Chances for Urban Electromobility

Field Test of Intermodal Travel System and Effect on Usage Intention

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Abstract. With growing cities, challenges of climate change, and ambitions for energy transition, innovations in urban mobility are inevitable. On the one hand, fossil-fueled vehicles are polluting the cities and could be substituted with electric cars. On the other hand, the sheer number of vehicles has to decrease and public transport needs to be enhanced. A possible solution addressing all challenges in one fully integrated concept is "Mobility Broker", which combines electric car and bike sharing with public transport in one intermodal traveling system. However, adoption and changes in mobility behavior are crucial for implementing new concepts. In this research, a prototype evaluation by 10 participants using the system for 2 months is presented. The usability of the system as well as the change in attitudes and usage intention before and after the hands-on experience is analyzed. The overall evaluation for intermodal traveling was positive but usability and a reliable infrastructure are crucial factors for usage adoption.

Keywords: Car-sharing · Bike sharing · Usability · Field test · Future mobility

1 Introduction

Most western societies face the challenges of urban mobility as cities everywhere are expanding tremendously [1]. Cities are confronted with environmental problems due to emissions as well as infrastructural problems caused by too many vehicles. With a change to electric car and bike sharing, both challenges could be met at once [2].

First of all, electromobility would mean decreased emissions in urban areas. Second, the implementation of electric car and bike sharing would make this technology available to a wide audience, as the transition from fossil-fueled to electric cars and e-bikes has, so far, only reached a very limited number of households. One reason for this are the higher acquisition costs of an electric car compared to a conventional one. Using electric cars as part of car sharing, however, is available at a much smaller cost [3].

To further reduce the actual number of cars in use, the next step would be the improvement of multimodal mobility options. To facilitate multi- and intermodal

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mobility behavior, an encompassing information system was developed. This system integrates heterogeneous mobility services by independent providers on one platform that the user can access to book a journey, for example. To achieve a holistic integration, services needed at various stages of the travels, e.g., travel information via user interfaces, tariffs, and available infrastructure, were combined, thus eliminating the need to manually patch together an itinerary and pay each provider individually. This system, called "Mobility Broker," allows users to query, book, and utilize different modes of transportation within one trip, free from barriers like different platforms for booking and information, different tariffs, etc. (see Fig. 1). In this paper, we report initial observations of test persons interacting with the system in its first practical usage phase, including renting stations on site, the app, and tariffs.

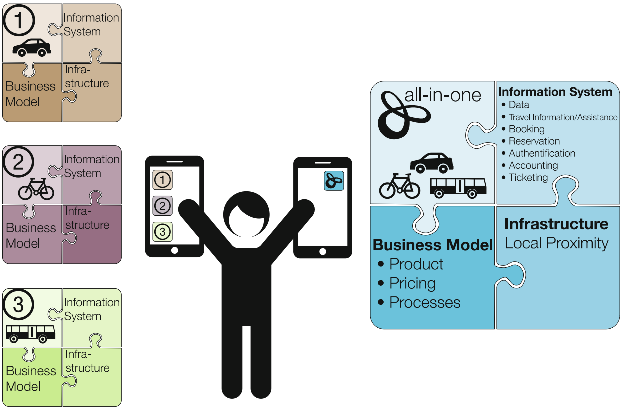

Fig. 1. Isolated mobility systems (left) vs. integrated "Mobility Broker" system (right)

1.1 The Intermodal Traveling System "Mobility Broker"

In past decades, the development of travel information systems moved from stand-alone solutions to integrated and complex information systems. Nowadays, advanced travel information systems (ATIS) use information and communication technology to provide travel information to a wide range of users who use various modes of transportation with a diversity of characteristics [4]. Beyond the provision of information, modern systems reduce the complexity of planning, booking, and utilization of intermodal travel chains [5].

As such, "Mobility Broker" manages heterogeneous modes of transportation offered by different mobility providers [6]. The respective system components, architecture, and information flows are described in [7]. Travelers interact with the system using a mobile application for android smartphones or a web portal which connects to the back-end using standardized APIs (see Fig. 2). A specific communication adapter is responsible for the communication with second party mobility providers. It exchanges travel information using a variety of open protocols, i.e., IXSI (Interface for X-Sharing Information).

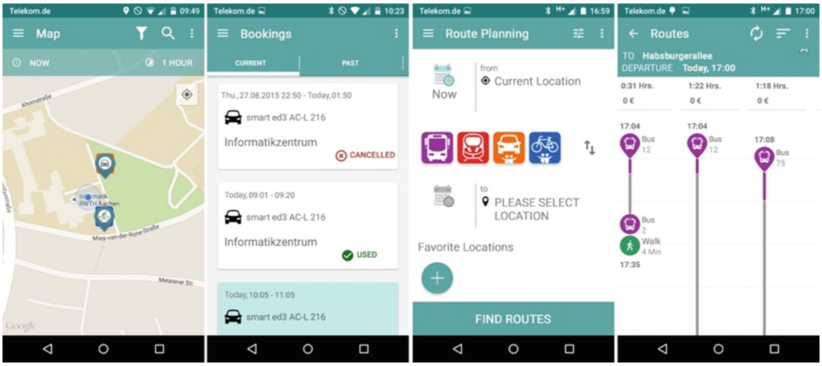

Fig. 2. Intermodal planning, routing, and traveling within the "Mobility Broker" app

IXSI connects vehicle rental systems with travel information systems and allows an asynchronous exchange of vehicle sharing information, e.g., availability [8]. In its current state, the system provides travel information concerning public transportation modes and enables the utilization of two e-cars and up to five e-bikes connected to associated charging stations.

1.2 Usability of Travel Information Systems

Travel information systems are a prominent research field [9–11]. Projects and applications vary significantly in a multitude of aspects [12]. Some related research is aimed at the effects of integrated solutions on the mobility behavior: Huwer [13] investigated synergies of combining car sharing and public transportation services in the German regions of Aachen and Mannheim. Although the technical integration was not the main focus of these studies, beneficial synergies could be observed. Moreover, Hoffmann et al. [14] evaluated integrated mobility services from the user's perspective. They offer a smart card solution as integrated authorization method, combined with a mobile application to provide travel information. Although these studies examined integration on various layers, they did not have an application with advanced functionalities, e.g., integrated accounting and booking. In addition, car sharing and public transportation services were provided by the same mobility provider.

What we know so far is that the increase of technology acceptance depends on the perceived usefulness and ease of use of a technology (Technology Acceptance Model, TAM) [15]. But will the acceptance of the multimodal mobility system and its components actually influence travel behavior? Recent research has shown that for public transport systems adequate user interaction is crucial for acceptance and usability [16]. Similar results were drawn for car sharing in combination with intermodal traveling [14]. To assess the actual usage intention of new intermodal traveling systems, the UTAUT2 model [17] provides valid dimensions used in similar contexts [18] and was adopted for this research.

To investigate effects of travel information systems, we examined test-person's reactions, using different scientific instruments. In [6], we evaluated "Mobility Broker" via an online survey, primarily focused on integration factors of the system. Within this work, we investigate some aspects even further. In contrast to previous studies, we concentrate on subsequent changes in the test-persons' attitudes towards specific transportation services resulting from using the system. As central, distinctive feature of this work, we investigated a test-group intensively by data collection at the beginning and the end of a field test, as well as monitoring user interaction with the system.

The research focuses on three aspects: (1) the usability of the multimodal mobility system (infrastructure and ticketing), (2) the willingness to use such a system in the future, and (3) the influence of using such a system on the actual mobility behavior.

2 Method

First, in a **pre-questionnaire**, the participants had to provide general attitudes towards electromobility (e-bikes and e-cars), intermodal traveling, and their usage intentions towards those new technologies by evaluating given statements on a 4-point Likert scale (see Sect. 3.2). They were also asked to describe their average mobility behavior, stating types and frequency of used means of transportation.

Afterwards, they were introduced to the intermodal traveling system "Mobility Broker" and its rental and ticketing processes. The app was installed on their mobile phones and the card needed for the rental process handed out. Then they were familiarized with the infrastructure (see Fig. 3). Participants were instructed on how to book, rent, and return e-bikes and cars at the stations. Afterwards, they were asked to perform these actions on their own in groups of two. They were voice recorded during this process to capture questions and comments (see Sect. 3.1).

Fig. 3. Bike-sharing (left) and car-sharing (right) rental procedure with "Mobility Broker"

The participants used "Mobility Broker" in a **field test** for two months. They were instructed to use the system in their daily mobility routines as much or as little as they liked. To compare the usage frequency of means of transport with the system and use without the system, the participants documented their daily mobility behavior in a diary. They also wrote down any experience with the entire system. This onsite observation served as additional input for the usability analysis.

At the end of the field test, the participants filled in a **post-questionnaire**. In its *first part*, the users had to evaluate "Mobility Broker" by UTAUT2 [17] dimensions (see Sect. 3.2), with the exception of price values, as the field test app was a free trial. In the *second part*, the statements of the pre-questionnaire concerning electromobility, intermodal traveling, and usage intention were presented once more. The comparison of the pre- and post-items measured the attitude change influenced by actual hands-on experience of the system in everyday life (see Sect. 3.3).

Ten **participants** (9 male, 1 female) aged 21 to 30 took part in this study. The sample was quite homogenous: All participants were students of computer sciences and interested in technology. As the station for bike- and car-sharing was located near the department of informatics, close to lectures and their daily student life, all participants had the same initial conditions to use the system.

3 Results

The results are presented in three sections. First, usability of Mobility Broker is evaluated using the comments from the field test and the pre- and post-questionnaire (qualitative data). Second, UTAUT is evaluated for the system as well as changes in mobility behavior (quantitative data). First of all, the general mobility usage (means of transportation and usage frequency) did not change within the field test study. The hypothesis that the opportunity to use an intermodal mobility system with new means of transport such as e-bikes and e-cars leads to an increased usage of intermodal traveling has to be rejected for this field test. Why and if this might change will be analyzed in the qualitative and quantitative results.

3.1 Qualitative Results – General Comments and Usability Concerns

General Comments. Most users reported that using the electric vehicles was fun; some explicitly mentioned the "good conscience" because of the electric engine. Participants wished for more stations and vehicles in Aachen. Due to the test phase character of the study, only one station could be used at the time. However, there are plans to expand the network of stations.

The sample saw great potential, especially for an e-bike system, in Aachen where university buildings are spread all across the city and, therefore, considered students one of the major target groups. Although participants reported that general handling of the app was easy, its functionality was sometimes restricted due to software problems, for example, concerning reservations. Users demanded a back-up solution for returning the e-car should the system malfunction. They also suggested that "favorites" from the app should be saved to a user profile so that they do not need to be recreated manually should a re-installation be required. In addition, users demanded a specific contact person whom they could turn to if the system did not work as required. Because of the test status of the station, responsibilities for repairs were sometimes not clear.

Unfortunately, the system experienced some problems during the test phase, for example, a crashed app or problems at the charging station (e-car) and with the e-car itself. One participant reported that he had not been able to use e-cars during the entire test phase due to issues at the station or with the car.

Reservation. Participants asked for the possibility of reserving e-bikes several hours or days in advance but were told that this was only possible for e-cars. In this context, it was also of interest to them if costs were attached to the reservation itself or if they were only charged when actually driving the car. Furthermore, they wanted to know whether the app showed the charging status of e-bikes and cars in the reservation phase, as to plan their travels more reliably. This was named as essential prerequisite to be able to use the system as intended.

Handling at Station. *E-bike.* The handling of e-bikes was problematic for some, as the bikes were hard to detach/attach from and to the station and participants were afraid to damage the locking mechanism.

The significance of the number indicating the available e-bike in the app was not clear to the participants: while they thought it referred to the number of bikes available, it was actually its designation (e.g., 2 did not mean that two bikes were available, but bike no. 2 was available). Further confusion was caused by the incongruence of slot numbers and bike numbers (e.g., bike no 2 was in slot number 3, so it was mistaken for bike no. 3). Sometimes, it was displayed that no bike was available although there was one at the station. Participants expressed that, should this be the case, they would want more information on why the bike was not available to them, e.g., that it was already reserved, broken, etc. This was also mentioned with regard to the app, which sometimes displayed error messages without further details on the cause of the error.

E-car. Generally, handling of the e-car at the renting station proved to be much more complicated to the participants than the e-bike. This was mainly due to the many steps required for usage, including detaching the charging cable which was locked separately.

First, it was not clear to the participants that they had to take the charging cable with them once they had unlocked everything. It was also hard for them to know whether the locking mechanism was deactivated: they had to be instructed to listen to the cable unlocking. (Un-)Locking the car with the card instead of a conventional key also caused some confusion. First, because it was counterintuitive to the participants and, second, because they knew other car-sharing systems that use the key.

Participants also expected a visual or acoustic signal when the car had been (un-) locked with the card. They were unsure about the time necessary to hold the card near the sensor for it to work. The visual feedback for locking the charging pole was also not intuitively understood (“blue” for “ok”/“start” instead of, e.g., green). It was also not readily understandable to the participants why the charging cable had to be unlocked using the card. Participants wishes for a combined solution that allowed to unlock both car and charging station simultaneously.

Participants sometimes experienced hardware malfunctions, for example, it was not possible to re-connect the car to the charging station, the car could not be used despite reservation, gears did not work, etc. The reliability of the e-car system was thus criticized. Furthermore, questions were raised as to when the app had to be used: some functions were only available via the app, others only at the station itself. It was not clear that, once participants had reached the station, they did not need the app anymore.

Handling During Renting Period. Participants reported that, in general, they had no problems handling the e-cars and e-bikes.

E-Bike. For the bikes, participants complained that there was no lock available to secure the bikes when they were not attached to the station. This locking system should also allow to check whether it had been used correctly, so if the bike was stolen, the users would not be held accountable. Questions were also raised regarding the distribution of bikes across different stations and how it would be handled if the bikes were concentrated at one station and therefore not available at others.

E-car. It was asked whether it was allowed to cross borders with the car. (Aachen is close to both the Netherlands and Belgium.) During the instruction, the car did not start for one participant. He speculated that the key was in the wrong position, because there was no acoustic feedback that the engine was running. Another point of criticism was the short range provided by the battery's limited capacity.

3.2 Quantitative Usage Evaluation

After the trial period, participants were asked to evaluate "Mobility Broker" in general, using the UTAUT2 scale [17] (Fig. 4). Agreement to the statements was measured on a 4-point Likert scale from −1.5 (do not agree) to 1.5 (fully agree). As the sample size with n = 10 was too small, the effects of different evaluation dimensions on usage intention by UTAUT2 was not measured statistically.

The **Performance Expectancy** was not overly positive, although its value for the participants' lives was favorable. **Effort Expectancy** was valued best of all dimensions. The system itself was referred to as easy to learn, clear, and understandable. Except for ease-of-use, all participants valued Mobility Broker positively. The **Social Influence** was overall low. Concerning the **facilitating Conditions**, it can be said from the data that the system seems to be well-designed to meet users' level of expertise. This underlines the positive comments on the usability of the app. Concerning the **Hedonic Motivation**, it is noteworthy that participants did not overly enjoy using the system but were generally positive towards it. Regarding the **Habit** to use "Mobility Broker" in the future, the participants could imagine using an intermodal traveling system in their daily life. Only the imperative use of the system was rejected. In a second test, with a bigger sample size, this item should be modified or left out. Finally, the **Behavioral Intention** to use the system in the future was also not particularly high.

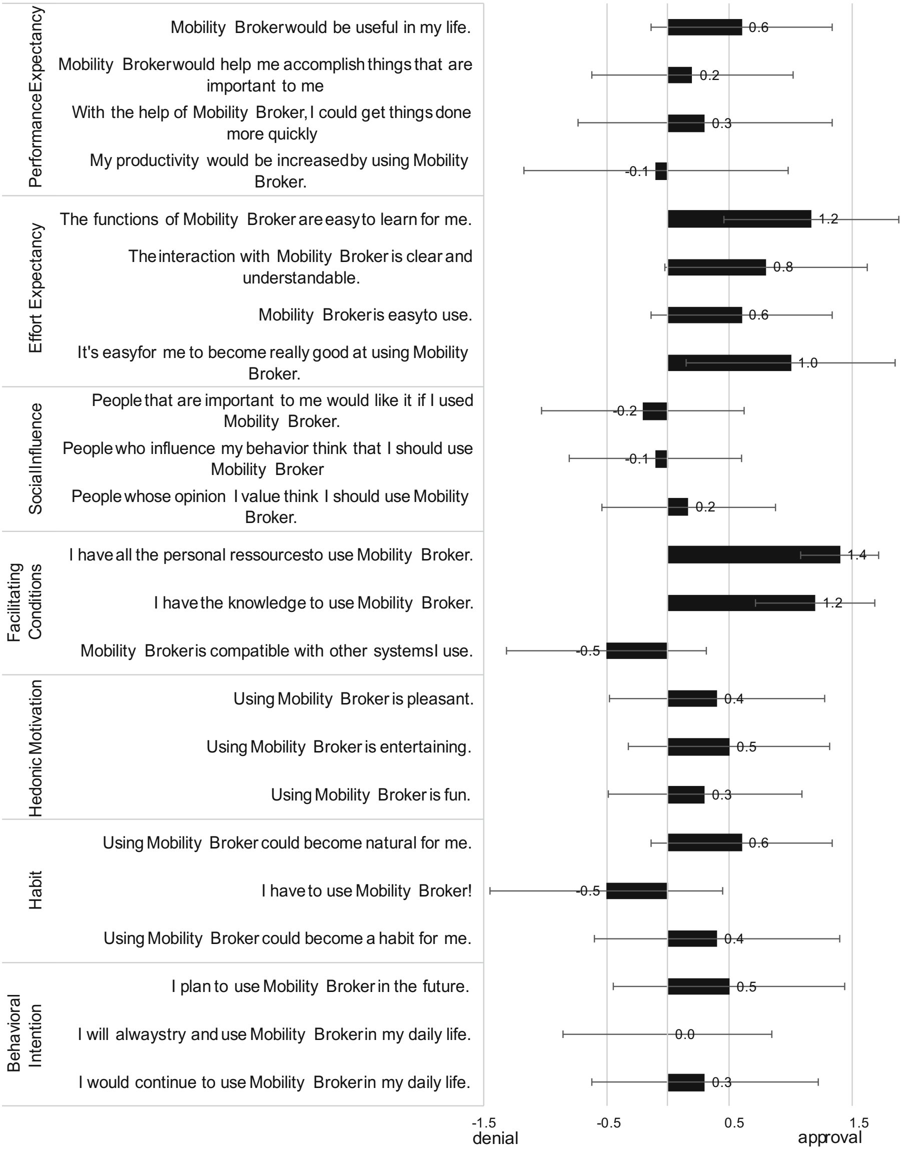

Fig. 4. Acceptance of "Mobility Broker" system, UTAUT dimensions (n = 10)

3.3 Attitudes Towards Electromobility and Intermodal Traveling – Before and After

The sample size was too small to report statistically significant findings. However, the results showed tendencies underlying the qualitative findings and are reported descriptively. The actual use of **electric car- and bike-sharing** (over a longer period) did influence the attitude towards these systems. Figure 5 shows mostly distinct differences between before and after the field test. Car- and bike-sharing were regarded positively for flexibility in mobility but while the test period improved the view of bike-sharing, the attitude towards car-sharing worsened, indicating the car-sharing process needs improvement.

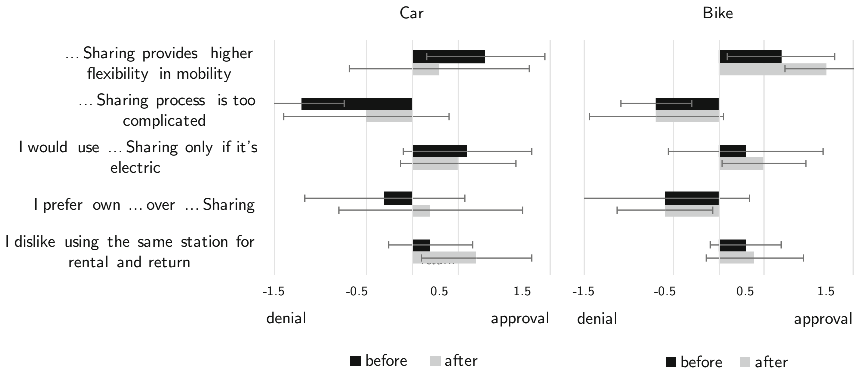

Fig. 5. Statements regarding car- and bike-sharing before and after test period (n = 10)

But although the participants determined several problems with the system, the overall sharing process for cars and bikes was appraised to be not too complicated. The amplification factor of the electric drive was negligible for the usage intention. While the test period had no effect regarding bike-sharing, the preference of an own car compared to car-sharing was strengthened. The concept of bringing the shared vehicle back to the same rental station was evaluated worse for the car, especially after the test period. Regarding the intermodal traveling process itself, the overall evaluation worsened a little after the hands-on experience. While the evaluation of an app did not change before and after the test period, again the infrastructure should be improved. More participants could imagine using multimodal traveling to transport heavy items after two months of testing. The perceived positive impact of multimodal traveling on traffic and the city climate remained unchanged after the field test (Fig. 6).

4 Discussion and Recommendations

The evaluation of the intermodal system "Mobility Broker" and its effect on usage behavior of new mobility concepts (electromobility and sharing services) shed light on users' perception of the system, usability issues and its potential to increase the use of sharing services.

With regard to the infrastructure, the communication of problems needs to be improved to prevent frustration of the users. Instead of stating that something was not available or wrong, knowing the reason would be greatly appreciated by the participants. In addition, notifying users when problems are detected and resolved would be beneficial. In general, system reliability needs to be ensured to make it attractive to use,

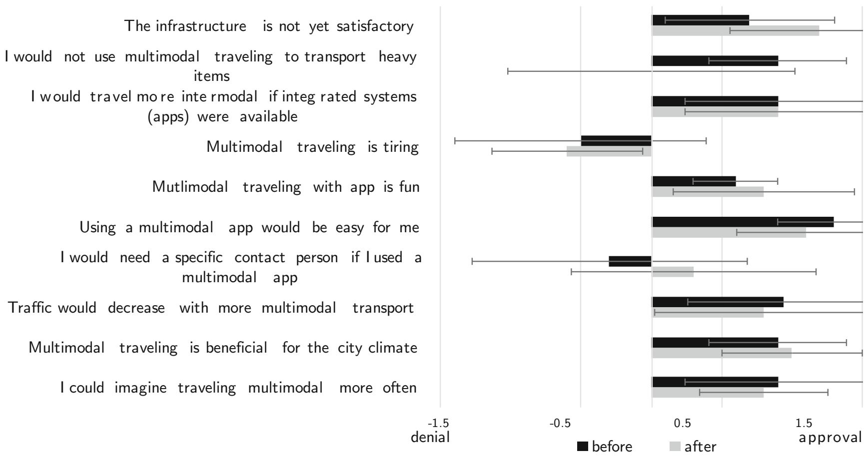

Fig. 6. Evaluation of statements regarding intermodal traveling before and after test period

especially concerning e-cars. A step-by-step guide for the renting station would also be helpful to the participants and could avoid confusion related to the right order of the required actions. This could, for example, be realized by a display at the station showing instructions. Furthermore, visual and acoustic feedback should be improved for some of the actions required at the station, and color codes should be more intuitive. One solution could be a small screen visible from the outside of the car displaying "locked"/"car returned" after locking the car. Although the comment did not refer to "Mobility Broker" itself, the missing engine sound of the e-car confused one participant, as he had no feedback whether he had started the car correctly. This means that not only the novelty of the renting system but also of e-cars need to be considered, and that there may still be barriers to using e-cars.

Concerning the e-bikes, the interactive display at the station at the time of renting should indicate the bike number instead of slot number of the bike to be rented out to avoid confusion with the information given in the app at time of reservation. A smoother locking/unlocking mechanism for the bikes is also needed, especially when considering that future users can be considerably older than our test group and might not be strong enough to release the bike from the tight lock easily. It is of great importance for the future success of the bike-sharing system that a transportable lock is offered and insurance issues are resolved. This could be a major hindrance, as one participant remarked he did not dare to leave the bike anywhere in case it would be stolen. Insurance also needs to cover usage other countries, especially in cities close to borders.

Concerning the analysis of UTAUT applied to the system, the results need to interpreted against the background of the specific setting and some limitations. The low performance expectancy is most likely due to the unreliable performance of the system at times, as reported by the participants (see Sect. 3.1). The low social influence is probably a result of the fact that the system is not yet commercially used, so the social network of the participants did not know about it and thus could neither recommend nor criticize its use. A lack of fun was also observed, which could be attributed to problems with reliability and lack of communication and contact persons when problems occurred. Most interestingly for the future usage of the system was the behavioral intention, which was low for the sample under study. From the qualitative data, it became clear that participants liked the idea of “Mobility Broker” in principle but criticized that the system was still too faulty to be used on a regular basis. This is also due to the trial character of the study. Regarding the app itself, the system is already well constructed, and has a good usability and ease-of-use. But for an intermodal traveling system, the travel routine itself is much more important. Therefore, more focus should be on the hardware and infrastructure.

5 Conclusion

The aims of the study were twofold: First, the interaction of the users with the system should be investigated to detect possible usability problems. Second, it was assessed in how far the trial period of “Mobility Broker” increased participants’ intention to use shared and electric modes of transport.

An obvious limitation to the study was the lack of more stations to rent and return e-bikes and e-cars. Regarding usability, the whole system was assessed. Although the app was evaluated quite positively compared to the reliability and the infrastructure of the whole system, another research approach could focus specifically on the app.

Finally, to gain general and statistically relevant results, the rather small sample size has to be enlarged. The very small and homogenous group of participants was a first step to evaluate an early prototype. The next step has to be the evaluation of a better functioning, improved intermodal traveling system with a broader sample to include effects of user diversity. These next research approaches could give deeper insights into the impact of actual hands-on experience with electric intermodal traveling systems on future mobility. Nevertheless, all participants enjoyed their experience with electric cars and bikes. Through this field test, they were made aware of the potential of electromobility as well as car- and bike-sharing. It is projects such as this, and having people interact directly with these systems, that can have a positive impact on urban mobility of the future.

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