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Usage of e-Scooters in Urban Environments

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Abstract

Since the introduction of the internal combustion engine (ICE), modern mobility has fundamentally changed. Today, it is impossible to imagine modern transportation without motorized vehicles. Powered Two-Wheelers (PTWs) represent a relevant section of such vehicles. In recent years, electric low-powered PTWs, also called e-scooters, became a notable trend. Without excessive emissions and noise, as well as convenient dimensions, e-scooters can help European cities ease their increasing problems with traffic, emissions, and parking. In this paper, we present the results of a real-life field test, performed in the City of Munich, Germany. By providing six vehicles, 38 subjects were able to incorporate an e-scooter into their everyday lives. Recorded with travel diaries and a pre-post-survey, usage and attitudes were evaluated. Results show that a majority of daily trips is suitable for e-scooters and charging infrastructure is sufficient for this kind of vehicle, while subjective safety, weather conditions, and baggage capacity are restricting attributes.

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1. Introduction

One of the basic human needs is transportation. Mobility allows us to take advantage of life and its possibilities. However, mobility does have its drawbacks, particularly in urban environments, where plenty of people utilize mobility options simultaneously. Poor air quality, traffic congestions, and lack of parking are a result of growing mobility needs. In order to solve these problems without imposing severe restrictions in personal mobility, alternatives to cars, powered by internal combustion engines, are necessary. One of these alternatives are electric-Powered Two-Wheelers (ePTWs). Unlike their conventionally powered counterparts, these vehicles utilize batteries and an electric

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powered drivetrain. Within the last two decades, development of this type of vehicles yielded models that are usable in urban environments, with Chinese manufacturers leading in this sector. In the European market, however, high-powered two-wheelers (motorcycles) dominate. With the availability of e-scooters, this could change. Due to their favorable properties, e-scooters could help to reshape current mobility and solve resulting problems in urban settings. In order to contribute to the subject and to investigate the potential of e-scooters as well as possible constraints and acceptance among users, a pilot study in the city of Munich, Germany was conducted. Therefore, groups of users were supplied with a vehicle and usage was recorded using travel diaries. Furthermore, participants of this pilot study were surveyed before and after the test in order to measure shifts in attitudes towards usage, usability, and vehicle features.

This paper is structured as follows: Section 2 presents the current state of literature. Section 3 summarizes the vehicle class of e-scooters. In Section 4 the design of the conducted pilot study is described. Results are presented in Sections 5 and 6. Finally, conclusions and future work are given in Section 7.

2. Literature Review

Since literature about e-scooters is scarce and predominantly covers the situation and development in China, where vehicles of this type are popular among city dwellers, here a general overview over existing literature about ePTWs is presented. One of the first analyses of ePTWs and its usage is presented in Weinert et al. (2008). In this paper, a broad introduction of the Chinese market, regulatory distinctions of PTWs in China, and industry development is given. According to this research, driving forces behind the success of ePTWs in the Chinese market are: cost and performance improvements, motorcycle bans due to deteriorating air quality and traffic conditions, local policy support towards electric ePTWs, and poor bus public transit service. In total, such a traffic environment encourages the purchase and usage of ePTWs and eBikes. In contrast, a strong demand for high-powered motorcycles, comprehensive bans of PTWs, and the support for public transit are resisting forces towards the usage of ePTWs.

A more usage centered analysis of eBikes in Chinese cities is presented by Cherry and Cervero (2007), where a survey among bike, eBike and liquefied petroleum gas (LPG) scooter users was conducted. The survey was conducted in Kunming and Shanghai in spring 2006 and focused on user characteristics and differences in usage between them (Shanghai is the only city known to have a relevant share of LPG scooters). The results indicate that people with above-average education and household income incorporate eBikes and LPG scooters as their most desired form of transportation in their daily lives. These vehicles are more affordable for this demographic, which allows them to upgrade from bike to eBike or eBike to LPG scooter. Furthermore, the analysis also demonstrates that many use eBikes and LPG scooters as a “second vehicle” in their household. Main reasons for this upshift in mobility are given by speed, less effort, economic costs of operating compared to cars, safety and avoidance of overcrowded low quality public transit systems. It is concluded, that bans on eBikes, as imposed in some cities in China would shift traffic towards already over-subscribed public transit as well as to automobile usage. A general overview of the market situation, especially in China, is given by Fu (2013). Alongside the market analysis, technological developments and employed technique relevant in this sector are presented as well as the various regulatory policies and classifications around the world. As one of few sources, the new regulatory standards of eBikes and ePTWs, introduced 2013 in China, are described. In order to evaluate the global ePTW market, Hurst and Gartner (2012) presented a market analysis and clarified the differences between the markets in Asia, North America, and Europe. The given forecast estimates China and India as the largest markets for low-powered ePTWs in 2018, expecting 12.4 million units to be sold in China and 1.1 million units to be sold in India. After all, Asia Pacific and especially China are expected to keep the position as key market for ePTWs. One of the first studies about PTW usage in European cities is presented by Kopp (2011) where the development of PTW usage in the city of Paris, France is analyzed. Findings indicate a rise in travelled passenger-kilometers by 36% between 2000 and 2007, adding to a share in road traffic of up to 17%. Surveying PTW users, the prevailing reason for using PTWs was commuting (>90%), making it the most relevant trip purpose. Another approach to understand usage of PTWs especially in western countries is presented by Thompson and Rose (2013). PTW usage in the Central Business District (CBD) of Melbourne, Australia was analyzed incorporating data from a parking patrol conducted on one day in 2011, which revealed that in the CBD of Melbourne sports bikes and scooters are the predominant types of PTWs observable. By analyzing registered addresses, trip distances were estimated, revealing that Scooters travelled significantly shorter distances than other PTW types.

The influence of national and regional policies on the adoption of electric vehicles is analyzed by Yang (2010). Here, the successful deployment of regional policies to foster growth in ePTW usage in China is portrayed, as well as the contrasting development in Taiwan. Therefore, a program to promote and subsidize low-powered ePTWs was commenced in 1998, spending NT$ 1.8 billion, which included tax reductions for manufacturers of ePTWs, subsidies for charging facilities, and rebates for buyers up to 50% of the retail price. However, there were neither bans nor other restrictions on gasoline-powered PTWs. In 2002, this program was discontinued due to the lack of success. The reasons for the failure are stated as insufficient quality of the products, retailers' fear of damaging their reputation due to the inferior quality, missing willingness of consumers to substitute gasoline-powered PTWs with their electric counterparts, and the absence of bans, usage constraints, or relevant savings when switching to electric PTWs.

3. Vehicles Class & Market Review

Powered Two-Wheelers (PTWs) is a wide-ranging category of vehicles, stretching from eBikes to high-powered motorcycles. While the nomenclature within the domain of PTWs is rather inconsistent, this article addresses the subclass of low-powered PTWs, also called mopeds or scooters, which are characterized by their maximum continuous rated power of no more than 4kw and a maximum speed of 45 km/h (30 mph), as defined in the EU-Regulation No 168/2013 as vehicle class L1e-B. Electric propelled versions of such vehicles will be addressed as e-scooters throughout this article. Nonetheless, definitions of this vehicle type does differ to some extend by country. Distribution of PTWs in general is quite diverse, based on the specific location. The European market in 2014 consisted of over 23.3 million motorcycles and about 9.7 million scooters (category L1e-B), while passenger cars accounted for about 252 million vehicles (ACEA, 2016; ACEM, 2015a). Thus, PTWs in general accounted for 11.5% in the European passenger-vehicle mix in 2014. Another picture emerges when studying the situation in Asian countries. Sales estimates of PTWs in China and India for 2015 were at over 20 million and over 13 million PTWs, respectively, in just one year (ACEM, 2015b). This mobility shift from walking, bicycling, or public transport to PTW usage, caused by urbanization, increasing income, and poor public transit options, encourages traffic congestions, air pollution, and increasing road safety concerns in urban areas. Since these points are crucial for urban development and public health, several city administrations in China started to ban gasoline-powered PTWs. In 2006, over 148 cities in China had installed bans or restrictions on such motorcycles (Weiss, Dekker, Moro, Scholz, & Patel, 2015). Since efforts in research and development were fostered by the initiation of electric mobility into the Chinese national five-year-plan (Weinert, Ma, & Cherry, 2007), the trend of e-scooters grew in China. Within the last years, mobility sharing systems emerged in several cities and offered car, bike, and e-scooter usage based on different time or distance based pricing systems (Hardt & Bogenberger, 2016). With ScootNetworks in San Francisco, emmy in Berlin, Scoo.me in Munich, Cityscoot in Paris, Motit in Barcelona and SCO2T in Vienna, COUP started in Berlin in 2016 and Paris in 2017. These systems offer a short-term rental for vehicles with various return locations and thereby providing mobility when public transit or owning a vehicle are not a sufficient option.

4. Pilot Study Design

While e-scooter usage in Chinese cities is thriving, usage in European metropolises is rather restrained. In order to learn about potential usage, user acceptance and attitudes towards e-scooters and the possible application in sharing systems, a field test was conducted between May and July 2016 in Munich, Germany, a city with a population of over 1.5 million and an area of about 310 km². The city provides different public transportations systems, like a subway system, tram lines, an extensive bus system, and a light rail system. Due to the focus on sharing and the restrains on the number of vehicles, this field test was designed as a group test.

Subjects were invited by email and online. Prerequisites to participate were given: minimum number of group members by three, a minimum age of 18, drivers license class B, as well as a shared venue in the Munich area in order to have a common place to exchange keys and to recharge batteries. To this end, seven groups volunteered, and subsequently six were chosen based on the number of participants. With 38 participants in total, the smallest test group comprised of three members, while the largest group comprised of 10 members. Average age of the participants was 37 years, and 86% of users were male. Since one of the groups struggled to use the provided vehicle due to an unsuitable seat height (85 cm) and missing experience with PTWs, five groups remained for analysis with 35 participants. All groups were equipped with an e-scooter, batteries, chargers, fitting helmets, and trip diaries. The e-scooter chosen for this field test was the “Kumpan electric 1954 L”, since it satisfied all given requirements best. This model can hold two passengers, yields a range of 80 to 100 km, has a top speed of about 48 km/h, and provides outside and inside charging. Vehicles were provided for an average duration of 8 weeks, although different damages occurred and had to be repaired, narrowing the availability down to 6.5 weeks on average. To gather data, testers were obliged to keep a trip diary when using the vehicle, filling in times of departure and arrival, trip purpose, and mileage. Trip purposes were defined according to the work of Pitterle et al. (2010).

5. Usage

Overall, the e-scooters were given to the test groups for usage for an average of 56 days. Over the course of the field test, different damages and technical issues accrued needing repair and thereby shortening the time available to 45 full days on average. As can be seen in Table 1, activity, defined by days with at least one trip, ranges from low 29% up to 81%. The average activity of all vehicles was 52.2 %. In these days of activity, vehicles were used to cover an average of 22.2 km per day. Total mileages ranged from 186 km up to 807 km. As to be seen in Table 1, the least active vehicle (group 5) also was used with the most amount of mileage per day. We expect this to be the result of usage on a route to long to be convenient to ride with an e-scooter, and therefor was discontinued after several tries. The data from the trip diaries revealed detailed usage, particularly trip purposes and trip distances, as well as activity on user level. While analyzing trips completed with the e-scooters, we made a distinction between trips made in total, trips per active days, and trips made per days available. With 49 trips on average, vehicles were utilized 2.09 times per active day and 1.1 times per days available, as can be seen in Table 2. While utilized these vehicles covered 11.2 km per average trip, with variation from 6.4 to 19.5 km. Predefined trip purposes were given as shown in Fig.1b.

Table 1. Activity by Group

group	test days	days avail.	days active	activity rate	mileage in km	mil. per act. day
1	58	46	28	61 %	510	18.2
2	53	45	24	53 %	594	24.8
3	43	43	16	37 %	186	11.6
4	59	42	34	81 %	807	23.6
5	63	52	15	29 %	506	33.7
avg.	56	45.6	23.4	52 %	520.6	22.2

Table 2. Trips by Group

group	mileage in km	trips	avg. km per trip	trips per active day	trips per day avail.
1	510	49	10.4	1.8	1.1
2	594	65	9.1	2.7	1.4
3	186	29	6.4	1.8	0.7
4	807	76	10.6	2.2	1.8
5	506	26	19.5	1.7	0.5
avg.	520.6	49	10.6	2.09	1.1

Two main purposes of usage stand out: commuting on the one hand, and leisure activities on the other hand. Shopping and running errands seems to be underrepresented with just 8% and 6% respectively, though. In order to compare these results in terms of correctness or deviation from other modes of transport, research is sparse. After all, the MiD survey, a quinquennial nationwide representative survey of traffic behaviour in Germany with several additional regional studies, and the evaluation for Munich (Pitterle et al., 2010) in particular, was chosen. Although, the data from this study refers to mobility patterns of persons, while our data refers to mobility data of vehicles, yet it is the most useful dataset available at this time and therefore is incorporated. Therein, the distribution of trip purposes is composed of 33% leisure trips, 24% shopping related trips, 19% commuting trips, and 12% errand trips. Business trips only account for 5% of all trips while pickup/drop-off accounts for 7%. Comparing our results with these shares, leisure trips are close to these numbers with 31%. The largest share of trips in this pilot study were commuting trips. Comparing these shares, a prevalence of these trips is apparent. However, due to the test environment, this deviance is explainable since common venues were workplaces; a likely reason to explain deviances in business trips, too. The disparity in shopping trips and running errands, however, are quite unusual and there seems to be no explanation for it, since parking with an e-scooter in downtown Munich should be rather easy. Comparing the average distances travelled as seen in Fig. 2a, apart from business trips and shopping, results are close to the data given by MiD (data was calculated from times and ranges given in the study). While business trips often aim for other cities and locations too far to ride with an e-scooter, thereby explaining the difference shown, the low share in shopping trips within the

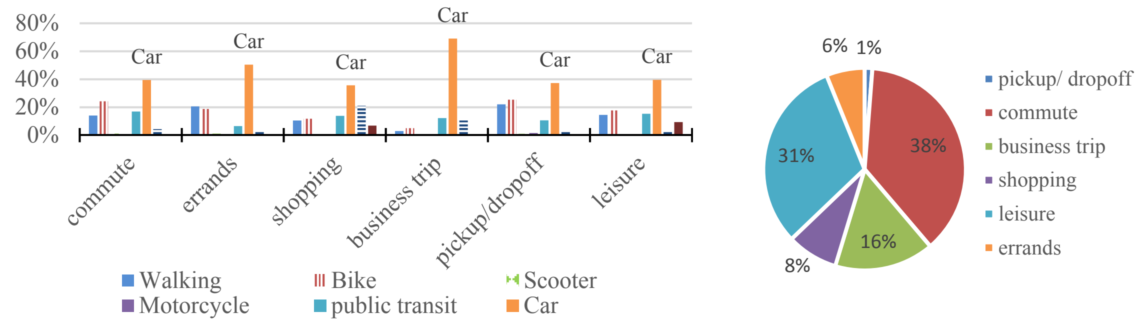

Fig.1. (a) trip purposes and mode of transportation; (b) trip purposes.

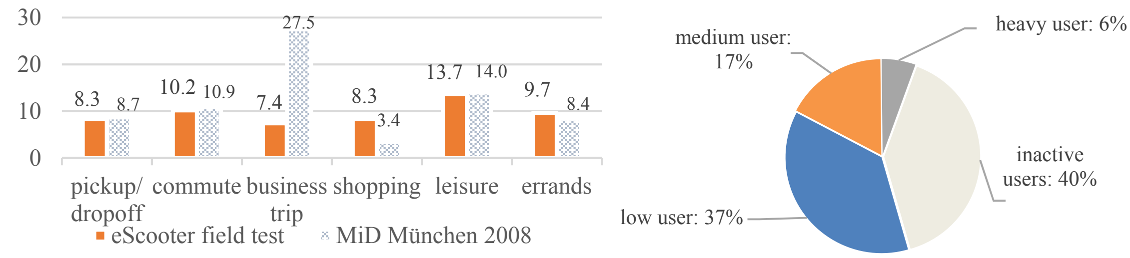

Fig. 2. (a) average distances travelled per trip purpose in km; (b) Distribution of Users.

data could be a reason deviations appearing in this comparison. Analyzing the trip diary data on a user level, an interesting pattern emerges. While 35 participants remained after removing the inactive group, these users incorporated the supplied e-scooter quite differently. Of those 35 users, just 60% (21 users) rode the vehicle after all, as could be detected by the drip diary entries. As depicted in Fig. 2b, 40% of users were not active after the instructional course, while 37% incorporated the e-scooter rarely. Just a quarter of participants utilized the vehicle often or very often (more than 15 trips, or 25 respectively). After all, anecdotal evidence revealed, that some users were keener to participate in this pilot study than others and therefore urged other users to participate. While the former are to be expected in the class of heavy or medium users, latter are assumed to range in the other classes. With this kind of distribution of users within a pilot study where users had to actively apply to, it can be concluded, that within the group of those who are showing basic willingness to test e-scooters, about one out of four embraces this form of mobility and adapted their daily mobility patterns towards the vehicle. Another third is not as vivid in usage, but was willing to test the supplied vehicles. Although, due to the small number of subjects, the results given here are not representative for the population of Munich, but give an first impression about the potentials of such type of vehicle.

6. Pre-Post Survey

Alongside the trip diary analysis, users were surveyed before and after the pilot study. With this longitudinal survey, effects of the pilot study on attitudes towards electric vehicles, and especially e-scooters, are supposed to be measured. Furthermore, they give insights into preconditions of subjects as well as available travel options, on how these serve different trip purposes and thereby generate daily travel routines of researched subjects. Since this pilot study was about PTWs, drivers licenses are a good indicator of two-wheeler fondness. The implemented pre-test part of the survey was completed by 42 subjects (four subjects finally did not take part in the pilot study). Among these respondents, all had a drivers license class B (class B: 100%). Furthermore, 43% of respondents stated to hold a drivers license class A (motorcycles), and two more respondents stated to hold license class A1, adding up to 48% of respondents who are permitted to ride PTWs with cylinder capacities up to 125cc. Compared to general statistics for Germany (VuMA, 2017), the number of PTW-license holders is highly overrepresented, although it was to be expected, that persons open to PTW-usage are more likely to participate. Asked for preexisting experience with PTWs, 76% of respondents stated some experience with scooters, while 38% stated experience with motorcycles. The same question was asked referring to electric vehicles. While 62% of respondents already drove an electric car, 58% of those even more than 8 times, only 20% (8) of respondents had some experience with ePTWs. In order to learn about the participants' daily mobility, the survey asked for the relation of trip purposes and mode of transport. Results are depicted in Fig. 1a. It is noticeable, that car usage is the dominant mode of transport, while PTW-usage is nothing but a side issue. Especially the two main trip purposes, commuting and leisure trips as derived from the trip diaries, as well as the block of business trips could profit from substituting car usage with e-scooters. In order to learn about trips that are not suitable to be substituted by e-scooters, respondents were asked, how often they were en route with other people. Results show that 86% of commuting trips are suitable for e-scooters with one seat, and 97 % for two-seater scooters. Leisure trips are suitable as well, with rates of 28% and 67%, with one seat or two seats respectively. Furthermore, 19.6% of the trips were not suitable due to cargo restrictions. Analyzing changes in attitudes towards ePTW usage, features, and usability, an online pre-post-survey was conducted among participants. In Fig. 3a, 3b, and 4, approval to the statements, based on a 7-point Likert scale, is depicted as averages of pre-test and post-test, as well as changes in these averages, sorted by amount of change of approval rates. As can be seen in Fig. 3a, usage of the vehicles changed attitudes towards usage in context of city settings. As expected beforehand, working with such vehicles raises attention towards them and therefore making participants more likely to notice these vehicles more often in their surroundings. Despite slightly increased, attitudes towards the idea of low-powered ePTWs disrupting "normal" traffic flow remained indecisive. This result seems to depend strongly on the context of usage. While around 50% of users answered with some level of disagreement, 25% answered in the agreement range. Asked for the advantageousness of these vehicles in the inner city, strong approval was given, with a light decrease compared to pre-test results. The time advantages due to usage of the vehicles in rush hour traffic turned out to be not as high as expected. Both statements towards possible enhancements of traffic laws regarding permitted vehicle top speed as well as adaptions of one of the main rings in Munich's road grid were conceived as opportunities to ease usage and acceptance. In summary, it can be concluded that by supplying such vehicles for testing, attention towards such vehicles in general can be raised, and users can confirm positive aspects of usage as well as disprove misconceptions like rush hour bypassing opportunities. Furthermore, administrative barriers like usage restrictions on road types or top speed limitations on vehicles can be evaluated first hand. Based on participants' experience, these barriers disrupt easy usage. Abandoning usage restrictions as well as raising speed limitations on these vehicles could have a strong positive influence on vehicle deployment and acceptance. Further, participants were asked for their approval of statements concerning charging, as seen in Fig. 3b. Participants found charging rather simple, although the supplied vehicles had two 10kg batteries, which had to be manually connected via power plugs. They were asked to evaluate the suitability of charging duration towards personal mobility needs, a slight increase between pre-test and post-test results was measured, although leaving agreement in the mid-range. Handling of batteries, as well as charging duration and frequency seems to be an important issue, although different models on the market do not differ sufficiently. Asked for assessment of charging costs, participants rejected the statement about high charging costs, although an increase between pre-test and post-test results is noticeable. This increase is expected to be a result of charging counts, due to range anxiety, leading to shorter charging intervals. The change in approval of the statement about the number of charging points being sufficient is remarkable. While pre-test answers predominantly rejected the statement, in the post-test assessment this rejection decreased significantly. By utilizing electric vehicles, the often-claimed lack of charging points is put to the test, since participants had to deal with it firsthand and thereby recognized that this claim is not as urgent as expected. It can be concluded, that charging technique and convenience are key components for further development in this vehicle class. Furthermore, assessment of charging cost does not deliver a clear picture. In Fig. 4 approval to statements about usage of the supplied vehicles is depicted. As can be seen, handling and learning to handle such a vehicle are assessed as easy. Asked if participants agree upon the fun of riding an e-scooter, a negative change is recorded. Since almost half of participants owned a drivers license for larger motorcycles, this result can have two different reasons. For one, expected joy of driving could have been interfered by experienced road situations being more stressful. Apart from that, people with licenses for high-powered vehicles could have missed the excitement of faster speeds. Assessment of weather influence, even rated high before the test, was rated even higher in post-test assessments, confirming the high influence of weather conditions on usage acceptance of two-wheeled vehicles. Here, rain gear and cold weather gear can be a solution. Two points vital in order to foster ePTW usage are subjective safety and baggage capacity. Subjective safety is an issue treated by traffic regulations and its enforcement, while the issue of baggage capacity has to be addressed by manufacturers. Both issues influence willingness to use these vehicles in everyday life. Eventually, participants were asked to assess parking capabilities of the supplied vehicles. As to be expected, one of the main advantages of PTWs in general and small e-scooters in particular is the ability to find a parking spot. Since there are barely no parking restrictions on this type of vehicle, finding a parking spot is one of the main advantages these vehicles have in a city like Munich. In conclusion, usage of these vehicles is easy and learning to ride them is simple. While finding a parking spot is a main advantage, baggage capacity, subjective safety, and weather influence are issues to be addressed when encouraging usage of this type of vehicles. With the described test procedure, it is possible to raise attention to this vehicle type, decrease fear of missing charging infrastructure, and help to evaluate usage and restrictions on issues like range and weather conditions.

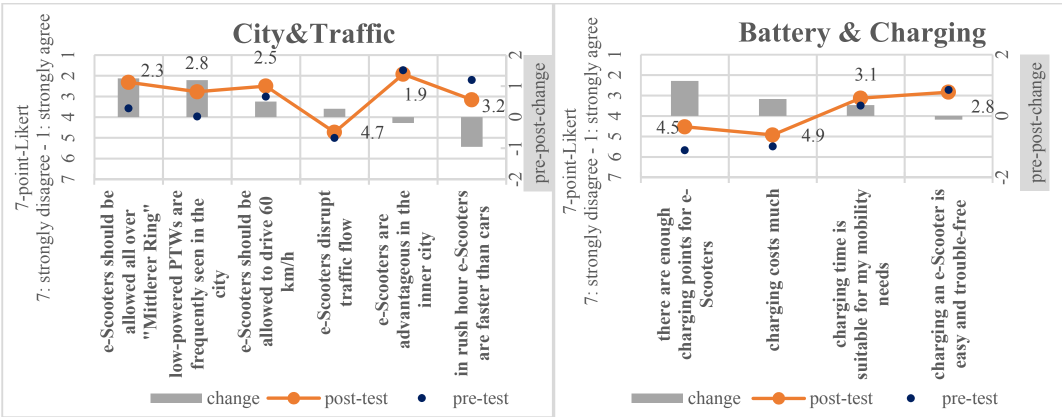

Fig. 3. (a) City & Traffic; (b) Battery & Charging

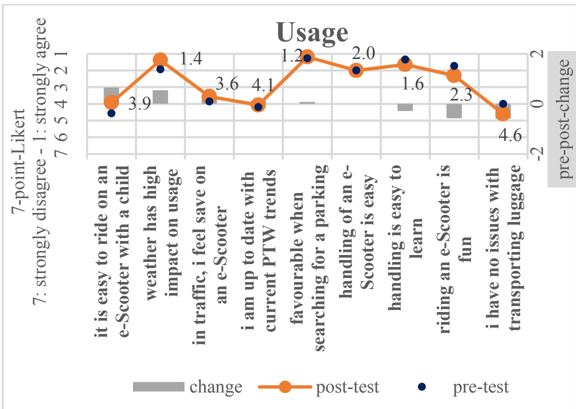

Fig. 4. Usage

7. Conclusion

While low-powered two-wheelers represent a footnote in the daily traffic of most European cities, recent development in electrification redefine the face of this vehicle class from loud and smelly two-stroke vehicles to modern, electric-powered, easy to handle vehicles without tailpipe emissions. Although e-scooters are popular in China, they are still scarce in European cities. Incorporating such vehicles could help to ease problems in inner cities like traffic congestions, air pollution, noise, and lack of parking. In order to investigate these vehicles and their acceptance by users, a pilot study was conducted in the city of Munich, Germany. By incorporating e-scooters to participants of this test, usage could be recorded by trip diaries, and attitudes towards usage could be recorded by employing a longitudinal survey. During this pilot study, participants rode on average 520.6 km per vehicle in 23.4

average days of activity. These trips had an average range of 10.6 km. Trip diary entries revealed the vehicles were used particularly for commuting and leisure trips, even for business trips within the city. These trip purposes represent a chance to establish e-scooters as alternative to cars, since these purposes are yet dominated by car usage. Participants utilized the supplied vehicles in different ways, where about one out of four embraced the given opportunity, however, about 40% of users did not incorporated the vehicle again after the instructional course. Nonetheless, there is a target audience for e-scooters, which utilizes these vehicles. Trip analysis combined with answers from the pre-post survey reveal that commuting trips as well as business trips can be covered with e-scooters, while leisure trips can be covered partly due to the number of travelers. The test procedure presented here can influence participants' attitudes, regarding attitudes towards usage and constraints of e-scooters. Awareness for this vehicle class is raised, and concerns about missing charging infrastructure can be reduced. Furthermore, attention to administrative barriers can be drawn, like usage restrictions on road types or top speed limitations on vehicles. By conducting this field test, advantages and disadvantages of usage could be identified. While easy parking is the most distinct benefit, weather dependency, baggage restrictions, and subjective safety are drawbacks of the vehicle class. After all, e-scooters are easy to handle and range as well as charging was confirmed not to be an exclusion criterion. Nonetheless, this study and its sample size was small and a first step into the topic of ePTWs and its usage in the context of European metropolises. In order to approve these results, further research is necessary, especially with a more sophisticated and detailed tracking system to avoid data evaluation problems as described in Hardt & Bogenberger (Hardt & Bogenberger, 2017), as well as a more representative user base.

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References

ACEA. (2016). ACEA Key Figures. Retrieved November 14, 2017, from http://www.acea.be/statistics/article/key-figures
ACEM. (2015a). ACEM - Market Data. Retrieved November 14, 2017, from http://www.acem.eu/market-data
ACEM. (2015b). *Industry report*. Brussels. Retrieved from http://www.acem.eu/images/publiq/2015/2015-report.pdf
Cherry, C. R., & Cervero, R. (2007). Use characteristics and mode choice behavior of electric bike users in China. *Transport Policy*, *14*(3), 247–257. https://doi.org/10.1016/j.tranpol.2007.02.005
Fu, J. (2013). The Role of Electric Two-Wheelers in Sustainable Urban Transport in China: Market analysis, trends, issues, policy options. *Sustainable Development, United Nations*, 1–17.
Hardt, C., & Bogenberger, K. (2016). The Price of Shared Vehicles – On current and future Pricing Strategies in Mobility Sharing Systems. *Transportation Research Board 95th Annual Meeting*. Retrieved from https://trid.trb.org/view/1394533
Hardt, C., & Bogenberger, K. (2017). Usability of escooters in urban environments — A pilot study. In *2017 IEEE Intelligent Vehicles Symposium (IV)* (pp. 1650–1657). IEEE. https://doi.org/10.1109/IVS.2017.7995946
Hurst, D., & Gartner, J. (2012). *Executive Summary: Electric Motorcycles and Scooters Electric Power Two-Wheelers: Market Drivers and Barriers, Technology Issues, Key Industry Players, and Global Demand Forecasts*. Retrieved from https://www.navigantresearch.com/wp-content/uploads/2012/12/EMOT-12-Executive-Summary.pdf
Kopp, P. (2011). The unpredicted rise of motorcycles: A cost benefit analysis. *Transport Policy*, *18*(4), 613–622. https://doi.org/10.1016/j.tranpol.2011.03.002
Pitterle, S., Krietemeyer, H., & Fink, B. (2010). *Mobilität in Deutschland (MiD) Alltagsverkehr in München, im Münchner Umland und im MVV-Verbundraum*. München. Retrieved from https://www.muenchen.de/rathaus/dam/jcr:2c6c0702-643e-4509-a4f0-d171dd8de0a6/broschuere_MiD.pdf
Thompson, R., & Rose, G. (2013). Use of Powered Two-Wheelers in an Australian Capital City. *Transportation Research Record: Journal of the Transportation Research Board*, *2388*(13–3597), 54–60. https://doi.org/10.3141/2388-08
VuMA. (2017). Frauen in Deutschland nach Besitz eines Motorrad-Führerscheins im Vergleich mit Männern im Jahr 2016. Retrieved June 27, 2018, from https://de.statista.com/statistik/daten/studie/290474/ umfrage/umfrage-unter-frauen-und-maennern-zum-besitz-eines-motorrad-fuehrerscheins/
Weinert, J. X., Ma, C., & Cherry, C. R. (2007). The transition to electric bikes in China: History and key reasons for rapid growth. *Transportation*, *34*(3), 301–318. https://doi.org/10.1007/s11116-007-9118-8
Weinert, J. X., Ogden, J., Sperling, D., & Burke, A. (2008). The future of electric two-wheelers and electric vehicles in China. *Energy Policy*, *36*(7), 2544–2555. https://doi.org/10.1016/j.enpol.2008.03.008
Weiss, M., Dekker, P., Moro, A., Scholz, H., & Patel, M. K. (2015). On the electrification of road transportation - A review of the environmental, economic, and social performance of electric two-wheelers. *Transportation Research Part D: Transport and Environment*, *41*(February 2016), 348–366. https://doi.org/10.1016/j.trd.2015.09.007
Yang, C.-J. (2010). Launching strategy for electric vehicles: Lessons from China and Taiwan. *Technological Forecasting and Social Change*, *77*(5), 831–834. https://doi.org/10.1016/j.techfore.2010.01.010