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E-Scooter Sustainability – A Clash of Needs, Perspectives, and Experiences

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Abstract. Electric stand-up scooters (e-scooters) are introduced in several cities worldwide, providing new means for people to travel around the city. While praised for their flexibility, e-scooters are also met with negative sentiments due to fatal accidents and chaotic parking. In this paper, we seek to understand the mobility of shared e-scooters and point to gaps in the user interaction between the digital and physical world. We carried out three data collections, including interviews, *in situ* observation, analysis of news media coverage. Our findings illustrate integration with alternate modes of transportation in urban context, and how technologies facilitate or hinder (micro-) mobility. We found that users of e-scooters primarily view these devices as an alternative to walking rather than other transportation forms. Additionally, we found that users' and non-users' needs, perspectives and experiences of e-scooters clash, in particular with regard to perceptions of sustainability. Based on these findings, we present three relevant perspectives of sustainability, extending the ongoing debate of sustainable HCI research. We contribute with an empirically supported understanding of the perception of mobility and sustainability for e-scooters in a Scandinavian urban context.

Keywords: Transportation · Sustainability · E-Scooters · Mobility.

1 Introduction

Shared electric scooters are on the rise. Their introduction in many urban settings around the world enables new forms of mobility. Sometimes referred to as micro-mobility, this development is defined as "*the movement to unbundle the car with lightweight electric vehicles*" [3]. While such mobility may help to alleviate pollution problems, for example CO_2 emission or traffic congestion [20], several challenges emerge with the introduction of electric scooters and other lightweight motorized vehicles. These challenges include fitting with existing infrastructure, *e.g.* cluttering and obstructing side-walks and paths, or sharing of the roads with other traffic users [9, 36]. Studies have shown that such challenges often lead to accidents with serious [14, 4] or fatal [5, 32] outcomes for riders and vulnerable road users (*e.g.* pedestrians). Additionally, the overall sustainability of the physical vehicle, from production to maintenance, has been questioned [29]. Despite such problems, shared electric scooters have become increasingly popular and are being introduced in new cities [6, 46].

The emergence of shared electric scooters is highly relevant for mobile technology research as they provide new mobility forms through digital and ubiquitous technologies. E-scooters are a micro-mobility technology, which can be seen as a solution to address the last-mile problem of making connections to major transportation hubs [26, 30, 41], and thus serve to solve real and critical issues of transportation. The increased popularity of e-scooters presents a dualism, in which e-scooters can offer both a positive and negative effect on transportation sustainability. Prior work in Human-Computer Interaction (HCI) has commented positively on the hybrid nature of e-scooters for bringing fun user experiences, yet stresses the reliability and conflicts over public space [42]. While this highlights the value of ethnographic accounts of user experiences, we have limited empirical understandings of how people view and subsequently alter their transportation choices based on the sustainability of these shared e-scooters. In particular, we lack an understanding of how such shared e-scooter mobility compliments personal and walking transportation.

This paper investigates shared e-scooter schemes, so-called free-roaming rental e-scooters, in an urban context. We collect user and non-user perspectives through three distinct data collection techniques; interviews with riders, observations of riders in urban environments, and a preliminary analysis of social media comments. Our study provides insights into end-user motivation for (not) using e-scooters, highlighting implications for the acceptance of e-scooters as an alternative mode of transportation in society. This study builds on and contributes to the growing literature in HCI on sustainable mobility. In particular, addressing the tensions of HCI research's historical focus on technological novelty against the ethical imperative towards achieving sustainability goals [37, 22]. We study the sustainability of e-scooters from three perspectives; green mobility, urban infrastructure and safety, and social and economic impact.

2 Related work

Sustainability is an increasingly studied topic in the HCI research community. Through an analysis of published work on sustainable HCI, DiSalvo et al. identified different genres of study within this topic; persuasive technology, ambient awareness, sustainable interaction design, formative user studies, and pervasive and participatory sensing [22]. Our work falls within the genre of 'formative user studies', in which researchers aim to assess how users "*think about and approach sustainability*" [22]. While research on e-scooters is still relatively sparse, we next illustrate their role in a more extensive system of Mobility as a Service (MaaS) initiatives integrating micro-mobility, pointing towards the future of urban mobility. Additionally, we present the concept of hybridity as recently introduced in relation to research and design efforts.

2.1 Urban Sustainable Infrastructure and Micro-mobility

Contemporary use of the term sustainability touches on many perspectives. While traditionally used to denote initiatives that lower carbon emission, sustainable mobility now also refers to efforts such as reducing traffic congestion in cities, *e.g.* promoting ride pooling/-sharing, public transport and micro-mobility [43] and the planning of infrastructure to lower traffic injuries and increase safety for all road users [11]. Banister argues that local public transportation, cycling, and walking have become less attractive, giving way to car-dependence – fueled by the car's image of freedom and choice. However, when well planned, urban infrastructure will keep average trip lengths below the thresholds for walking and cycling and, in this manner, eliminate the need to have a car. This mental transformation of transportation needs depends on peoples understanding and acceptance of sustainable mobility [10]. Public Bike-Shares (PBS) have been around since the 1990s, and technological advances have since enhanced their efficiency and made them more accessible. PBS offer capacity to meet user needs for work, non-work, and leisure trips. In connection with public transportation, these bike-shares offer an improved first- or last-mile connectivity between home, public transport, and work places [15]. Bullock et al. found that while PBS offers an urban transport sustainable alternative, transportation modal shift from cars to bikes are infrequent. On the other hand, most shifts have been from walking, public transportation, or taxis. Bullock et al. argue that this shift resulted in journey timesavings, which is both a personal benefit of urban livability but also a considerable contribution to the urban economy [15]. PBS as a substitution for bus rides is further emphasized by Campbell and Brakewood, who argue that for mutually reinforcing sustainable transport networks it is vital to understand how public transit systems are interrelated with PBS [16]. Results from a PBS initiative in Beijing suggest that the placement of docks is critical for considering it a viable last-mile solution in connection with existing public transportation [30]. In an extensive literature review for KiM (Netherlands Institute for Transport Policy Analysis) from 2018, Durand et al. express the need for better insights on how free-floating e-scooter schemes impact travel behavior [23].

Smith and Schwieterman found that for short-distance travel (0.5-2 miles or 0.8-3.2 kilometers) in parking-constrained areas, e-scooters would be cost-efficient and a reliable alternative to private cars. Furthermore, they found that dockless e-scooters (in comparison to docked bikes) could fill a void for intra-neighborhood trips where transit-coverage is limited [38]. Usage data from dockless bikes and dockless scooters in Austin in March 2019 – as collected during the technology and culture event SXSW – showed that while trips covered very short distances, the time spent covering the distance added up to an average speed of four miles per hours, considerably less than the topspeed and comparable to powerwalking. This data suggests that people were not solely commuting but rather 'joyriding': "*More than a first- or last-mile solution, micromobility can actually be an extra-mile opportunity.*" [4]. Reports from Portland [2] and NACTO [6] support these statements, highlighting that reasons for riding e-scooters include fun/entertainment or curiosity, and that shared e-scooter use is most common to usage with recreational bike-share use; social, shopping, and other.

2.2 Mobility as a Service and Ownership

The MaaS alliance describes Mobility as a Service as the "*integration of various forms of transport into a single mobility service accessible on demand.*" [1]. Goodall et al. argue that transport operators must change their thinking in terms of business models, in favor of harnessing technological advances and enable a greater variety of choice of mobility modes, different uses of data, and a higher level of responsiveness [26]. Similarly, Spickermann et al. argue that the mobility sector, public authorities, and customers must break away from conventional thinking when it comes to the future of mobility and embrace integrated multi-stakeholder, multi-modal mobility scenarios [41]. Spickermann et al. argue that electric vehicles can be integrated into multi-modal concepts and help to promote the integration of transport modes in urban areas [41]. Empirical studies in HCI have investigated whether existing car-norms can be challenged by providing travelers with small electric vehicles [27] or creating awareness about the actual cost of car ownership and driving, that was transferable to other trips [40]. Hasselqvist et al. reported negative and positive experiences in the context of social structure, infrastructure, the individual, and near materiality. They further suggest sustainable HCI to focus on the *tension between the odd and the norm*. Spickermann et al. argue that a younger generation might be more likely than the older generation to relinquish the traditional ownership model [41]. Electric vehicles has also been suggested as a venue for design research to promote inclusion and thereby foster acceptance of new modes of transport and personal mobility. Don Norman express that design must strive to be inclusive of all ages, as a good example the Scooter for Life by PriestmanGoode is mentioned: "*Powerful lightweight motors and batteries promise to motorize many new things, including walkers, wheelchairs, bicycles, tricycles, baby carriages, and shopping carts. If these devices are stylish and useful, they will empower everyone, from the very young to the very old*" [33].

2.3 Hybrid Mobility

Recently, Fuchsberger introduced the notion of hybridity [24], in which the digital and physical are merged. Hybridity builds upon Weiser's vision of ubiquitous computing [47] and is used to evoke an image of merging: "*Everything computational may be considered hybrid, since it merges the digital with the physical*" [24]. Fuchsberger provides an example (among others) of hybridity; books have been adapted to viewing on smartphones and designers have tried to carry over this way of reading into physical books that can be held in one hand while flipping pages in a motion that resembles swiping a smartphone. Thus, understanding past developments may help overcome present issues. However, Fuchsberger warns that hybridity is not just mapping past development into current ways of living. Radical re-thinking is needed. Particular areas for HCI and design research are gaps where the physical and the digital world do not align with expectations *e.g.* concurrently keeping a physical calendar and a digital calendar and risk conflicting entries [24]. E-scooters can be viewed as a hybrid form of mobility, as digital (smartphone app functionality) and physical (e-scooter and road infrastructure) aspects are highly interdependent. Understanding the gaps in riding experiences can inform future directions for improving this mobility service and practice.

Tuncer and Brown illustrate through video-ethnography how e-scooter users perceive themselves as hybrid road users [42]. They observed riders instantaneously changing from riding in the bike lanes, to positioning themselves in the middle of the road 'like a car' and dismounting to jump red lights while positioning themselves as pedestrians in zebra crossings. Hildén et al. highlight the value of engaging with public transport users to identify their travel needs [28]. Prior work on sustainability also points to the importance of studying not solely the device or product, but instead focus on the perspectives of both user and non-users within the community [39]. These viewpoints motivate our work in the study of rider and non-rider perspectives and experiences concerning e-scooter sustainability.

3 Study

Our study focuses on riders' use and perception of shared e-scooter mobility services, as well as the co-existence of riders with other road users while moving around the city. We applied a mixed-methods approach consisting of three separate data collections: individual interviews with e-scooter riders, observations and first-hand experiences by riding along with other riders, and finally an analysis of social media comments (analyzing experiences from both riders and non-riders). In total, we conducted eight one-on-one interviews, seven *in situ* (group) observations of a total of sixteen people, and analyzed 300 comments from a Facebook group of a prominent Danish national newspaper (Politiken) on news about e-scooters in Denmark.

3.1 Individual Interviews

Eight people (four women, four men) participated in the individual interviews, ranging in age between 25–58 years (M=33.1 see Table 1). We recruited participants through postings on personal as well as specific group pages on Facebook and through our own networks. Our participants had a diverse range of experience using rental e-scooters, with four of them having taken more than ten rides. As illustrated in Table 1, our eight participants had used e-scooters from different cities in primarily Denmark (Copenhagen, Aalborg, Aarhus) and secondarily New Zealand (Auckland, Christchurch). Participants had used various digital electric scooter services or platforms (*e.g.*, VOI, Lime).

Interviews were conducted as semi-structured interviews using an interview guide either in person or through a video conference call. The interview guide contained questions about experiences with riding e-scooters and adherence to regulations, general views on urban mobility, the role of electric motorized vehicles and technologies, and the digital facilitation of mobility. Examples of questions include: "*In which instances would you prefer the e-scooter over other forms of transportation?*" or "*How well do you know the regulations for riding e-scooters in your local area?*"

The interviews lasted between 25 to 70 minutes, with six of the eight interviews lasting more than 45 minutes. All interviews were audio-recorded for subsequent analysis.

ID	Gender (age)	Trips	Purpose (city)	Usual means of transport
P1	F (25)	>10	Sightseeing (Auckland, Christchurch)	Public, bike
P2	M (28)	3	Appointment (Copenhagen)	Public, bike
P3	M (25)	>10	Sightseeing & commuting (Auckland, Christchurch, Aalborg)	Public, bike
P4	M (30)	6	Job errands (Copenhagen)	Public, car
P5	F (32)	>10	Commuting (Aarhus)	Public, car, privately owned e-scooter
P6	M (38)	>10	Commuting (Copenhagen)	Public, car, e-skate board
P7	F (58)	1	Commuting (Copenhagen)	Bike, car
P8	F (29)	1	Appointment (Copenhagen)	Public, Bike, motorcycle

Table 1. Demographics of the eight participants in our individual interviews.

3.2 In situ Observations and Interviews

We further conducted seven *in situ* observations and interviews with a total of sixteen people while riding e-scooters in Copenhagen, Denmark (Table 2). Our motivation for this data collection was to obtain first-hand experiences of riding these scooters and to observe e-scooter users while riding. We chose Copenhagen as city for this part of the study as its size fits e-scooters because many significant attractions are reachable using scooters, but also due to the fact that Copenhagen has a long tradition for bike riding and bike lanes, and thus provides a potential infrastructure for scooter riders (in line with argumentation from *e.g.* [8]). We chose to conduct these *in situ* interviews while riding with other riders as a kind of research in the wild as inspired by Rogers and Marshall [35] for conducting research in the everyday and in naturalistic environments.

We conducted our observations and interviews over two consecutive days. Observations were carried out in two distinct ways; 1) As a pedestrian, observing central points in the city center of Copenhagen at predetermined time frames

ID	Demographics	Nationality	Trips	Purpose
W1	F (24) + M (34)	France	1	Tourist commuting
W2	F (52) + M (56)	England	3	Tourist commuting
W3	F (15 + 16)	Denmark	2	Joyriding
W4	F (14 + 13)	Denmark	2	Riding to train station
W5	F (10) + parent	Denmark	1	Joyriding
W6	M (15 + 15 +16)	Denmark	>10	Joyriding
W7	M (41 + 43) + F (38)	Germany	1	Tourist commuting

Table 2. Demographic details of the participants in the *in situ* study.

– *e.g.* an hour outside the central train station during the morning commute, and 2) observation while riding an e-scooter, following the flow of traffic and clusters of e-scooters (as it appeared in the apps). We took observation notes to be written up later (interpretive description) inspired by the anthropological tradition of field notes [18]. To immerse in the environment, we carried out most of the observations as participant observation while riding an e-scooter around the city. Using the e-scooter as a *personality prosthesis* helped in approaching people on or by e-scooters([17]) and most of the in-situ interviews resulted from this observation mode. We approached riders in traffic, taking into account the traffic flow and complying with local traffic regulations. We provide an illustrative example. When approaching W1 waiting at a red light, the observer made introductions, initiated interviews, and proceeded to follow them when the light turned green in order not to disturb the flow of traffic. The seven *in situ* interviews were carried out using the same semi-structured interview guide as used in the aforementioned individual in-person interviews. We proactively supplemented the guide with questions related to the current environment and situation of the riders. The duration of these interviews was considerably shorter due to the context of our observations.

3.3 Social Media Comments

Lastly, we analyzed social media comments on e-scooter newspaper articles to obtain experiences and opinions from both users and especially non-users. Introducing new modes of transportation to an urban context already surging with mobility offers is noticed by all road users, and therefore we wanted to obtain a first-person perspective on both user and non-user experiences. Inspired by prior work by Vistisen et al. [44], we collected and analyzed feedback and interactions from the comment section of an internationally recognized Danish news media called Politiken. During spring 2019, Politiken requested stories and experiences from citizens' everyday interactions and encounters with e-scooters. Two follow-up articles based on the responses to these requests and the corresponding social media comments were used for this part of our study.

3.4 Data Analysis

Interviews were transcribed for analysis and subjected to thematic analysis inspired by Braun and Clarke [13]. One author was responsible for data collection. All observation and *in situ* notes and transcripts were read by this author for recall purposes, then coded, and subsequently arranged into themes using affinity diagramming. Identified themes were scrutinized and iterated on in collaboration by all authors. Our analysis of the collected social media comments is based on a total of 300 comments. Comments were individually assigned an ID reference and manually sorted in an analysis framework consisting of two axes with two sets of dichotomous stances. This allowed us to assess the comments qualitatively based on of what was posted: 1) user (e-scooters) and non-user, 2) positive statements and negative statements. Each comment was plotted into one of four quadrants of our analysis framework, while keeping in mind that the individual comment was often to be read as part of a larger discussion. We proceeded to identify clusters of comments. Comments that solely contributed with unsolicited ridicule or spite (commonly known as trolling) were excluded from the analysis, as well as comments that merely pointed critique towards the news media and its journalism rather than the topic of interest.

4 Results

We next present our findings under the themes identified during analysis. These themes include the diverse range of mobility needs expressed by e-scooter users, the environmental perceptions and motivations towards the e-scooters as a *green* mobility solution, the hybrid mobility experience of these devices, and finally the non-user perceptions as observed through social media comments found on a news article. P1-P8 refers to individual interview participants, whereas W1-W7 refers to *in situ* interview participants (riders in the wild).

4.1 Mobility Needs

Our first finding concerns the mobility need of the participants and generally we found that the participants would use these scooters for shorter rides, but also for more causal rides and activities. Most of our interview and *in situ* participants viewed the scooters as *walking on wheels* rather than substituting other transportation modes (*e.g.*, bike, car). As the pricing scheme of these services is generally counted by the minute, rides often preferred to use the scooters for shorter distances (less than 5 km, approximately 3 miles) – comparable to walking distance. Most participants found it less physically straining to move around by e-scooter as compared to walking or biking. We further found that our participants would use rental e-scooters for one of three purposes; convenience and ad-hoc trips, everyday commuting, and tourist or sightseeing purposes.

Six of our eight interview participants found the e-scooters more conveniently available than other transportation modes (e.g. buses or metro), which supports the comparison to walking (P1-P4, P6, P7). They all emphasized the ease that comes with the free-floating, dock-less scheme of retrieving and parking the e-scooters as compared to locating a transportation hub – *e.g.* train station, bus stop, bike rack that has a fixed placement. Although, as participant P3 pointed out, this required a critical mass of available e-scooters for the convenience to be noticeable. P2 particularly enjoyed how the free-floating scheme of the e-scooters offered a door-to-door solution rather than going by bus. P6 owned multiple transportation means, even an e-skateboard, but every now and then made use of the shared e-scooters.

"*It's simply faster. A walk of 30-40 minutes I can ride in 10 minutes, especially for routes that cuts through bus corridors. if you have to change buses, even once, it gets annoying.*" (P6)

Participant P4 only used the e-scooters for running errands on the job, due to them being ready-at-hand and in close proximity. While P8 thought of e-scooter riding as a fun experience, she also found it too expensive compared to her usual means of transportation and would prefer to walk every now and then.

Some participants (3/8) primarily used the e-scooters for commuting (P5, P6, P8). Note that participant P5 was the only one included in this study that owned an e-scooter instead of renting; she primarily used an e-scooter as a last-mile solution. She argued that parking in the inner city is costly, and free spots are hard-to-find. Therefore, she often parked her car outside the city and used the e-scooter to cover the distance from the parking lot to her destination.

Finally, several of our participants would use the scooters for causal activities like being a tourist for sightseeing activities, as they were seen as useful for tourist transportation due to the need to get around to planned destinations and take ad-hoc detours to visit places on a whim. Several of our participants (P1, P3, P7, W1, W2, W7) used e-scooters to get around while abroad to avoid the strain of walking everywhere:

"*We had walked ourselves half to death. I think one day we walked a half-marathon [distance]... We just wanted to experience all the things.*" (P3)

4.2 Environmental Motivations and Perceptions

Our participants, both those interviewed individually and *in situ*, generally held the perception that the e-scooters had a positive environmental impact. Two teenagers (W3) even noted the positive environmental impact as a factor for choosing e-scooters: "*It's environmentally friendly because of the electricity.*" P7 would like to see urban centers completely emission-free, and in this regard welcomed the small electric vehicles (e-scooters and e-bikes) although she preferred the use of regular bikes.

Interestingly, more of the participants seemed to perceive the e-scooters as environmental neutral or positive due to the fact that they would compare the scooters to petrol-fueled cars. In this sense, they indirectly argued that alternative transportation to the scooters would be by driving a car or taking a taxi. However, as noted above, often scooters were used when walking and walking would be the natural alternative. As articulated by P3: "*... I like the idea of riding or driving on electricity compared to petrol ... not that it is the most important thing in the world, but it is sort of a feel good thing ...*". Some of the participants even followed Youtubers on the green transition or pro-environmental behavior. E.g. P6 occasionally watched a show called Fully Charged on using electricity for various types of transportation means like scooters or cars. Also, P6 considered buying an electric car and believes that more restrictions will be implemented in major cities in the years to come. A few of them even stressed that cities in Denmark, e.g. Copenhagen, ought to brand themselves for being sustainable or green due to the fact that a lot of electricity is produced from wind turbines in Denmark.

Our analysis of social media comments showed a big contrast in the perception of the environmental impact of e-scooters. Almost as many social media comments welcomed e-scooters as a green, environmentally sound mobility choice as the number of comments which rejected this perception.

Positive statements regard the emission of riding e-scooters: "*E-scooters don't emit* CO_2." In particular when compared to the emission of other forms of public transportation; "*All in all a very green way of transporting yourself. It is greener than taking the bus.*" Whereas negative comments state that e-scooters are "CO_2 *sinners on a large scale!*" One comment linked to a report on the negative climate impact, while other comments presented concerns regarding the lifecycle assessment of the production and discarding of e-scooters and their batteries. Another comment emphasized that charging electric vehicles is dependent on sourcing electricity from other resources than fossil fuels.

4.3 Digital and Physical: Hybrid Mobility Experiences

Rental e-scooters are physical vehicles that require a digital counterpart to be used (*e.g.*, unlocking/locking in the mobile application). As such, e-scooters merge physical and digital aspects of mobility. We observed several digital factors that influenced the use of these devices. Understanding the concept on the first encounter was expressed by all interviewees as an initial challenge, albeit quickly overcome. However, all applications require a data connection, which was perceived as a challenge when *e.g.* traveling abroad without a suitable data plan. Two participants (P1, P3) explained how they would ad-hoc create temporary hotspots for locking/unlocking the e-scooter or even have to drag the e-scooter to a Wi-Fi hotspot to commence a ride.

Digital regulations affected the user's driving behavior in the physical world. For example, some rental companies have mapped out zones that can only be viewed digitally, and while you can physically park your e-scooter in a red zone, it is not possible to end your ride in such a location. Adversely, in response to the many complaints of haphazard parking of e-scooters, green zones have been implemented to nudge riders into parking in more appropriate areas by offering a payback of an amount of the cost for the trip.

While only two participants mentioned having noticed (and understood) the red zones on the map, P3 consciously used the app to earn free riding credits.

Riding without credits was discouraging to the point where he would instead use another mode of transportation. Additionally, W6 stated that they were *"trying to find a way around"* paying for the rides, as one of them demonstrated how they successfully hacked the e-scooters to double the hard-set speed limit.

4.4 Non-User Perceptions

Social media comments presented a mixed perception in terms of e-scooter mobility. Interestingly, several of the non-users perceived e-scooters as a substitution for *e.g.* a private car or public transportation, rather than walking (as opposed to the riders that we interviewed): "*Every time someone travels by e-scooter instead of a car or a bus they will contribute to reduce congestion and that is something I would like to applaud.*". A few of the comments perceived e-scooters as a lazy substitution for walking and urged people to make better lifestyle choices regarding their transportation habits.

Challenges arise when reckless e-scooter riders are driving among pedestrians and other vulnerable road users. Lack of consideration demonstrated by some riders are expressed in several social media comments, *e.g.* "*They drive way too fast for anyone to react or sidestep.*" Challenges additionally arise in connection with inconsiderate parking, cluttering up streets and sidewalks. One social media comment expressed the view of e-scooters as a toy rather than a vehicle: "*Scooters, skateboards and the likes are playthings and has no place on public roads, paths or sidewalks.*" In response, comments from the social media analysis stressed that the physical infrastructure is seen as a necessary part of better regulation of e-scooter riding and micro-mobility in general.

Some comments emphasized the number of accidents involving e-scooters since their widespread introduction. One comment included a link to a report supposedly supporting their statement "*e-scooters have significantly more accidents per driven kilometer than other related vehicles.*" Another comment stated that emergency rooms report a dramatic increase in head trauma injuries for e-scooter riding. In response to this, a person commented that they did not see accidents as a result of introducing the e-scooters but urged to direct the attention to the people riding them to regulate themselves rather than more external regulation: "*You wouldn't ban cars just because some are drunk driving.*"

5 Discussion

Given their increasing popularity and impactful presence on existing infrastructure, the topic of e-scooters fits well within the ongoing efforts of sustainable HCI research. In particular, the clashes between users and non-users of e-scooters proves that the e-scooter is not introduced into a transportation vacuum. Instead, it stirs a critical question at the center of discussions: The role of HCI in technology innovation. Disalvo et al. and Silberman et al. emphasize the tensions between a historical focus on technological novelty and the ethical imperative of HCI towards sustainability goals [22, 37]. In this discussion, we present different sustainability perspectives for e-scooters and integrate knowledge within and beyond the HCI literature to accommodate the need for studies to inform the design and operation of systems people use in their everyday practices [37]. Further, we demonstrate that e-scooter mobility is not solely a derived demand but also a valued activity [10].

5.1 Green Mobility/Environmental Focus

The perspective of e-scooters as a sustainable mobility mode, as based solely on their limited emission, has been widely critiqued. While Hollingsworth et al. agree that e-scooters as a substitute for private car usage results in a universal net reduction in environmental impacts [29], there are many other factors to take into account. The results of a Monte Carlo analysis, in which the total life cycle of e-scooters is assessed, point towards initiatives for e-scooter collection and charging approaches, *e.g.* fuel-efficient vehicles for collection, only collecting and charging in case of low battery, and reducing driver distance for collection. Importantly, they found that these results were susceptible to e-scooter lifetime, concluding that the positive environmental impacts will not be substantial unless the individual scooter lifetime exceeds two years [29]. Similar conclusions for PBS are found in a study by Luo et al., who conclude that if replacing car trips, both docked and dockless PBS can be seen as sustainable modes of transport when well designed and operated. They add that in particular environmental positive impacts are gained when PBS is used as a first/last-mile solution in combination with public transportation. Adversely, PBS is not necessarily the more sustainable choice compared to the bus, electric bikes, personal bikes, and walking [31].

In line with findings from Smith and Schwieterman [38], our findings show that the use of a shared e-scooter was primarily viewed as an alternative to walking over other modes of transportation. Additionally, shared e-scooters were preferred for relatively spontaneous mobility needs where routes can be navigated ad-hoc, *e.g.* more direct routes than offered by public transportation. Survey data from several U.S. cities suggest that people using docked bikes are more likely than people using e-scooters to commute for work or connect to other modes of transit [6].

Our findings show that both users and non-users generally perceive e-scooters as a sustainable mode of transportation in relation to *e.g.* a private car, due to running on electricity. However, e-scooters are not necessarily viewed as a sustainable *green* mobility offer when looking at a lifecycle assessment of production, upkeep, and discarding, as well as the source of the vehicle's energy. Our results indicate that the general public typically does not consider all these aspects when forming their opinion on green transportation alternatives. This observation holds for both users and non-users alike. How to effectively communicate the impact of e-scooters on the environment, balancing both the benefits and drawbacks of their production and expected (long-term) use, is an open research question with a potentially extensive impact. For example, work within

HCI is being carried out to meet demands for charging small electric vehicle fleets, as their large quantity could pose a threat to power grid consumption and demand in the future [34]. Our results provide insight into the conflicting needs of end-users of such transportation technology, with a desire for e-scooters that are both widely and instantly available at an attractive price point.

5.2 Urban Infrastructure and Safety

Our findings mention infrastructure as a determining factor of the riding experience, *e.g.* dedicated bike lanes vs. cobblestone surface. Among others, Tuncer and Brown argue for HCI research to open the delicate debate on the amount of space currently dedicated to cars and how this prioritization misaligns with expectations of urban transport sustainability goals [42]. Banister also addresses the role of policy measures to widen the notion of the street, not only as a road, but also a space for people, green modes, and public transportation [10]. Redesigning infrastructure has also been attributed to increased safety for the individual, as presented in the 'vision zero' policy regarding transport safety, and sets itself apart by stating that designers of road safety policies and infrastructure initiatives are held responsible instead of the individual drivers in cases of serious or fatal accidents [11]. In 2019, the Norwegian capital Oslo proved successful in implementing Vision Zero with zero bicyclist or pedestrian deaths [19]. However, HCI research has questioned the implementation of a universal road safety culture and urges researchers to be attentive to local history, understandings, and practices of road safety [45]. The impact of these policies on sustainable HCI research and practice is currently poorly understood, providing opportunities for future study and engagement with policymakers. Furthermore, recent work highlights how the assessment of recent governmental policies provides HCI researchers with an additional tool to identify topics of societal relevance for future work [12]. To the best of our knowledge, this perspective has not yet been explored within the context of e-scooters.

Our findings showed that the dockless, free-floating scheme was crucial to considering the e-scooter over *e.g.* the docked (e-)bikes or public transportation, as they were viewed as a convenient door-to-door transport solution. Along with the aspect that it was considered as a more fun way to travel. However, the application of free-floating e-scooters requires reaching a mass that accounts for the density of a city and distribution of scooters to be available – as similarly argued by Campbell and Brakewood in relation to PBS [16]. Adversely, inconsiderate behavior and reckless riding was seen as detrimental to the acceptance of e-scooters. Research has pointed to e-scooter riders being more likely to ignore traffic regulations than other road users [9]. Unsurprisingly, our findings suggest that not following traffic regulations could result in insecurity in traffic for other road users, in the worst case leading to collisions and accidents.

Banister argues that public acceptability is an essential and often neglected part of sustainable mobility policies [10]. Our findings point towards different stakeholders, both public and private, that are expected to regulate better driving experience for riders to co-exist with other road users. Examples include the municipality for infrastructure and local regulations, rental companies for responsibilities towards respecting local regulations, and riders themselves to ride with more respect for other road users. Multi-modal mobility requires all stakeholders to engage in its success [23, 26, 10, 43]. Rental companies have committed in different ways to communicate good riding practices to their users through *e.g.* campaigns rewarding users for demonstrating good practices along with investing in projects for appropriate infrastructure.

5.3 Social and Economic Sustainability

Ridesharing schemes have received negative attention for being mostly beneficial to middle and high-income households. In particular, low-income and transportation-scarce households, where vehicle ownership may not be an option, have been found to be disadvantaged in terms of accessibility to these services [21]. Our participants generally found e-scooters expensive to rent. Additionally, the use of e-scooters requires a certain level of (digital) literacy skills. HCI research has suggested that these factors, in other shared mobility schemes, point towards an unfair disadvantage for socio-economically disadvantaged groups [21]. Organized campaigns of vandalism have appeared, *e.g.* 'Uber Plätten!' (translation: 'Puncture Uber'), which incite and guide activist action against Uber vehicles, primarily bikes and e-scooters in Berlin against a perceived negative contribution to social mobility [7]. HCI research has focused on how the introduction of on-demand MaaS initiatives have created a mobile workforce. While this reliance on 'gig-economy' might increase worker flexibility and create new job opportunities, we also need to be aware of how this affects work conditions [25]. Future HCI research could investigate the social and economic sustainability of e-scooter pricing and availability.

Our findings indicate the sharing of e-scooters as a resource for tourists. This specific user group expressed a preference for e-scooters based on their ease of accessibility. At the same time, some noted that access to data networks and potential roaming costs could hinder their actual use.

Hasselqvist et al. found that one of the most echoed concerns of choosing small electric vehicles over cars was how other people characterized it as odd or extreme. Participants found that it can be unpleasant to break with social norms and expectations, and carefully chose how they explicated motivations of swapping their car with electric vehicles to non-participants[27]. Similarly, the clash of user and non-user perspectives demonstrated in our findings suggest that e-scooters are not yet fully socially accepted as a mobility mode. We argue that ethnographic studies of mobility can offer a lot in the discussion on how different modes of transportation may continue to co-exist in an urban context.

5.4 Utilizing Hybridity to Regulate Riding

The inherent hybridity of e-scooters as a mobility service is an interesting case on how digital and physical elements are combined to form the rider experience. We present our considerations on utilizing vehicle design and interaction in designing for e-scooters, based on our study's findings and prior work.

Our findings suggest practices of exploiting the hybrid aspects of e-scooters, both in detrimental approaches like 'hacking the system' *e.g.* tinkering with hard-set speed limits and positive approaches of 'gaming the system', *e.g.* earning credits in intended and legal ways. Facilitating ways of earning credits may contribute to viewing rental e-scooters as an attractive option. Tuncer and Brown additionally observed how e-scooter users 'hacked the city' by *e.g.* rental users utilizing e-scooters as a first- or last-mile transportation, to establish routes ad-hoc to more direct train lines that were previously too far away from their starting point [42]. We see potential to support this type of transportation navigation with real-time data, taking into account saturation across a range of transportation modes and suggest alternative routes that feature intra-modal travel plans. As addressed by our participants, ideally a payment plan that rewards users for *e.g.* frequent use outside of peak hours or for making sustainable transportation choices could be coupled with this dynamic application of route planning. Recent mobility research has suggested embracing the thought of mobility as a service to implement payment plans that resemble other services like streaming [43].

The mobile applications used to rent the e-scooters already provide various 'nudging' mechanisms, *e.g.* financial incentives when parking in appropriate locations. We see this as an open space for HCI researchers who wish to explore how the riding behavior of e-scooter users can be improved. Our findings showed that only a few participants were aware of how rental companies intervene or nudge users to regulate their e-scooter use, *e.g.* through no-parking zones or by directing riders to suitable parking zones by offering ride credits. Data-capabilities of these hybrid vehicles and companion apps may be utilized to determine where zones may be conveniently located – meanwhile increasing the risk that the free-roaming nature of e-scooters is reduced. Additionally, to accommodate the data connection issues, public Wi-Fi hotspots could be created that would encourage parking next to one, and to make it easier to ride for tourists or people with restricted access to data.

Our findings emphasize the need for a reasonable mass of e-scooters to increase the reliability of this transportation mode to be available when needed, as riders dynamically and rapidly re-position e-scooters around the city. Tuncer and Brown also point to rental e-scooters having issues with the reliability of position and availability [42]. In response to availability and reliability, a reservation feature might be considered. Reserving a particular scooter in advance will ensure that it will be available even if you have to walk to get to it. Further research following these lines of thought may uncover interesting potential solutions to make shared e-scooters more attractive. Additionally, in an effort to challenge the idea of ownership, application supported initiatives could facilitate sharing instead of renting schemes [42].

Limitations Our *in situ* approach to both participant recruitment and observation enabled us to participate in and experience the physical elements of e-scooters on the streets. A challenge we have encountered in this regard has been recruitment, as the real world is characterized as being multi-located, hybrid, and mobile. We have attempted to accommodate the recruitment challenge by triangulating data collection approaches. Additionally, as we have studied e-scooters in the context of a Scandinavian country already well-known for its biking culture, results will not be readily transferable to other countries.

6 Conclusion

This study investigated dockless, free-roaming shared e-scooter schemes in an urban context by inquiring about the mobility needs of their users, as well as the issues they present for users and non-users alike. We explored this research question through three distinct data collections; individual interviews, in-situ observation, and an analysis of comments on social media. We present implications for the acceptance of e-scooters as a new mode of transportation, that is introduced into an existing multitude of alternate transportation modes. Our work extends the existing debate on policies of urban infrastructure, in particular within sustainable HCI research – highlighting the urgent ethical imperative of innovation and designing new technologies. We discuss three sustainability perspectives to take into account when imagining how e-scooters may make beneficial integration with a multi-modal urban mobility system; Green Mobility/environmental focus, urban infrastructure and safety, and social and economic sustainability. Additionally, we argue that the e-scooter is well suited for this integration as we view it as a hybrid vehicle, incorporating both digital and physical components. These hybrid qualities motivate design possibilities with respect to sustainability goals for an urban society.

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