Porojkow and Lißner *European Transport Research Review* (2024) 16:32
https://doi.org/10.1186/s12544-024-00657-x

European Transport Research
Review

ORIGINAL PAPER **Open Access**

Friend or foe? A spatial approach to overlay bicycle and scooter trajectories

Iwan Porojkow[1*] and Sven Lißner[1†]

Abstract

Dockless e-scooter schemes have seen increasing popularity in 28 German cities. Increasing use on insufficiently dimensioned bicycle infrastructure can lead to conflicts between e-scooter riders and cyclists. A new approach was developed in order to detect potential zones of conflict by overlaying aggregated bicycle and e-scooter trajectories in the City of Dresden, Germany. Bicycle data is being obtained by the annual STADTRADELN campaign where cyclists record and transmit daily trips via GPS for a period of three weeks. Simultaneously, e-scooter API data has been collected over a course of 8 weeks from June to September 2021. Origin/Destination data has been generated and routed over a OSM network in order to obtain aggregate d e-scooter flows. We extrapolated the aggregated bicycle data to match them with the timeframe of the e-scooter data acquisition. Afterwards we spatially joined both: bicycle and e-scooter flows and calculated the link wise proportion of e-scooter trips in relation to bicycle trip volumes. Two important findings emerged: (1) Residential roads have a higher proportion of e-scooter trips. (2) E-scooters are exposed to high bicycle trip volumes on primary roads with bicycle infrastructure. We conclude that this approach can detect possible links of conflict, where overtaking cyclists or insufficient space can lead to dangerous situations. That approach is biased towards a missing route choice model for e-scooter riders or better route data of e-scooters, which needs further research.

Keywords E-scooter, Bicycle, Safety, Conflict analysis, Bicycle infrastructure, Micromobility

1 Introduction

Similar to America and Asia, e-scooters are now firmly established in the streetscape of European cities. E-scooter usage in Germany has been legalized in mid-June of 2019. This has also led to a run by sharing companies in large German cities. As of mid-2022, seven providers are represented in 28 German cities. In addition to large cities, medium-sized cities are also currently affected by the market ramp-up Despite the slowing effect of the COVID-19 pandemic, there has been a positive development in the number of providers and scooters [1, 2].

The emergence of e-scooters in European cities sparked controversy as public perception sees e-scooters as a safety concern due to their use and parking on sidewalks, endangering pedestrians [3, 4]. In Paris, a referendum led to a ban of rental e-scooters led by "complaints of users jostling through pedestrians on pavements or dumping their rides awkwardly at intersections," supported by almost 90% by its residents [5]. Although e-scooters are advertised as a mode for the "last-mile," geographic availability is limited to densely populated and frequented neighborhoods, primarily in city centers where e-scooter trips are more likely to occur. These geofences, are not standardized as pointed out in research in Vienna and

---

[†] Sven Lißner Co-author.

*Correspondence:
Iwan Porojkow
iwan.porojkow@tu-dresden.de
[1] Chair of Transportation Ecology, Technical University of Dresden, 01062 Dresden, Germany

Poland [6, 7]. A study of a moped-sharing system in Barcelona, operating similarly to e-scooter rentals, indicates service inequalities due to the exclusion of neighborhoods with lower income and public transit accessibility [8].

Dockless mobility providers, like e-scooter companies, can provide a vast array of mobility related data such as historical origin-destination (OD) data or entire trajectories, which can be used for scientific and transport planning purposes. Through the practical absence of publicly available trajectory data due to privacy concerns, one can use spatiotemporal origin/destination (OD) data for planning and research. This limited set of data allows to estimate key traffic parameters such as average speeds, travel times, distances and links [9, 10]. E-scooters are seen as a crucial part in multimodal traffic chains and as an integral part of a paradigm shift towards sustainable mobility [11, 12]. This assertion is justified by the assumption of substituting access and egress trips to public transport hubs, which are usually done by foot, with e-scooters to make the whole trip chain more confident as an alternative to car traffic. However, trips done by e-scooter are competing with bicycle trips or trips on foot [1, 2, 13, 14].

The German regulation for small electric vehicles (Elektrokleinstfahrzeuge-Verordnung, eKFV) requires e-scooters to be moved on bikeways unless explicitly stated by a sign dedicated to e-scooters [15]. Due to constraints of dimensions and capacity of bicycle infrastructure, it is conceivable that e-scooters can pose conflicts between cyclists and scooter riders, sustained by the possible cannibalization of transport modes, especially those involving active travel [16, 17]. E-scooters travelling at their maximum speed of 20 km/h [15, 18] can pose an obstacle to cyclists travelling at higher than average speeds [19].

In previous research, no papers are known that attempt to quantify these potential conflicts of use with bicycle traffic. Younes et al. address this issue by analyzing and comparing determinants of dockless scooter share and station based bike-share rides, without referring to used infrastructure [17]. Furthermore, bicycle counting stations do not currently quantify the e-scooter volume at counting cross-sections; rather, it can be assumed that e-scooter riders are often counted as cyclists. Thus, no data is available on the proportion of e-scooters on bicycle facilities.

The contribution of the present paper to international research is a quantification of e-scooter trip volumes on bikeways and an estimation of potential conflicts. For this purpose, we obtain and route OD data of e-scooters and overlay them with aggregated bicycle usage data to identify potential conflict areas.

This paper consists of five sections: The next section presents a literature review on previous studies on e-scooter and bicycle usage. Section 3 describes the data acquisition, processing and analysis. Section 4 presents the results, adressing the research questions. Section 5 discusses further implications and limitations while finishing off with conclusions in Sect. 6.

2 Related work

While e-scooters have become an attractive means of transport after its emergence in 2018 [12, 13], research has been conducted on e-scooter usage and demand. A broad range of studies addressed the impact of socio-demographic variables on e-scooter usage [9, 17, 20]. Thereby, a male focused population below the age of 40 [10, 21, 22] as well as higher median income households [21, 23], tend to use e-scooters more often. Many users who reportedly used e-scooters once or in infrequent periods [21], therefore lacking experience, can lead to an increased insecure e-scooter usage in road traffic. E-scooter trips tend to cover shorter distances than bike sharing trips [24], thus being convenient for covering short trips [13, 14, 25]. As a consequence, e-scooter trips are seen as competitive to other active means of travel [2, 17].

Focusing on Europe, a comparative analysis conducted in 30 cities throughout 8 European countries reveal similarities in their temporal patterns, indicating peaks during times where users prefer to take leisure trips, underlining the convenience and availability of e-scooters [26]. A Swedish study conducted in Gothenburg revealed temporal peaks on Fridays and the weekends, covering distances up to 1.7 km which last up to 10 min, particularly in the city center [27]. Similar findings have emerged in Paris, France, where over one-third of all trips are taken during the weekend, most lasting 19 min in the mean and 11 min in the median [28]. Only 19% of all repondents in Paris used rental e-scooters for commuting [28]. Further research studying e-scooter usage via an online survey in Belgium, the Czech Republic, Norway, Sweden and Australia concludes that sidewalk usage is shared among all countries above, further impacting pedestrian safety due to insufficient infrastructure [4].

According to a study conducted by Tuli et al. in Chicago, (higher) temperatures, precipitation and wind determined e-scooter usage [23]. Regarding environmental influences, Corcoran concluded that weather conditions accounted for similar bike share usage behavior in Brisbane, Australia as in the latter findings [29]. Younes et al. identified factors contributing to increased e-scooter usage, like weather, gas prices and temporal factors, such as the day of the week, public holidays or vacation seasons [17]. Temporal usage patterns may differ between study areas. Bai et al. compared temporal patterns in Austin (US) and Minneapolis (US), highlighting different peak times [9]. Zuninga-Garcia et al. highlight that average speeds during the morning peak are higher than in the other hours [30]. According to current research, daily commuting as the main travel purpose appears to be unlikely for e-scooter users [2, 9, 17, 21], thus reducing competition between cycling and e-scooter use to a lower level. However, fostering aforementioned contributing factors could lead to a shift towards increased daily usage of e-scooters [14]. Such potential can be seen primarily in city centers, around university campuses [10], recreational facilities such as parks [23], areas incorporating bicycle facilities, public transport stops [25] and areas maintaining a high level of walkability [9], where e-scooter usage can be seen the most.

Several studies examined this variables of the surrounding environment to identify determinants of e-scooter use [6, 10, 31]. Hosseinzadeh et al. conclude that e-scooters are mainly used in a pedestrian-friendly environment [10]. Caspi et al. further explored increased use in city centers and areas with well-built bicycle infrastructure [31]. Moran et al. confirm increased demand in city centers based on geofencing measures of six providers in Vienna (AUT) [6].

In addition to possible spatial interdependencies, interactions with other means of transport, e.g. public transit, were also investigated [16, 32]. Both competitive and collaborative effects on public transport could be identified [16]. Wang et al. provides a synopsis of the previous research literature. The share of daily (scooter)trips among e-scooter users varies between 19% and 43% n the lierature reviewed. Trips done by foot are being heavily substituted [32], whereby e-scooters substitute less than 10% of the observd cycling trips [21, 32]. As a result, 90% of all e-scooter trip could account into additional traffic on bicycle infrastructure if the latter findings are applied to German regulatory and legal conditions [21]. Laa et al. conducted a user survey in Vienna, Austria. They concluded that an increase in e-scooter usage leads to increased demand on bicycle paths, which should entail improvements and upgrades to existing infrastructure [32].

On the other hand, cannibalization of bike sharing trips seems likely at first and has already been studied several times [17, 24]. McKenzie's findings in Washington conclude that bike sharing is mainly being used for reoccurring daily trips while e-scooters are used more casually, e.g. for leisure, recreation and tourism activities [24]. Against this background, a substitution of bike sharing trips during peak hours seems rather unlikely, again increasing the likelihood of spatial interactions between cyclists and e-scooter riders. Gibson et al. investigated the interactions of e-scooter users with pedestrians in Christchurch (New Zealand). According to their survey with 12 respondents, conflicts arise due to the prevalence of e-scooters on ways designated for other modes of transport. This is mainly due to the fact that there are no exclusively designed ways or paths for e-scooters. However, according to Gibson et al., this new mode of transport has the potential to disrupt urban land use. According to the interviewees, particular potential for conflict arises from the upright, low-movement posture of e-scooter users [33]. Shared space has so far been designed primarily for cyclists and pedestrians where road space is limited [34]. E-scooters, however, were not incorporated in the road design and are thus mostly perceived as arythmic and sometimes disturbing due to their different driving dynamics [33]. In order to minimize pedestrian interactions, Gössling et al. proposed that e-scooters should be used on cycleways as it already is legally mandatory in Germany [12]. Therefore, Creutzig et al. poses the question of whether future road design should accommodate new modes of transport [35]. Hitherto, there are currently no reliable figures to estimate the degree of possible competition for space between cyclists and e-scooters. There is a gap of literature analyzing the share of e-scooters on cycle paths. Laa et al. are the first authors who analyze e-scooter trips on cycle paths. However, their analysis is limited on two locations in Vienna where bicycle and e-scooter trips have been counted, accounting for 5 – 7% of all observed trips [32].

This research aims to close this gap by analyzing datasets of bicycle and e-scooter use using accessible bicycle use and vehicle location data of e-scooters.

3 Methodology

3.1 Data acquisition

E-scooter data was obtained at a 15-minute interval via the publicly available Lime-API for the city of Dresden (Germany). The API was queried over a period of 8 weeks from July 14th to September 8th 2021. The traffic volumes of the e-scooter users are then spatially and temporally intersected with a data set of the STADTRADELN cycling campaign. This campaign is being held annually throughout Germany in order to collect anonymous and aggregated GPS-based bicycle trip data. Data acquisition has been embedded via 8 virtual machines to circumvent API limits and request denials. Returned data contains the location in latitude and longitude format, a unique scooter ID, state of charge (SOC), remaining range as well as a timestamp of the last activity. A timestamp of each query was appended to each e-scooter. The data collection process resulted in 3.7 million e-scooter locations. E-scooters do not appear in the data set when they are in use, while reappearing e-scooters in a different than the previous known location indicates a trip [24]. In this case, OD pairs can be generated for each unique ID and enriched with the haversine distance to further identify authentic trips. Furthermore, timestamp and SOC differences have been calculated.

3.2 Data processing

The preprocessing involves removing trips which fall below a distance of 150 m and those which exceed a travel time range of 120 min. This approach is methodically similar to other studies, albeit applying slightly different cutoff values [17, 24, 36]. 51.950 trips have been identified with this approach. Further steps include filtering implausible trips by calculating velocities and trip durations. A local Graphhopper implementation has been used to calculate the network distance, detour factor as well as the possible route geometry taken in the study area. A bicycle routing profile has been used on an underlying OpenStreetMap network of Dresden to calculate the traffic volumes, as the e-scooter riding behavior resembles cyclists riding behavior [37].

Mean velocity is determined by dividing the network distance by the timestamp difference. Velocities and trip durations can only be estimated within a range due to the coarse temporal scraping resolution and the ambiguity of the last activity timestamp. At the time of writing, it was not clear which kind of activity was associated with the aforementioned timestamp. Thus, exact velocities and durations cannot be specified. We discarded 823 trips, which exceeded the legal velocity limit of 20 km/h and excluded those trips whose detour factors were outside the reasonable range (1 to 3), which systematically excludes round trips, as they are not routable.

Non-user trips are defined as trips, which serve operational purposes, where e-scooters are recharged, repaired or redeployed. The former purposes are automatically excluded during the data collection process, as we assume that recharging and repairing e-scooters takes longer than two hours. The latter purpose redeploys e-scooters to strategically suitable areas where e-scooter usage is more likely. According to Reck et al., vehicle repositioning involves close placement of at least two e-scooters [38]. The exact short time span is not defined in literature, thus we define a time span of three minutes as appropriate. The process of identifying repositioning trips is structured as follows: (a) Sort scooter locations after their last activity timestamp in ascending order. (b) Measure their distance by creating lines between all sorted scooter locations. (c) Discard scooters with a distance greater than 20 m to its predecessor. (d) Create a buffer with a 10-meter radius around the remaining scooters, dissolve these buffers and intersect them with the remaining e-scooters. (e) Divide the remaining scooters into 5-minute time slices and count appearing scooters within the three-minute time span. Discard these scooters, which do not appear at least two times inside the time span. This method identified 2.206 repositioning trips.

Another part in the filtering process is the identification of round trips. Heumann et al. introduced a method in which he could identify round trips by calculating the energy consumption rate E [39]. It is defined as the change of the SOC of a trip divided by the trip length, stating the percentual change of the e-scooter battery per travelled meter [39]. Round trips are characterized by longer than average durations and its destination close to the origin [28]. The dataset would show slow average velocities, short distances and long trip times. As a result, the energy consumption rate would appear significantly higher than during a normal ride. Assuming the range of 30 km with the observed e-scooters, we use the proposed round trip threshold factor of 2.5 [39], which equates for the energy consumption rate $E < -0{,}0083\%/\mathrm{m}$ to successflly identify a trip as a round trip. This led to 14.696 identified round trips, roughly making up to 30% of all e-scooer trips. In addition, 5.303 trips showed no change in SOC due to bad data quality, making differentiating round trips impossible. This has been confirmed by several test trips during the survey period, where we ensured that a significant and measureable change in SOC will occur to monitor the API data quality. In many cases, the SOC has not been transmitted via the API. Therefore, instead of excluding round trips, we kept these trips to avoid false negative results.

The resulting e-scooter trip geometries are aggregated via the spatial “stplanr” library for R in order to obtain link wise e-scooter trip volumes. Aggregated cyclist trip data has been obtained by the annual STADTRADELN campaign over a period of three weeks, in which cyclists record their trips in a gamified, competitive fashion. Associated studies by Lißner, Huber [40] and Harten [41] describe the campaign and data acquisition in more detail. Cyclist trip data and aggregated e-scooter data is spatially joined on a link wise level.

4 Results

For the time period of 8 weeks, we aggregated spatial and temporal data for 48.921 trips, allowing a deeper insight into fundamental trip characteristics. The accuracy contains a certain amount of uncertainty as trip data was acquired at a 15-minute granularity. Figure 1 shows the distributions of all post-processed trips in respect to trip length, trip duration, trip velocity and haversine distance.

Table 1 displays aggregated routed and haversine distances, as well as trip duration and trip velocity. Given the inaccuracies of the latter two values, similarities can be seen in other study areas [36]. The majority of all trips are characterized by a rather short duration and trip length. The mean velocity remains at a low level, indicating that riders pass through many intersections in the street network.

Figure 2 shows the weekly temporal pattern of all post-processed trips. On weekdays, peaks can be seen starting at 4 AM to 5 PM. The abundance of morning peaks

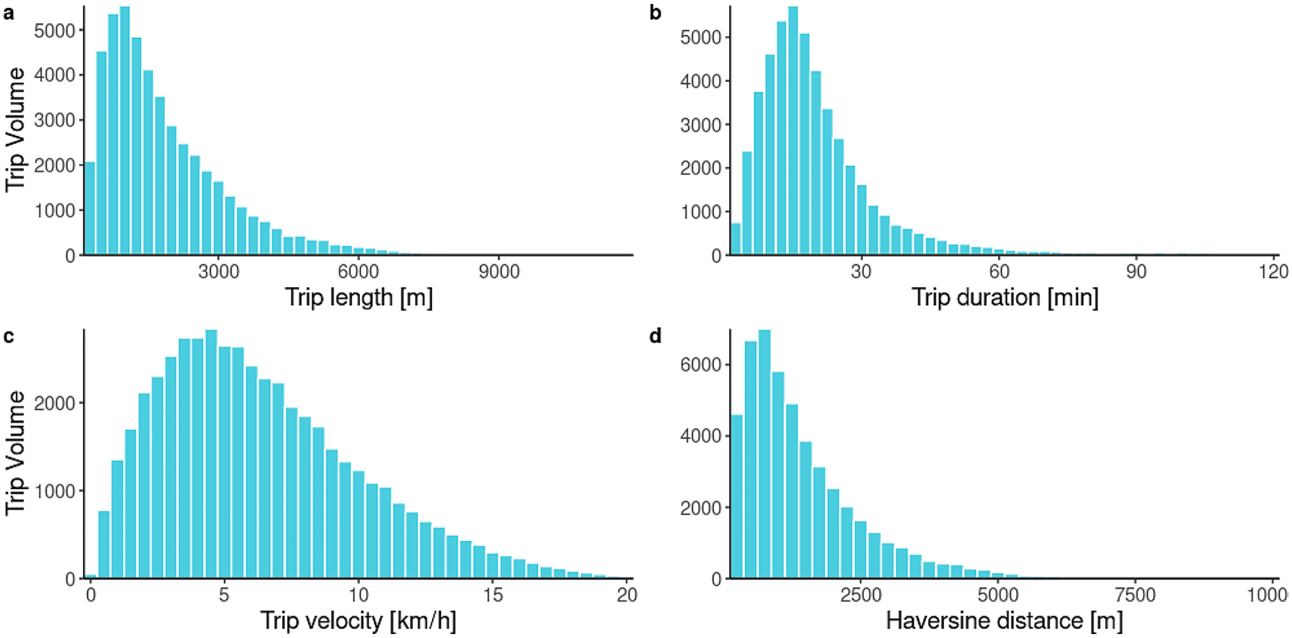

Fig. 1 Distributions of (**a**) Trip length; (**b**) Trip duration; (**c**) Trip velocity; (**d**) Haversine distance

Table 1 Descriptive statistics for acquired trips after post-processing (*n* = 48.921)

Trips	Average	Median	SD	Minimum	Maximum
Haversine distance [km]	1.45	1.13	1.12	0.15	10.01
Trip length [km]	1.87	1.49	1.38	0.15	11.72
Trip duration [min]	20.6	17.1	14.7	2.0	119.5
Trip velocity [km/h]	6.4	3.5	3.8	0.11	19.9

indicates solely casual e-scooter use. On weekends, we can observe peak shifts towards the late evening and night-time, clearly pointing out usage for leisure or nightlife purposes as it can be seen in the literature [17, 24, 28], where public transit does not satisfy trip demands, as already pointed out in a similar study conducted in Berlin [39]. This indication can be emphasized by a decrease in use on Sundays and Mondays.

4.1 Spatial distribution and comparison

As the e-scooter trip volume represents an exhaustive survey, we need to extrapolate bicycle trip volumes to match the period of 8 weeks in order to compare bicycle and e-scooter trips with each other. This is being done by an ordinary least squares model. 14 permanent bicycle counting fixtures throughout the city represent the underlying independent variables, indicating the annual daily bicycle volume per week (ADB_W). Corresponding link sections with appropriate bicycle trip volumes recorded during the STADTRADELN campaign (MOV_{21}) represent the dependent variable. After fitting the OLS model with a goodness-of-fit value of $R^2 = 0.89$, we multiply the resulting ADB_W values to match the time period of our e-scooter data set. Users of the bicycle data

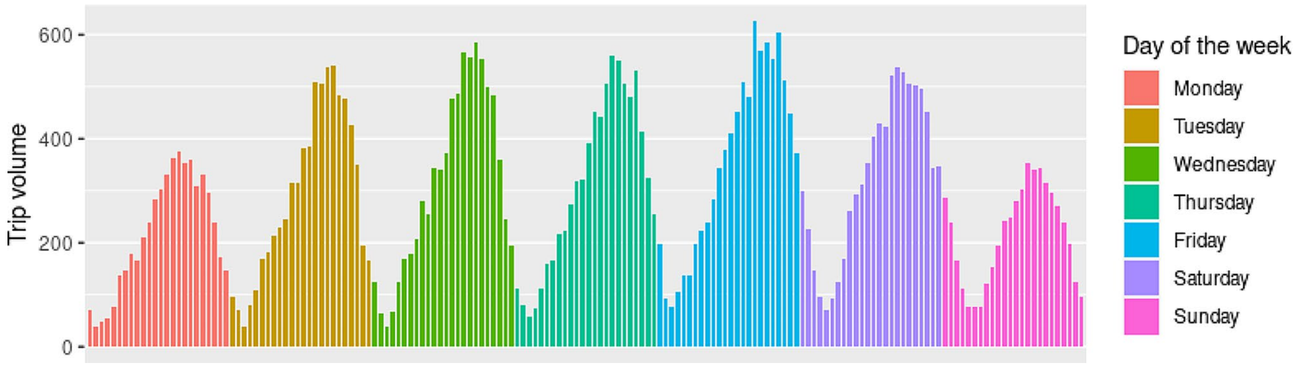

Fig. 2 Trip distribution by time of day and day of week of all post-processed trips

are representative in terms of age and gender distribution, providing a clear picture of daily bicycle users [41]. In contradiction, the socio-demographic structure of e-scooter users in Dresden is unknown. However, studies state that e-scooter riders are predominantly male and young (<40 years) [28, 32].

Figure 3 shows the percentual proportion of e-scooter trips compared to the adjusted bicycle trips. The line width is non-proportional to the actual bicycle and e-scooter trip volumes. It is noticeable that bicycles dominate on arterial roads, while e-scooter proportions appear to be significantly higher on residential roads. Popular destinations such as tourist sites, university campuses and multimodal transportation hubs lead to an increased percentage around the area.

4.2 Temporal comparison

The bicycle count data which has been used in the previous chapter will be used for the temporal analysis. To ensure consistency in the datasets, we calculated the average values for trips during weekdays (Tuesday, Wednesday, Thursday) and the weekend (Saturday, Sunday) and normalized them.

Bicycle trips peak between 7 and 8 AM and 5–6 PM during weekdays, whereas e-scooter trip usage gradually rises over the course of the day, only having a single peak in the evening. This contradicts the temporal pattern for commuter trips, indicating that e-scooters are predominately used for leisure trips. However, bicycle and e-scooter usage looks similar in the weekends. Bicycle trips peak earlier in the afternoon at 3 PM, while e-scooter trips occur more often at night and peak at 4 PM due to the indication of heavy leisure use. Figure 4 shows the temporal overlap of e-scooter and bicycle traffic during weekdays and on the weekend. These temporal patterns support the findings that e-scooters are primarily being used for leisure.

5 Discussion

5.1 E-scooter use

This study has successfully obtained e-scooter trip data via a public API. Existing and newly developed methods allowed us to generate OD data, which then was routed on a OpenStreetMap network, allowing further analysis and insights of trip characteristics of e-scooter riders on a large scale. The relative amount of e-scooters compared to bicyclists remains on a low level. It can be stated that e-scooters present a relatively small niche as opposed to everyday bicycle use. Temporal overlaps can be seen during the evening, and close to frequent spots where e-scooter rentals are more likely to occur. It should be kept in mind that, together with a steadily increase in bicycle and e-scooter ridership in the near future, insufficient street design and street space can lead to inconvenient situations where cyclists or e-scooter riders can get displaced on paths not designed nor intended for their use, creating potential conflicts with vulnerable road users.

5.2 Implications for street design

The majority of German on-street cycleways are not sufficiently dimensioned or missing at all. Due to the

Fig. 3 Percentual proportion of e-scooter traffic

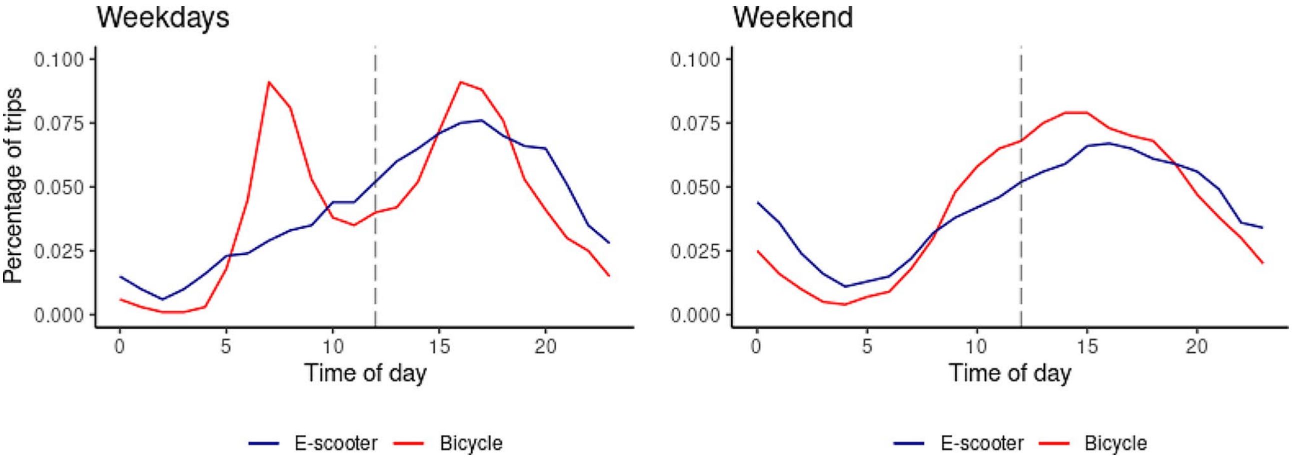

Fig. 4 Percentual proportion of e-scooter traffic

differing riding dynamics and speed limitations, bicyclists have to overtake e-scooters more often and safely, thus taking up space, which is usually reserved for motorized traffic [2]. Road segments with increased demand of bicycle and e-scooter traffic should provide more space and protection against unauthorized use by cars, which could obstruct and endanger both cyclists and e-scooter riders. Such measures to protect both cyclists and e-scooter riders could include sufficient space allocation in combination with protective elements, making cycleways impassable for cars. Residential roads though pose different challenges, as many factors can contribute to potential conflicts, especially on walkways and at intersections, which are prone to accidents [16]. Identified critical links can help policymakers to redesign these in order to accommodate safe mixed traffic.

5.3 Limitations and biases

Routing OD pairs is heavily biased, as the algorithm favors the shortest or the fastest route. As opposed to revealed-preference methods, contributing factors for e-scooter route choice are not known in this study and are not yet available. Further studies are needed to analyze contributing route choice factors for e-scooter riders in order to generate a reliable route choice model for future research. Similar studies, which developed e-scooter route choice models such as Zhang et al. cannot be applied on citywide level, as they conducted their research on a university campus [37]. The results might be skewed because the methods have been applied to a single city. Conducting a comparative study across multiple cities in Germany would offer more comprehensible results. Data quality during the acquisition is an issue as well, as the API is not prone to erroneous data outputs. Additional data sources such as standardized data feeds should be considered. Extrapolation of bicycle trip volumes is also biased towards major arterial roads, as the study area does not provide automatic counting stations on minor or residential roads.

6 Conclusion

E-scooter use is on the rise in many major cities in Europe, Asia and the US, providing an additional way of transport with a low land use footprint. Although the infrastructure development lags behind current demands, taking slow leaps forward, this study can help to analyze areas of high demand as well as potential conflict zones, using open data. This approach is applicable in multiple cities throughout Germany if appropriate e-scooter route choice models can be used, making comparisons possible. A naturalistic GPS-based revealed-preference study can further enhance the understanding of e-scooter riders' route and infrastructure choice preferences, decreasing inaccuracies in routing OD pairs over the shortest route and quantifying illegal sidewalk usage. Combining these insights with existing accident data can help identify conflict zones and strengthen the quality of information about these zones within the street network.

The results indicate that residential areas as well as cycleways on arterial roads accommodate e-scooters together with cyclists, whereas interactions have to be observed in respect to potential conflicts. In conclusion, the data driven identification of segments of interest can be vital for allocating road space in favor of vulnerable road users, making overall bicycle and e-scooter travel safer.

Author contributions

Equal contribution Iwan Porojkow: conceptualization, data analysis, conclusion Dr. Sven Lissner: literature review, conceptualization, writing.

Funding

This research has received funding from the mFUND research initiative by the German Federal Ministry for Digital and Transport (BMDV). The results were presented at the Transport Research Arena (TRA) Conference in Lisbon, Portugal, November 14-17.

Open Access funding enabled and organized by Projekt DEAL.

Data availability

The dataset supporting the conclusions of this article is available in the Mobilithek, https://mobilithek.info/offers/537343263319699456.

Declarations

Consent for publication

Not applicable.

Competing interests

There are no competing interests.

Received: 28 March 2023 / Accepted: 24 May 2024

References

1. Tack, A., Klein, A., & Bock, B. (2020). E-Scooters in Germany: A data-driven contribution to the ongoing debate. https://scooters.civity.de/en.
2. Agora Verkehrswende (2019). E-Tretroller im Stadtverkehr, Berlin. https://www.agora-verkehrswende.de/veroeffentlichungen/e-tretroller-im-stadtverkehr/.
3. Kazemzadeh, K., Haghani, M., & Sprei, F. (2023). Electric scooter safety: An integrative review of evidence from transport and medical research domains. *Sustainable Cities and Society*, *89*, 104313. https://doi.org/10.1016/j.scs.2022.104313.
4. Šucha, M., Drimlová, E., Rečka, K., et al. (2023). E-scooter riders and pedestrians: Attitudes and interactions in five countries. *Heliyon*, *9*, e15449. https://doi.org/10.1016/j.heliyon.2023.e15449.
5. France 24 (2023). Paris ban of 'nuisance' electric scooters comes into effect: Paris will on Friday become the first European capital to ban floating electric scooters from its streets, leaving fans desolate but relieving those who loathed their nuisance factor. https://www.france24.com/en/live-news/20230828-paris-bids-adieu-to-love-or-hate-electric-scooters.
6. Moran, M. E., Laa, B., & Emberger, G. (2020). Six scooter operators, six maps: Spatial coverage and regulation of micromobility in Vienna, Austria. *Case Studies on Transport Policy*, *8*, 658–671. https://doi.org/10.1016/j.cstp.2020.03.001.
7. Štraub, D., & Gajda, A. (2020). E-scooter sharing schemes operational zones in Poland: Dataset on voivodeship capital cities. *Data in Brief*, *33*, 106560. https://doi.org/10.1016/j.dib.2020.106560.
8. Bach, X., Miralles-Guasch, C., & Marquet, O. (2023). Spatial Inequalities in Access to Micromobility Services: An Analysis of Moped-Style Scooter Sharing Systems in Barcelona. Sustainability 15:2096. https://doi.org/10.3390/su15032096.
9. Bai, S., & Jiao, J. (2020). Dockless E-scooter usage patterns and urban built environments: A comparison study of Austin, TX, and Minneapolis, MN. *Travel Behaviour and Society*, *20*, 264–272. https://doi.org/10.1016/j.tbs.2020.04.005.
10. Hosseinzadeh, A., Algomaiah, M., Kluger, R., et al. (2021). Spatial analysis of shared e-scooter trips. *Journal of Transport Geography*, *92*, 103016. https://doi.org/10.1016/j.jtrangeo.2021.103016.
11. Shaheen, S., & Cohen, A. (2019). Micromobility Policy Toolkit: Docked and Dockless Bike and Scooter Sharing. Institute of Transportation Studies, Berkeley. https://escholarship.org/uc/item/00k897b5.
12. Gössling, S. (2020). Integrating e-scooters in urban transportation: Problems, policies, and the prospect of system change. *Transportation Research Part D: Transport and Environment*, *79*, 102230. https://doi.org/10.1016/j.trd.2020.102230.
13. DuPuis, N., Griess, J., & Klein, C. (2019). Micromobility in Cities: A History and Policy Overview. https://www.nlc.org/wp-content/uploads/2019/04/CSAR_MicromobilityReport_FINAL.pdf.
14. Scott Smith, C., & Schwieterman, J. P. (2018). E-Scooter Scenarios: Evaluationg the Potential Mobility Benefits of Shared Dockless Scooters in Chicago. https://www.researchgate.net/publication/330093998_E-Scooter_Scenarios_Evaluating_the_Potential_Mobility_Benefits_of_Shared_Dockless_Scooters_in_Chicago.
15. (2019). Verordnung über die Teilnahme von Elektrokleinstfahrzeugen am Straßenverkehr: Elektrokleinstfahrzeuge-Verordnung - eKFV. https://www.gesetze-im-internet.de/ekfv/BJNR075610019.html.
16. Ziedan, A., Shah, N. R., Wen, Y., et al. (2021). Complement or compete? The effects of shared electric scooters on bus ridership. *Transportation Research Part D: Transport and Environment*, *101*, 103098. https://doi.org/10.1016/j.trd.2021.103098.
17. Younes, H., Zou, Z., Wu, J. (2020). Comparing the Temporal Determinants of Dockless Scooter-share and Station-based Bike-share in Washington, D.C. Transportation Research Part A: Policy and Practice 134:308–320. https://doi.org/10.1016/j.tra.2020.02.021.
18. Arellano, J. F., & Fang, K. (2019). Sunday Drivers, or Too Fast and Too Furious? Findings. https://doi.org/10.32866/001c.11210.
19. Angela Francke, S. (2018). Lissner Big Data in Bicycle Traffic. Technische Universität Dresden. https://tu-dresden.de/bu/verkehr/ivs/voeko/ressourcen/dateien/forschung/nrvp_gps/20171214_Guideline_WEB_Engl_final.pdf.
20. Reck, D. J., & Axhausen, K. W. (2021). Who uses shared micro-mobility services? Empirical evidence from Zurich, Switzerland. *Transportation Research Part D: Transport and Environment*, *94*, 102803. https://doi.org/10.1016/j.trd.2021.102803.
21. Wang, K., Qian, X., Fitch, D. T., et al. (2023). What travel modes do shared e-scooters displace? A review of recent research findings. *Transport Reviews*, *43*, 5–31. https://doi.org/10.1080/01441647.2021.2015639.
22. Degele, J., Gorr, A., Haas, K. (2018). Identifying E-Scooter Sharing Customer Segments Using Clustering. In: 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC). IEEE, pp 1–8.
23. Mehzabin Tuli, F., Mitra, S., & Crews, M. B. (2021). Factors influencing the usage of shared E-scooters in Chicago. *Transportation Research Part A: Policy and Practice*, *154*, 164–185. https://doi.org/10.1016/j.tra.2021.10.008.
24. McKenzie, G. (2019). Spatiotemporal comparative analysis of scooter-share and bike-share usage patterns in Washington, D.C. *Journal of Transport Geography*, *78*, 19–28. https://doi.org/10.1016/j.jtrangeo.2019.05.007.
25. Merlin, L. A., Yan, X., Xu, Y., et al. (2021). A segment-level model of shared, electric scooter origins and destinations. *Transportation Research Part D: Transport and Environment*, *92*, 102709. https://doi.org/10.1016/j.trd.2021.102709.
26. Li, A., Zhao, P., Liu, X., et al. (2022). Comprehensive comparison of e-scooter sharing mobility: Evidence from 30 European cities. *Transportation Research Part D: Transport and Environment*, *105*, 103229. https://doi.org/10.1016/j.trd.2022.103229.
27. Ali, S., & Peci, G. (2022). Usage patterns and environmental effect analysis of e-scooter sharing system: A case study in Gothenburg, Sweden. Masters thesis, Chalmers University of Technology. https://odr.chalmers.se/items/71bcb5f4-7260-45f3-a2c6-a7864f2e1241.
28. 6t-bureau de recherche (2019). Uses and Users of Free-floating Electric Scooters in France.
29. Corcoran, J., Li, T., Rohde, D., et al. (2014). Spatio-temporal patterns of a public bicycle sharing program: The effect of weather and calendar events. *Journal of Transport Geography*, *41*, 292–305. https://doi.org/10.1016/j.jtrangeo.2014.09.003.
30. Zuniga-Garcia, N., Ruiz Juri, N., Perrine, K. A., et al. (2021). E-scooters in urban infrastructure: Understanding sidewalk, bike lane, and roadway usage from trajectory data. *Case Studies on Transport Policy*, *9*, 983–994. https://doi.org/10.1016/j.cstp.2021.04.004.
31. Caspi, O., Smart, M. J., & Noland, R. B. (2020). Spatial associations of dockless shared e-scooter usage. *Transportation Research Part D: Transport and Environment*, *86*, 102396. https://doi.org/10.1016/j.trd.2020.102396.
32. Laa, B., & Leth, U. (2020). Survey of E-scooter users in Vienna: Who they are and how they ride. *Journal of Transport Geography*, *89*, 102874. https://doi.org/10.1016/j.jtrangeo.2020.102874.
33. Gibson, H., Curl, A., & Thompson, L. (2022). Blurred boundaries: E-scooter riders' and pedestrians' experiences of sharing space. *Mobilities*, *17*, 69–84. https://doi.org/10.1080/17450101.2021.1967097.
34. Hatfield, J., & Prabhakharan, P. (2016). An investigation of behaviour and attitudes relevant to the user safety of pedestrian/cyclist shared paths. *Transportation Research Part F: Traffic Psychology and Behaviour*, *40*, 35–47. https://doi.org/10.1016/j.trf.2016.04.005.
35. Creutzig, F., Javaid, A., Soomauroo, Z., et al. (2020). Fair street space allocation: Ethical principles and empirical insights. *Transport Reviews*, *40*, 711–733. https://doi.org/10.1080/01441647.2020.1762795.
36. Zou, Z., Younes, H., Erdoğan, S., Washington, D. C. (2020). *Transportation Research Record* 2674:285–299. https://doi.org/10.1177/0361198120919760.

37. Zhang, W., Buehler, R., Broaddus, A., et al. (2021). What type of infrastructures do e-scooter riders prefer? A route choice model. *Transportation Research Part D: Transport and Environment*, *94*, 102761. https://doi.org/10.1016/j.trd.2021.102761.
38. Reck, D. J., Haitao, H., Guidon, S., et al. (2021). Explaining shared micromobility usage, competition and mode choice by modelling empirical data from Zurich, Switzerland. *Transportation Research Part C: Emerging Technologies*, *124*, 102947. https://doi.org/10.1016/j.trc.2020.102947.
39. Heumann, M., Kraschewski, T., Brauner, T., et al. (2021). A spatiotemporal study and location-specific trip pattern categorization of Shared E-Scooter usage. *Sustainability*, *13*, 12527. https://doi.org/10.3390/su132212527.
40. Lißner, S., & Huber, S. (2021). Facing the needs for clean bicycle data – a bicycle-specific approach of GPS data processing. *Eur Transp Res Rev* 13. https://doi.org/10.1186/s12544-020-00462-2.
41. Maike von Harten, & Lissner, S. (2021). Stefan Huber Mobilität von Radfahrenden in Deutschland -Nutzerbefragung im Rahmen der Kampagne Stadtradeln. https://www.researchgate.net/publication/350544756_Mobilitat_von_Radfahrenden_in_Deutschland_-Nutzerbefragung_im_Rahmen_der_Kampagne_Stadtradeln.

Publisher's Note