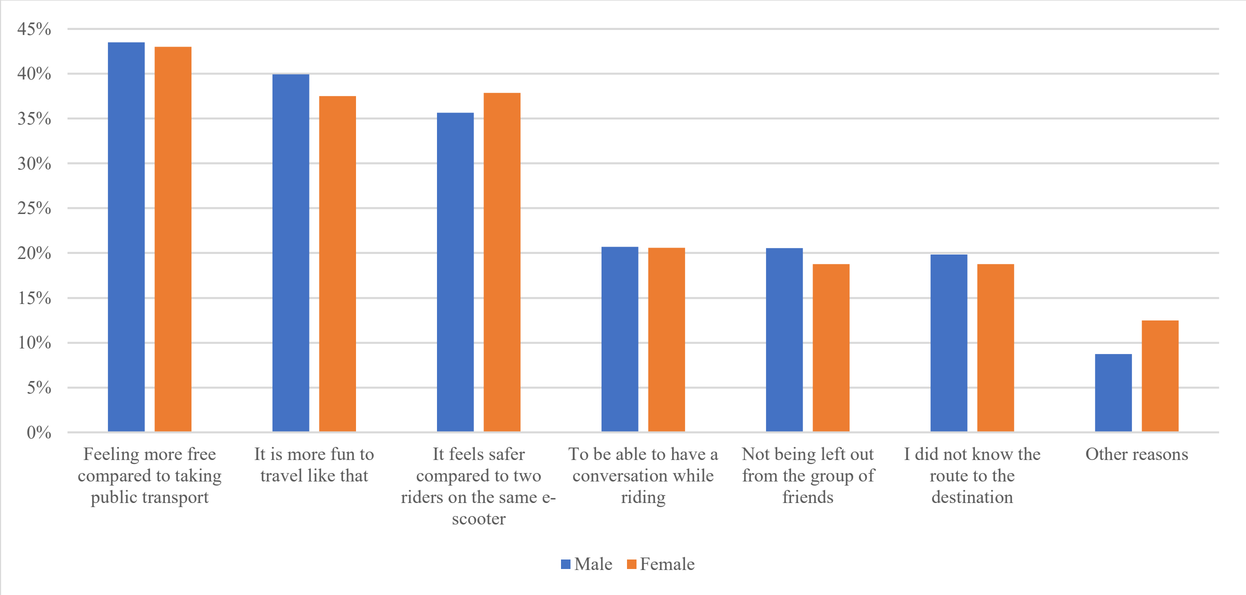


Figure 71: Flock riding reasons for shared e-scooter users

Two following two figures depict distribution of answers for suggested improvements, one on a more general level grouping all users and non-users, and the second one with further classification based on usage frequency. Based on these, non-users mostly suggest in rules and regulation, while e-scooter users are more looking for street infrastructure and parking improvement to help them to use e-scooter easier and safer in the city. The "other improvement" which is also highly selected by the users refers mostly written comments, which include:

- Increase operating area
- Various pricing schemes with lower fees
- Limit fleet size
- Monitor sidewalk and teenager e-scooter riding
- Alcohol limit
- Folding helmets

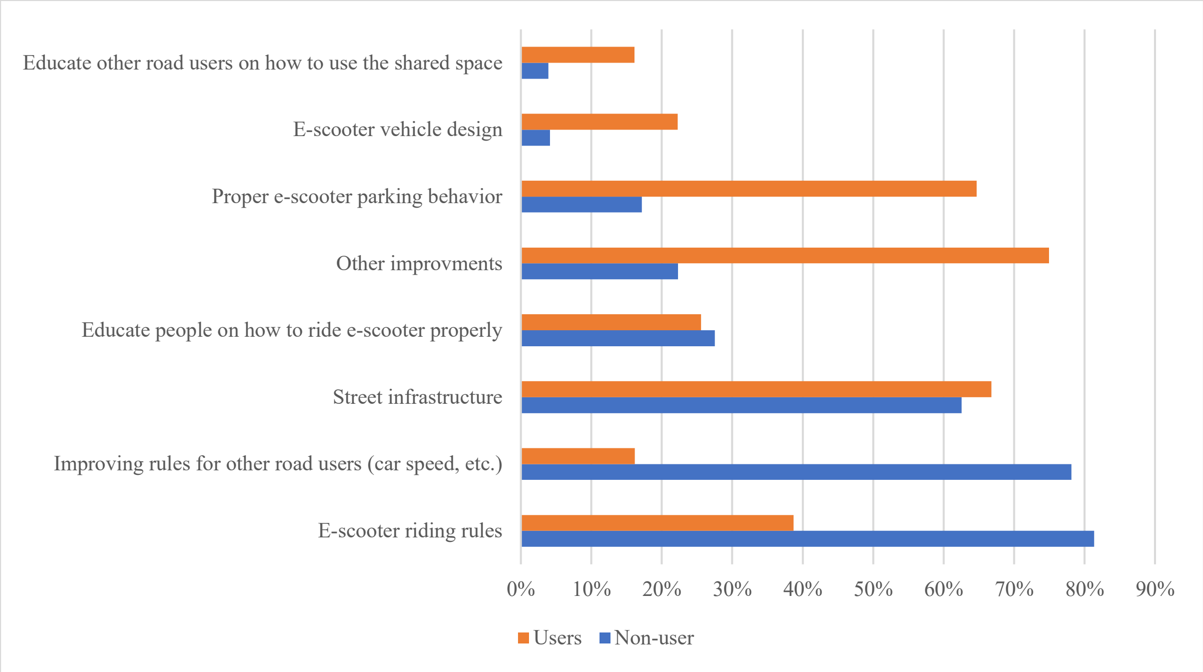


Figure 72: Suggested improvements regarding e-scooters from users' and non-users' perspective

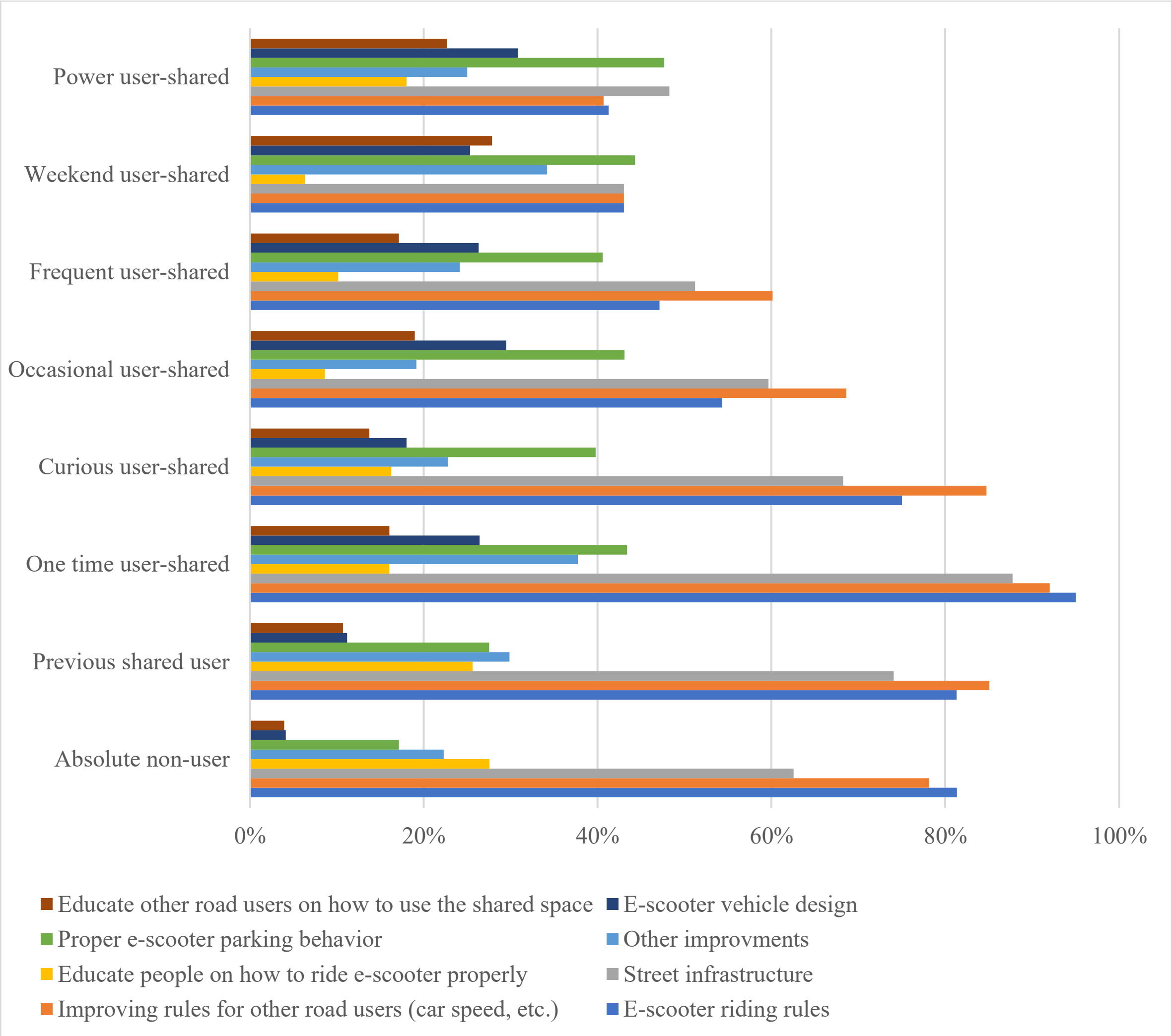


Figure 73: Suggested improvements regarding e-scooters based on usage frequency

3.4 Implications and directions for developing responsible and adaptive governance processes

Coding and classification of site visit qualitative data indicates a plethora of issues in the current streetscape infrastructure in Helsinki. Each one of these issues is not significant by itself, but their cumulative effect is. Thus, simply put, Helsinki has a large number of small problems – despite the significant efforts in recent years to improve existing and build new cycling infrastructure. As has also been indicated by city's own Cycling Barometer studies, streetscape conditions in the city centre are less satisfactory than in the suburbs, especially because many of the streets in the city centre have been designed and constructed decades ago. Classification of issues has led to identifying two main areas of issues in the user experience at the streetscape level. These issues have to be contrasted to the statement in the Helsinki City Strategy 2021-2025, where on part on transport it is stated that "Helsinki is a city that uses urban space efficiently and wisely for the benefit of its residents to meet their varying needs."

Contrasting that statement, one set of issues relates to desire lines, especially when there are multiple modes sharing street space (Hamilton-Baillie, 2008). The usage of desire lines as design heuristic in streetscape design, does not seem to be adequate in many of the observed locations (see examples in Figure 74). As such, these inadequate desire lines as designed or constructed lead to undesired conflict points between different traffic flows and queueing areas, inadequate sight distances and conflict angles, which besides crashes or near-crash situations can be observed as hesitation behaviour, especially by pedestrians. Two, there is a range of challenges with designed and implemented streetscape details (see examples in Figure 75). These challenges span across several elements, from defects in the pavement surface, curb heigh, curb location, sign or street furniture placement, poor drainage alignment, to inadequate lighting. Partly related to lack of standardized elements, and partly related to poor management of construction sites taking into account diverse users, these elements are not just inconvenient, but are also a cause for hazards – especially relating back to the wheel size of e-scooters. However, even beyond e-scooters, these details are hazard for all other streetscape users.

Reasons for this could be found in several historical causes. On the one hand, design practice might not rely on using initial free-hand drafting where desire lines between surrounding land use points are clarified and iterated before proceeding to computer-aided design and space allocation to different streetscape surfaces. Simultaneously, design culture in Finland overly relies on strict looking up and directly implementing pre-determined design elements from design guidelines, which has its legacy in highway design, where it is most adequate. On the contrary, practice of urban design requires more nuanced reflectivity to deal with constraints of urban space and diversity of users and objectives. Moreover, much of the streetscape design does not include reconsideration of parking supply, which is a limiting factor for space re-distribution in the design phase, despite the lacking evidence that current supply of car parking is adequate for managing demand. Besides understanding that streetscape is a place for diverse user experiences, there is a need to also develop a mindset that understands adaptiveness of urban space over time in a year. For example, streetscape design does not have to rely only on large infrastructural actions, but can also rely on adaptive and temporary changes, such as pop up bike lanes and other street changes that are active only some months of the year. Turning the gaze back to educational institutions, another potential reason for the existing mindset is historically lacking education in engineering and architecture, even in top Finnish universities, where urban streetscape design has not been adequately addressed as multidisciplinary design activity. Other reasons, such as lacking know-how on how to construct adequate design details or lacking adequate construction materials, hand in hand with construction market features, could also be there. Finally, an underlying issue in currently-siloed organizational processes have to be assumed, where issues in higher levels of planning propagate to the level of actual user experience, without in-built and timely feedback loops.

Figure 74: Examples of locations with inadequate desire lines in the Helsinki streetscape

Figure 75: Examples of locations with inadequate infrastructural details in the Helsinki streetscape

Changing perspective from streetscape to policy, there is a need for integrating design thinking (Björklund et al., 2020; Kimbell et al., 2022; Monteiro et al., 2022) into governance system for managing the mobility transition. As such, approaching policy as an iterative design problem (Howlett & Mukherjee, 2018) enables the institution to take quick but selective actions within a dynamic environment, but also to develop long-term institutional memory and heuristics for dealing with irreducible deep uncertainty. In addition, developing process and tools (e.g., web-based canvas) for multi-actor deliberation on the policy design enables moving from antagonism towards agonistic approach to transition management. Agonistic approach involves legitimate adversaries co-creating decisions, while not having agreeable views, but still having unquestionable rights to present and defend those views (Mladenović & Haavisto, 2021; Valkenburg, 2020). Finally, approaching policy as design would enable a process that can rely on iterative stages, consequently enabling creativity and understanding different aspects of the whole (see Figure 76).

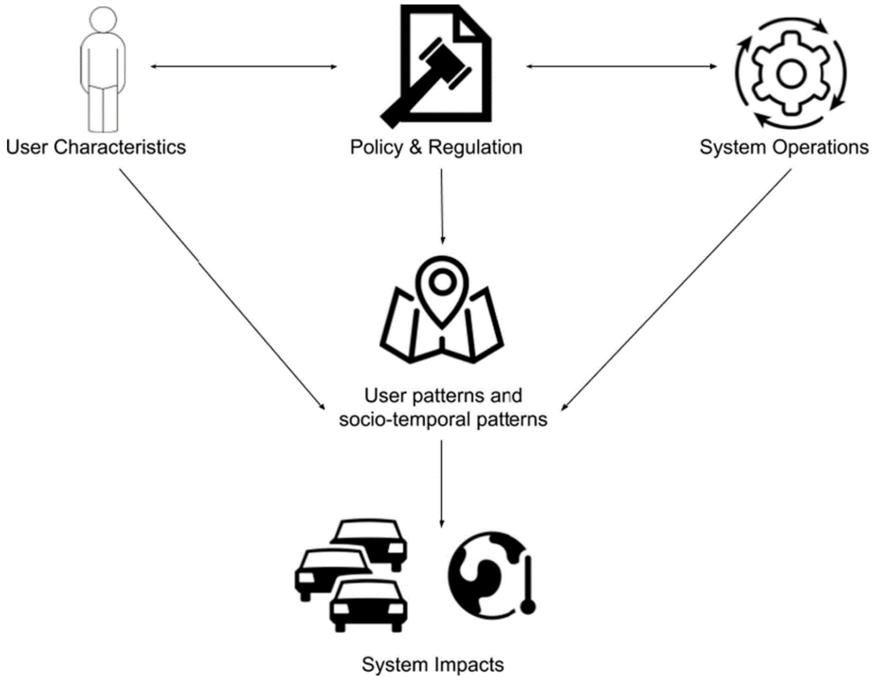


Figure 76: Relationship of micro-mobility policy toolkit pillars (Latinopoulos et al., 2021)

The starting point for good policy design is understanding the concept of policy package. A policy package is a combination of policy measures that addresses one or more goals, and is designed so to improve both effectiveness and implementability as opposed to individual policies (Givoni et al., 2013; Givoni, 2014). An example is depicted on Figure 77, where taking congestion charge as Policy X in the graph shows us that this policy is highly effective in changing behaviour, but is also among the least politically and publicly acceptable, thus having low overall implementability. However, by being integrated with some other complementary policies (in the figure below indicated as Policy Y and Z), in a relatively highly-effective package, the package itself might achieve a higher overall implementability.

Figure 77: A depiction of policy packaging to improve effectiveness and implementability

Extending the above example of three integrated policies, we have to underline that not every bundling of policies should be considered as bespoke design. Just as in any other design, as the spectrum includes also other undesired activities towards non-design itself, such as patching, layering, and stretching (Figure 78). Although some of these might be effective enough, it is only customized policy design that can guarantee optimal outcomes.

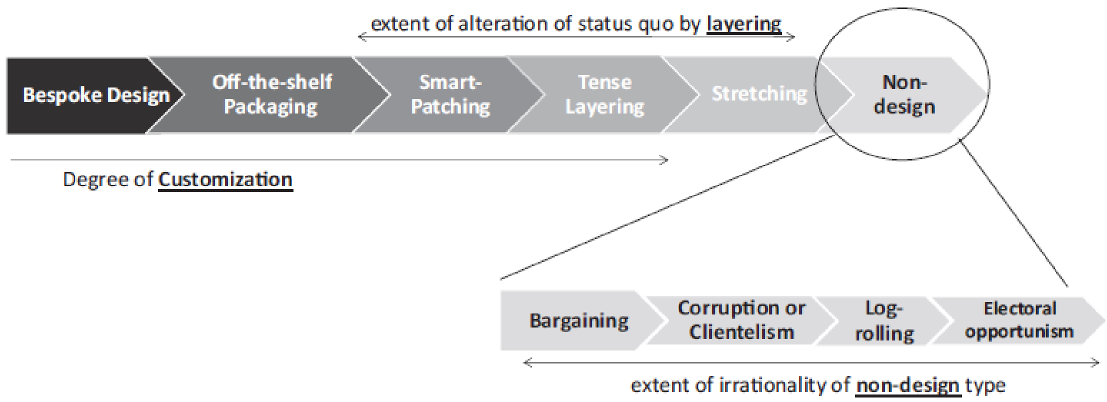


Figure 78: Design and non-design policy processes (Howlett & Mukherjee, 2018)

In the policy design process, one of the central challenges is assessing effectiveness and implementability of each policy action. From the following Figure 79, we can see that effectiveness is mostly about achieving desired change in someone's behaviour in order to achieve societal goals. Positioning a policy on the effectiveness axis, requires from us to understand the relation between policy and intended change, but also other aspects, such as undesired effects. In addition, by its design, various policies can have a degree of variability and directionality, in terms of how adjustable they are for achieving certain goals, but also which actors do they address and to what extent, as sometimes achieving goals requires changes in a chain of actors' behaviours. For example, variability can be explained by the pricing level chosen in a parking pricing scheme, while directionality can be explained by the assumed user for the parking pricing scheme, such as a visitor or a resident. In the same figure, on the Y axis, we have implementability, which is mostly about overcoming various barriers, but also about wider acceptability, which relates to the questions of governance as a process - including such qualifiers as process transparency. This dimension forces us to consider what kind of underlying public acceptance challenges we might face, such as the often most influential one – perceived policy fairness (Bergquist et al., 2022). Figure 80 shows a tentative initial ranking in terms of effectiveness and implementability for the package introduced in 2021, policies targeting directly users, and policies targeting e-scooter operation.

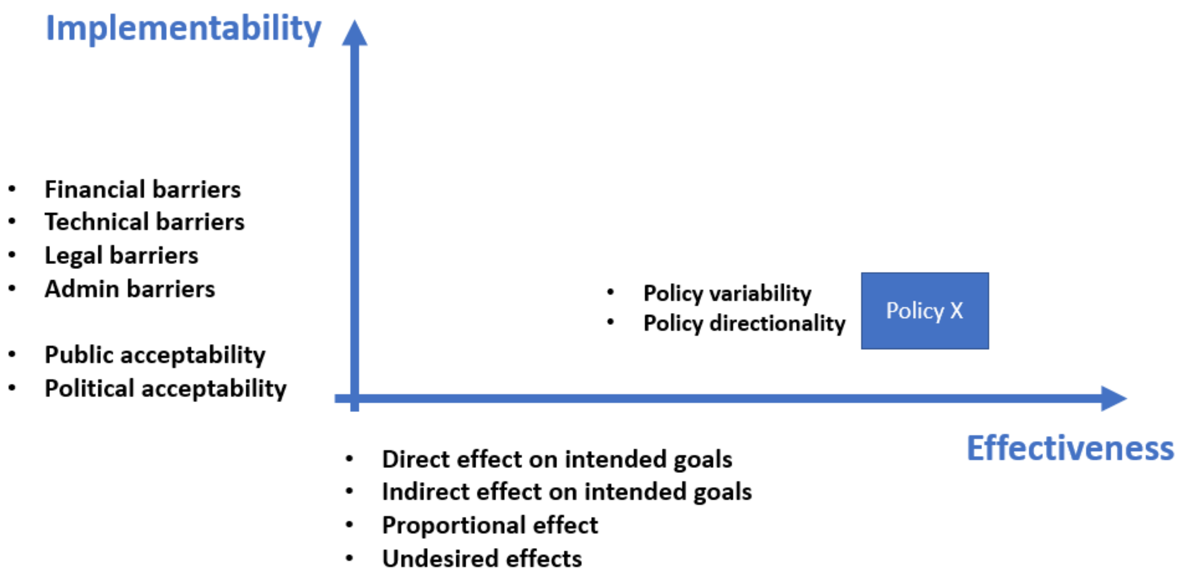


Figure 79: Examples of aspects included in policy effectiveness and implementability

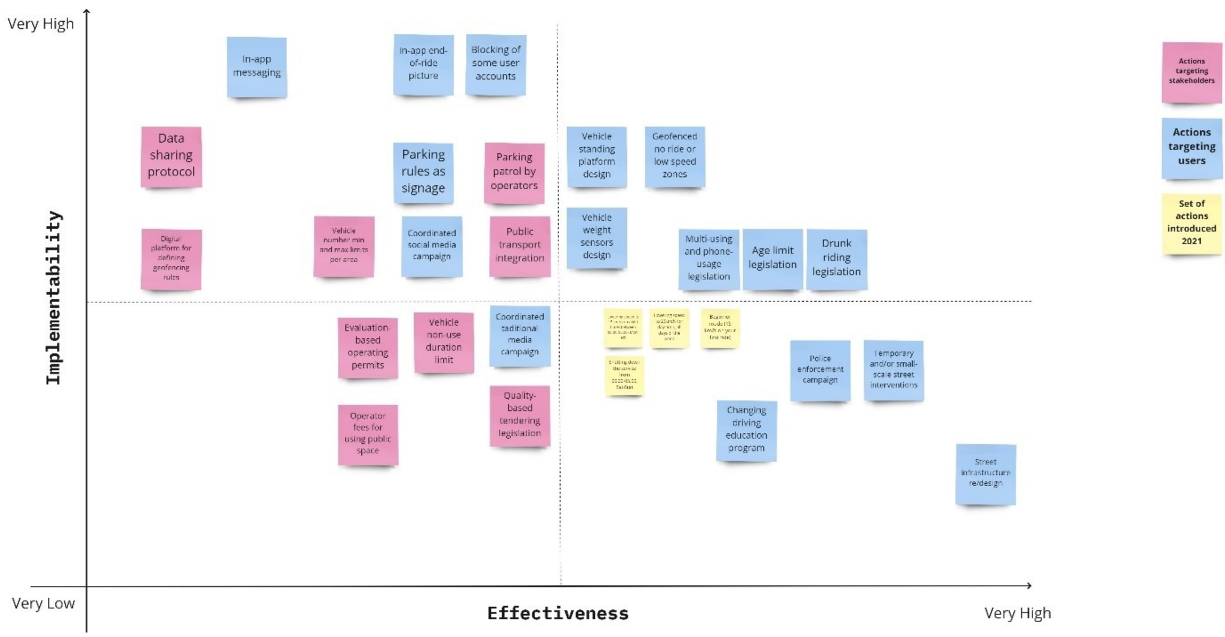


Figure 80: Tentative ranking of policy effectiveness and implementability

The discussion around policy effectiveness ties back to the fundamental questions about human behaviour and its change. For having such discussion, one useful framework is depicted on Figure 81, as the so-called Capability, Opportunity, Motivation – Behaviour (COM-B) Wheel. Here, capabilities refer to a person's physical or psychological ability to perform the behaviour. Opportunities (refer to anything in the physical or social environment that may encourage or discourage a behaviour. Motivations refer to internal reflective and automatic mechanisms that activate or inhibit a behaviour. The key aspect to take into account is that there is a need to understand structural discrepancies among heterogenous groups of people (Dibaj et al., 2021; Chung & Wong, 2012). Moving away from hypothetical transport system user towards a more diverse understanding of different users, practices, and behaviours can help in identifying effective intervention policies (Mladenović et al., 2021b). Moreover, we have to underline that policy effectiveness has temporal evolution as well, since introducing regulation could also shape behaviour over time, where social mechanisms of guilt have a role to play (Brandt et al., 2023).

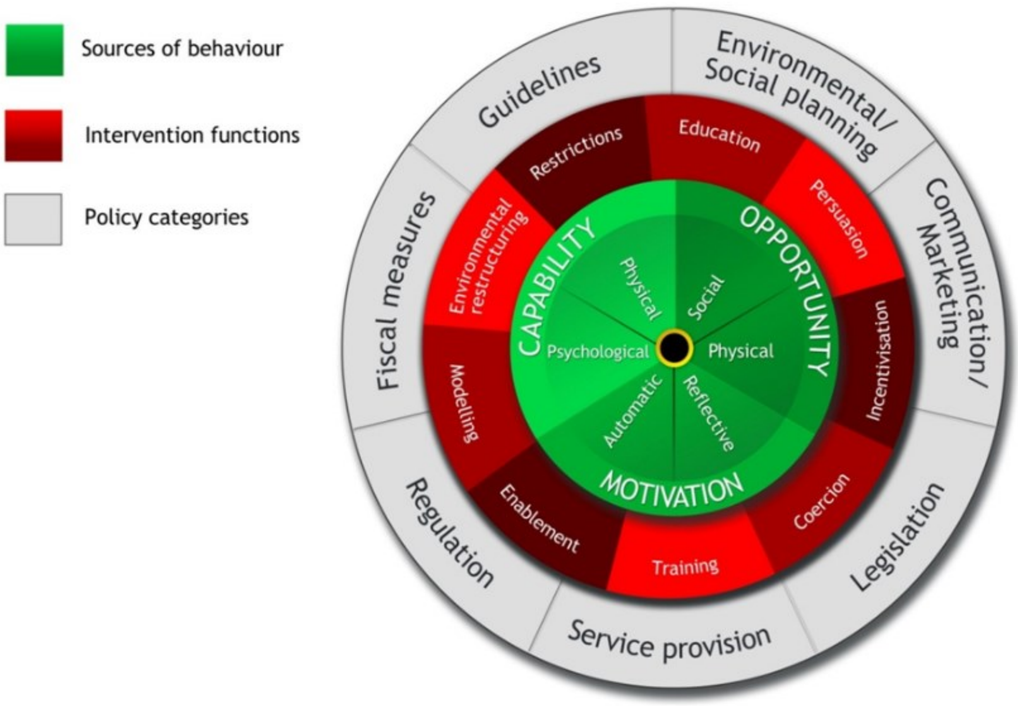


Figure 81: Capability, Opportunity, Motivation – Behaviour Wheel (Michie et al., 2014)

Having these aspects put in place, following the communicative planning logic mentioned above, policy design as a process focuses on agonistic deliberation across diverse actors about the position of each policy in relation to X or Y axis. Here, we recognize that individual policies rarely emerge without the background of existing and other potential new policies. This means that one component of policy design canvas should be a policy inventory. On the one hand, for developing such policy inventory, one can look for inspiration into existing policy taxonomies (Stead, 2021), such as the one depicted in the Figure 82, including both substance and process. In addition, scanning the existing literature on e-scooter related policy worldwide, provides us with potential policies to include in the policy inventory (Asensio et al., 2022; Brown, 2021; Button et al., 2020; Field & Jon, 2021; Gössling, 2020; Hirst, 2021; Janssen et al., 2020; Ma et al., 2021; Mitra & Hess, 2021; Nadkarni, 2020; NASEM, 2022; Oeschger et al., 2020; Riggs et al., 2021; Sareen et al., 2021; Useche, 2022b; Ydersbond et al., 2020). Policies found in the literature as implemented or proposed by cities worldwide include policies directly targeting users and policies targeting shared e-scooter operators, sellers, or manufacturers are listed below. Besides these actions listed below, we also want to underline that further design of e-scooter vehicle (standing platform, rear wheel cover, kick stand, multi-riding sensor, etc.) as well as pricing scheme should also be part of effective set of actions.

- Legislation on intoxicated e-scooter riding;
- Legislation on age limits for using e-scooters;
- Legislation on maximum one rider per e-scooter;
- Legislation on no use of phones while riding;
- No ride or low speed zones, defined with signs and in-service by geofencing;
- Parking requirements and rules on the street level (Figure 83[1]);
- Providing informational materials regarding e-scooter rules and regulations and other coordinated and behavioural campaigns (see Hoekstra & Wegman, 2011; Elvik, 2016);
- Including e-scooter safety education in driver training programs;
- Legislation on maximum speed limits built into e-scooter technology;
- Distribution requirements to ensure a specific number or percentage of fleet be made available in targeted communities;
- Establishing digital micro-mobility platform for defining dynamic geofencing rules for riding and parking;
- Establishing transparent data-sharing protocol between operators and the city;
- Dynamic or performance-based operator caps;
- Operating permits with time limits based on trial and evaluation periods;
- Operator fees for renting public space, per time or per unit;
- Other various dynamic economic incentives for operators;
- Establishing requirements for responding to user feedback/community complaints;
- Allocating funding for infrastructural treatments, especially for shared streetspace interactions
- Relational policies for other modes (e.g., public transport integration, car parking policy, vehicular speed limits in the city centre, etc.);

[1] Source: https://www.bergen.kommune.no/innbyggerhjelpen/vann-vei-og-trafikk/vei-transport-og-parkering/sykkel/elsparkesykler-i-bergen

	Information	*Governing Resource Authority*	*Treasure*	*Organization*
Substance	Advice Training Reporting Education Advertising Surveys	Licenses User charges Regulation Self-regulation Vouchers Quotas	Subsidies Grants Loans Tax expenditures Program funding	Bureaucracies Public enterprises Quangos
Purpose				
Process	Information-suppression Information-release	Advisory group creation Interest group or party bans Denial of access	Interest-group Funding Campaign funding Denial of funding	Administrative re-organization Administrative delay and obfuscation

Figure 82: A taxonomy of substantive and procedural policy instruments (Howlett & Mukherjee, 2018)

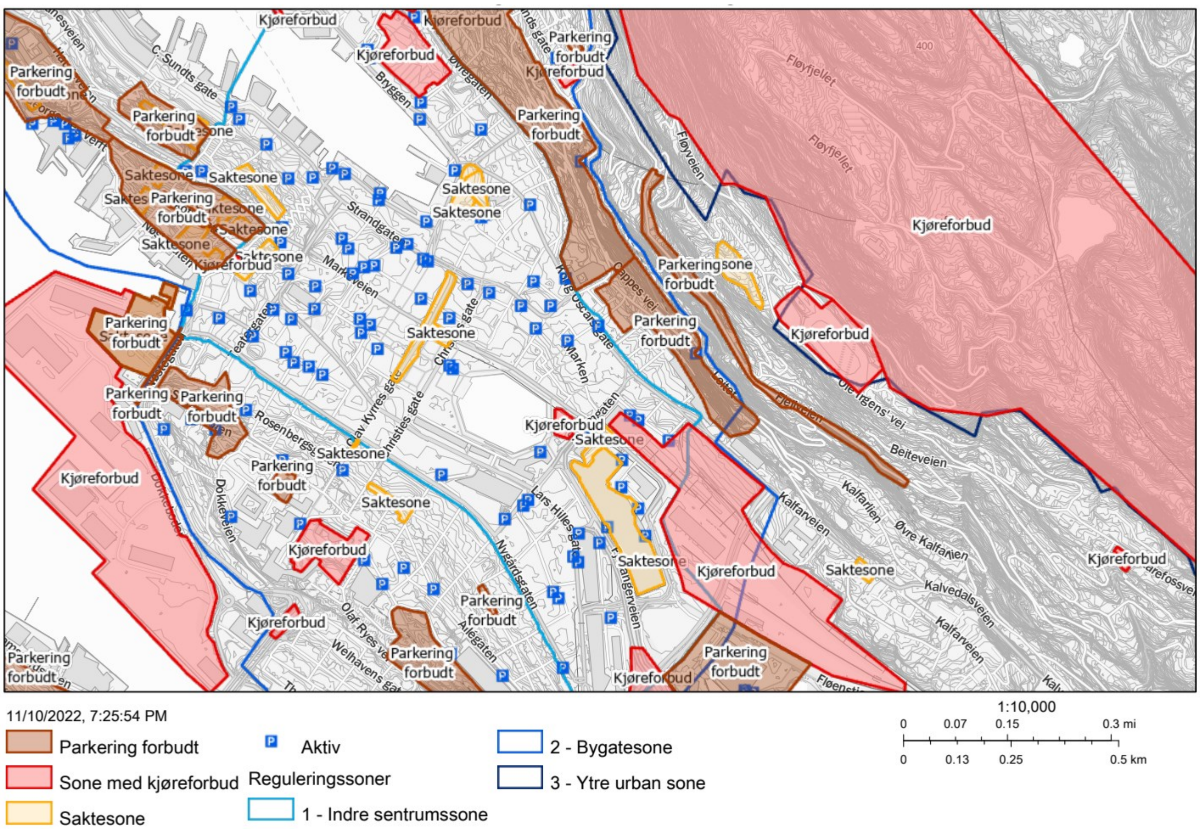


Figure 83: E-scooter parking and riding rules in Bergen, Norway

Besides the policy inventory, which is just one component of the policy canvas, each policy should be relationally assessed, visually or analytically (Taeihagh, 2017), using the categories of a) preconditional, b) synergetic, and c) contradictory policies (Figure 84). A preconditional policy would be a measure without the inclusion of which, one or more other measures will not function, thus being on the critical path for action. Synergetic policies are measures which facilitate the functional ability of one or more other measures, although these other measures can still be implemented independently. Finally, contradictory policies are those measures that produce conflicting outcomes or incentives, which mean that they are 'at odds' with the purpose of other (primary or additional) measures. The feature of policy is determined in relation to each other, while drawing from above-mentioned diverse taxonomies. For example, if an important primary and preconditional policy would be off-street parking maximums, a synergetic policy would be on-street parking charging, while a contradictory policy would be off-street parking minimums or no pricing for on-street parking. Similar relations between policies can be established with other, non-transport, policy domains, such as education, social, and health domains. In addition, these policies can be evaluated in terms of main responsible actors on different governance levels (e.g., municipal, national, EU), and in terms of timing for their initiation and implementation (see example from Table 37).

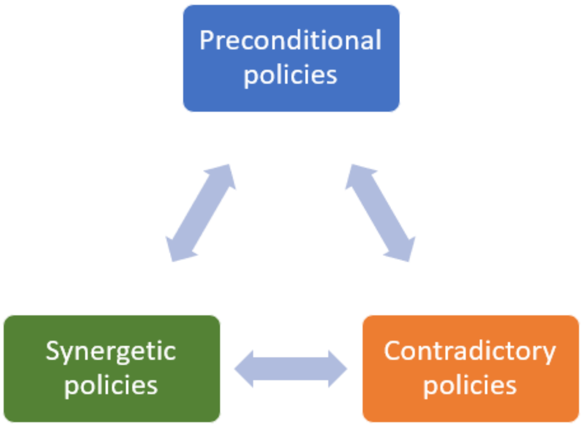


Figure 84: Depiction of relational formulation of preconditional, synergetic and contradictory policies

Table 37: Examples of short-term and long-term actions across diverse stakeholders

Actor	**Short-Term Action**	**Long-Term Action**
City-level	• Temporary traffic arrangements in the city centre	• Improving street infrastructure
Ministry-level	• Analysing possibilities for legislation on drunk-riding, age limit, multi-riding, and speed limit	• Statutory power assigned to municipalities to use geofencing based rules
Operator-level	• Continuation of campaigns coordinated with public sector	• Continuation of e-scooter vehicle design to prevent multi-riding
Other actors	• Development of targeted campaigns for certain groups of non-cooperative behaviour	• Developing e-scooter safety education as part of driver training programs

Underlying design as an iterative process, the following Figure 85 depict possible steps in one full iteration of a policy design process. The first iteration might need going through all these steps, although not necessarily in that order. Subsequent iterations can focus on some of these steps, until a saturation point has been achieved, with at least surface level agreement in the agonistic deliberation. In addition to the policy canvas and associated multi-actor processes, this project, and previous research (Dudley et al., 2021; Lo et al., 2020; Sareen et al., 2021) inform us, if micromobility is to be an enabler of a transition to low-carbon and socially-just mobility system, that there is a need for a stronger involvement of central government, including judicial and regulatory development. Moreover, there is a need for assigning needed statutory power with adequate financial resources and associated expertise on the city level. Despite the many previous calls for better safety and other data collection, such as (Airaksinen, 2018; Chapelon & Lassarre, 2010), this cannot be achieved without additional resources as well as defining the role of the data (Mladenović, 2021c). Ultimately, the institutional change required goes back to underly assumptions and rationales (Figure 16). As identified in previous research on governance of e-scooters (Field & Jon, 2021; Kim, 2019; Sareen et al., 2021), Finnish transport governance culture has to embrace the state of constant change and conflict, discussion on meanings of emerging urban mobility technologies, and drop the aspiration for solely evidence-based and illusory comprehensive rationality before actions are taken. Ultimately, such governance culture would rely on learning based on negotiations of meaning and clear experimental phases of technology deployment (Beers at al., 2019; Mladenović et al., 2021a).

Figure 85: Full iteration cycle for steps in multi-actor policy design process

4. Summary of Findings and Recommendations

This project has focused on two underlying and intertwined challenges within the case context of Helsinki. One relates to behavioural change of mobility system users, especially focusing on e-scooter users, while the other focuses on the institutional change of multi-level multi-sector transition actors, including all the parties involved in this project and beyond. The first aspect is rooted in a larger challenge of sociotechnical transitions dynamics, while the second aspect is rooted in a larger challenge of developing adaptive governance in Helsinki and Finland.

Having in mind the dynamics of sociotechnical transition involving e-scooters, the first research question focuses on temporal and spatial changes in occurrence and severity of shared e-scooter related emergency cases within the City of Helsinki. Overall, the proportional number of emergency cases in relation to the total number of trips is decreasing over years. Such ratio was 0.013% in 2021 before September restrictions, while 0.005% in the rest of 2021, and 0.004% between January and August 2022. As such, the level of safety for e-scooters is approaching the safety level of cycling, with its estimated proportional value of emergency cases to trip being in a range of 0.001% to 0.007%. Moreover, the number of serious injuries (Level 3 and 4), has decreased by 83% and 100%, respectively, in 2022. However, we have to underline that the safety level of cycling is not zero either, so the performance of Helsinki's mobility system is not yet achieving vision zero targets.

Beside the trend over years in the proportional number of emergency cases, the age of injured has shifted from 28.7 (average) and 25.6 (median) in 2021 to 31.2 (average) and 27.9 (median) in 2022. The issue of intoxicated riding has declined slightly between the years, with about 44% of injured identified as intoxicated in 2021, while this number is about 35% in 2022. Although crashes with e-scooters have been associated with weekends in 2021, their temporal distribution per day has shifted to weekdays in 2022. Similarly, after introducing the usage restrictions, the hourly distribution has shifted from having a peak at 1 am to the peaks being 7 pm and noon. Besides temporal redistribution, from the available data on the spatial location of crashes, we can conclude that crashes remain concentrated in the city centre, as that is the core operating area for all companies. However, new locations of crashes have appeared in in the city centre as well as in areas where e-scooters operation has been expanded in 2022.

The second research question focused on the types of observed competences and behaviours of shared e-scooter users in the City of Helsinki. Based on video observations at several locations, about 50% of observed users in 2021 have been classified as highly or moderately non-cooperative. This type of non-cooperative behaviour includes such issues as multitasking while riding, not keeping distance when passing, almost crashing or crashing into other people or infrastructure, multiple riders on the same e-scooter, appearing drunk while riding, and other issues. As opposed to gender, age is an important factor in non-cooperative behaviour, with majority of those classified as non-cooperative being estimated as under 25 years of age. However, we have to highlight that despite the fact that non-cooperative behaviour has been observed in all locations, the ratio of non-cooperative users declines based on infrastructural properties of the location, such as clearly designed desire lines and well-implemented design elements.

Video observations have clearly shown that there is a behavioural issue with two or even three users on the same scooter. This issue is frequently associated with teenage group of users, but has also included another problematic group – parent/adult multi-riding with a child on the same scooter. However, observations have also shown a variety of user practices. Here, we underline the aspect of carrying objects while riding, from shoulder bags, to shopping bags attached on e-scooter handle/s, to luggage bags positioned on the standing platform. Similarly, observations show diverse user appearances which include office-professional and gala clothing. Besides multi-riding, there are also clear groups of people travelling together on separate e-scooters, or with e-scooters and other modes, such as walking and cycling, which shows the social aspect of travelling. About one fifth of all the observations include food delivery workers, and about one tenth of users use privately owned e-scooters or other emerging micromobility devices, such as electric monowheels and electric skateboards.

The third research question focused on user and non-user perspectives on the usage and restrictions of shared e-scooters in Helsinki. The questionnaire analysis has shown that frequency of e-scooter usage varies from one-time users (6.1%) to everyday users (9.8%), with three most frequent being occasional (33.1%), frequent (23.6%), and curious user (22.8%). In addition, similar to video observations, the scale of those having or planning to buy a private e-scooter is around 10% of the user base. Despite the majority of users being in their late 20s or early 30s and male, e-scooter usage in Helsinki includes all age groups and income categories. The usage also involves a diverse set of trip purposes, although leisure and socializing activities are the most common. Commuting to work is also among the frequent trip purposes, and even more so for those using their private e-scooter, as well as shopping, which relates back to video observations of users carrying shopping bags. In addition, shared e-scooter usage in Helsinki is mostly replacing public transport in the form of buses or trams, taxi or other on-demand mobility services, and walking, while private e-scooter usage is more clearly associated with a reduction in private car driving.

The most frequent reasons mentioned for using e-scooters revolve around users being in a hurry and trying to travel faster than with other modes, in combination with e-scooter usage providing a fun experience. Other relevant reasons for e-scooter usage involve carrying objects, such as luggage and groceries, as well as socializing while traveling in groups. Existing users are mostly perceiving e-scooters as beneficial or completely beneficial, either for their personal everyday mobility or for the society and people's everyday mobility. In addition, users mostly suggest improvements in infrastructure, parking, and provide other, more specific, suggestions. In contrast, the most frequent reasons for not using an e-scooter include being satisfied with the current way of traveling and not seeing a clear necessity, as well as not feeling safe using an e-scooter in Helsinki. Regarding perceptions for their personal everyday mobility or for the society and people's everyday mobility, non-users are mostly perceiving e-scooters as damaging or completely damaging, which shows quite contrasting attitudes between users and non-users. In addition, although non-users agree with users on the need for street infrastructure improvements, they are more often suggesting changes in rules and regulation for e-scooter usage. The following Figure 86 provides a general overview of pros and cons of e-scooters in a current urban mobility regime, based on direct project findings and background literature.

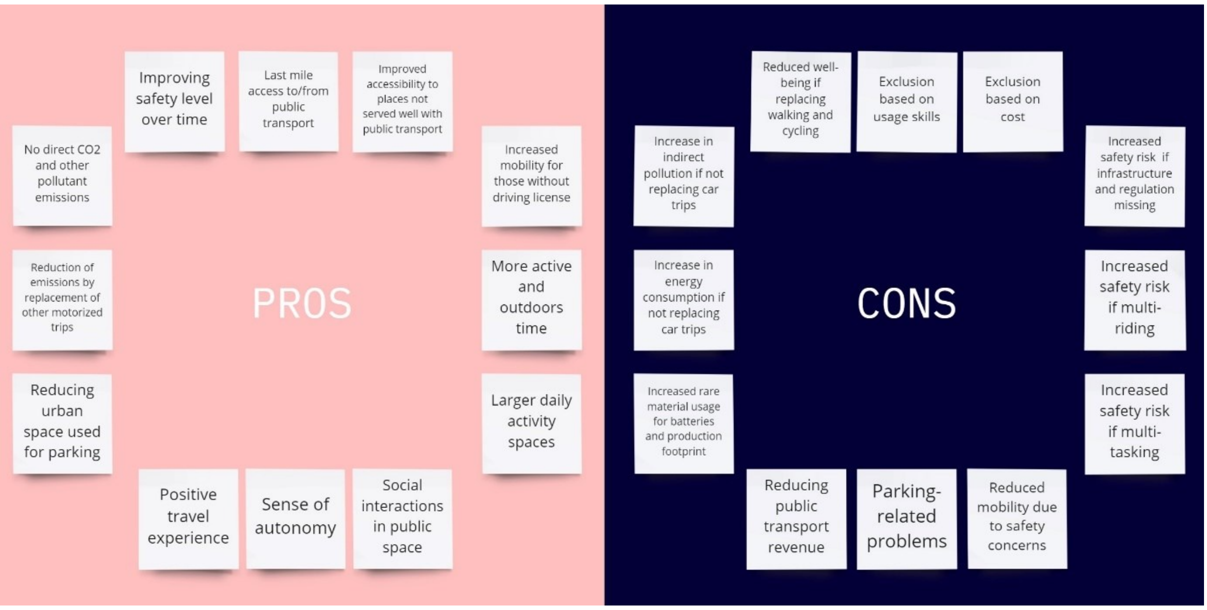


Figure 86: A general overview of pros and cons of e-scooters in an urban mobility system

Turning the gaze from the challenge of sociotechnical transitions dynamics to the issue of adaptive governance for emerging mobility technologies, there are several implications for further development. First, we cannot emphasize enough that challenge with adaptability largely relates to street infrastructure and urban space distribution, also over time in a year. Infrastructure design, construction, maintenance and use of temporary arrangements will have to continue to develop by relying further on state-of-the-art principles that account for inherent diverse human travel experiences and anticipated increasing diversity of urban mobility technologies. However, recognizing that responsible governance also includes e-scooter developers and deployers, we have to underline also that vehicle design (e.g., standing platform) and business model (e.g., pricing schemes) iterations have to continue, accounting for both dynamics-kinematics and broader behavioural change aspects.

Even though effectiveness of restrictive measures introduced in September 2021 has not been tested statistically, it can be inferred that it has had a positive effect, at least on the number of emergency cases. However, that package of reactive measures should not be taken as a good standard in practice. As explained above, there is a need to develop comprehensive policy design processes, including a policy design canvas and associated process-rules. Those elements should be co-developed in collaboration between a wide range of stakeholders, and with the aim to enable deliberation of different policy actions, identifying their effectiveness in terms of behavioural change, as well as their implementability. Here, we would advise to avoid thinking about effectiveness of isolated measures, and thus we do not recommend any single policy action in isolation. Optimal policy design would instead rely on national level regulation around such aspects as drunk riding, speed, and user age, national level and multi-stakeholder campaigns especially targeting non-cooperative behaviour (e.g., parent-child multi-riding, teenager or child multi-riding, drunk riding, etc.), development of education programs for all mobility system users, spatio-temporal and geofenced restrictions and rules for usage/parking in specific urban areas, as well as further development of user recognition and verification technology in the e-scooter vehicle and associated digital platform. Ultimately, as we can anticipate negative effects of removing the existing restrictions, and following the logic of the precautionary principle[1], our advice is not to remove them until a more comprehensive package of actions has been designed and put in place.

On a more general level, as it usually goes with emerging technologies being deployed in a society, some underlying challenges in the governance culture have also emerged. The following figure attempts to summarize most important assumptions, principles, and actions for developing the governance culture in Helsinki and Finland. Briefly put, governance culture will need higher reflectivity on the concept of emerging technology and agonistic debate, adaptability and responsibility with intervening less but in a wiser way, as well as long-term organizational learning based on experimentation and evaluation. Simultaneously, there is an important question of what the hierarchical position of e-scooters with respect to other transport modes in Helsinki is. We would argue that they should be ranked below walking and cycling, as the most active and sustainable modes, and above private car driving, as the least active and sustainable mode. What needs strategic clarity is the relationship between e-scooters and traditional public transport modes, and with that, the evolving definition of shared urban mobility[2].

On a pragmatic level of decision-support tools and data, there is a clear need to improve data collection of emergency cases and crashes, in both the coding scheme and location information, as well as in the resources allocated. Wider data collection and sharing practices between stakeholders, including wider sets of travel behaviour information, should be developed in line with the development of performance indicators for evaluating deployment cycles, and integrated with the development of the abovementioned policy design canvas. Multi-sided data sharing processes and policy design should include data collation and distribution platform, which can also support decisions about digital/georeferenced street-level rules needed for e-scooters and other emerging urban mobility modes.

Future research and development should continue in at least the following three streams. First, there is a need to further understand different mechanisms of user behaviour in a clear relation to policy effectiveness, especially of specific policies such as campaigns. For example, that would include relations to wider cultural trends, such as social isolation, common good perception, and alcohol culture, as well as more individual aspects, such as competences and meanings when using e-scooters. Second,

[1] https://eur-lex.europa.eu/EN/legal-content/summary/the-precautionary-principle.html
[2] https://www.radslaget.se/radslaget

there is a need to further understand diverse stakeholder perspectives and objectives in the dynamic sociotechnical transition, and the role of wider societal discourses, including media, in shaping the transition and governance path. Last, moving beyond the theory of technological acceptance and diffusion, there is a need to improve theoretical conceptualization of emerging technology in the urban mobility domain, to account for mutual reshaping of society and technology through more explicit although non-linear process of societal (un)learning. The following Figure 87 visualizes various targets for developing the Finnish governance culture in the domain of emerging mobility technologies. These points provide a set of interdependent aspects on human behaviour, technology and governance that are tentative targets for evaluating and developing assumptions underpinning the governance culture in Helsinki and Finland. If Finland is to be at the forefront of urban mobility system transformation, deliberate changing of underpinning assumptions is as important as innovation in strategies, processes, and decision-support tools.

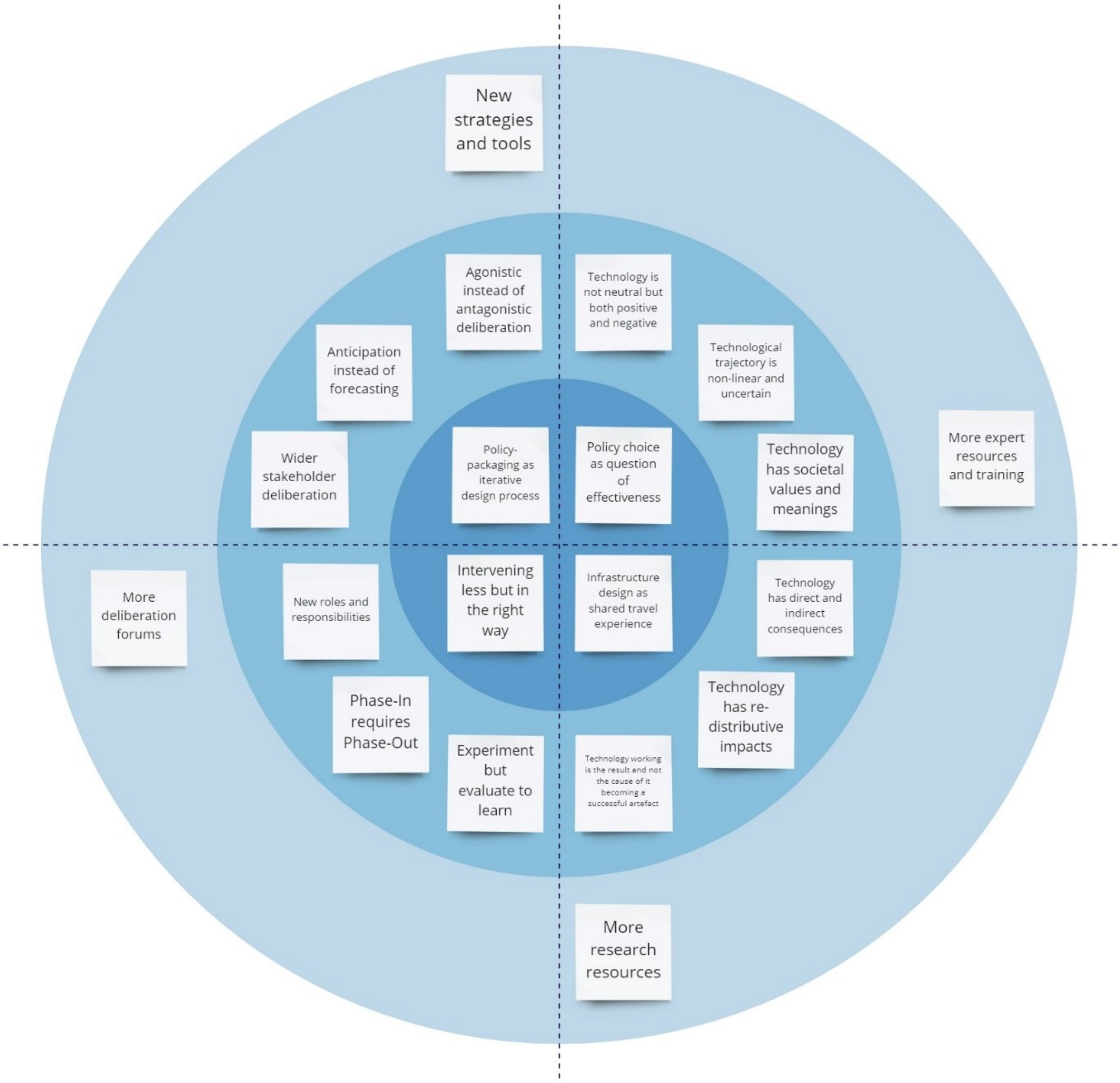


Figure 87: Targets for developing Helsinki and Finnish governance culture in the domain of emerging mobility technologies

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