Car Sharers' Interest in Integrated Multimodal Mobility Platforms: A Diffusion of Innovations Perspective

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Abstract: Integrated multimodal mobility (IMM) platforms are being discussed as a promising solution to facilitate the transition to sustainable transport in both urban and rural areas. The idea behind such platforms is to provide a one-stop-shop offering information, booking and payment options for multiple means of transport. The aim of this paper, based on diffusion of innovations theory (DoI), is to investigate the interest in IMM platforms, as well as the factors in potential user groups that may influence the intention to use them. A sample of 711 car-sharing users responded to an online questionnaire containing items on DoI variables, as well as on the specific requirements concerning IMM platforms. The results show that few members of car-sharing schemes have used IMM platforms before, but that the interest in them is generally high. Perceived *advantage and personal compatibility* show the strongest associations with the intention to adopt IMM platforms followed by *innovativeness, observability of use (social visibility of the innovation)* and *perceived technology security*. Additionally, a target group was defined for the efficient and effective promotion of IMM platforms in an early market phase. Measures to promote IMM platforms were suggested based on this group's perceptions and their specific requirements.

Keywords: integrated multimodal mobility; diffusion of innovations; car-sharing; mobility; mobility-as-a-service; sustainability

1. Introduction

Cities are continuing to attract an ever growing number of people [1], and most of their inhabitants still rely on private cars for their everyday transport needs [2]. This development leads to an increase in motorized urban traffic that is neither pleasant for inhabitants nor good for the environment. Urban transport also causes health problems due to air and noise pollution and is a significant contributor to greenhouse gas emissions [2]. At the same time, people living in more remote areas often have fewer transport choices and are even more reliant on the use of private cars. New options, such as car- or bike-sharing solutions, have been enriching the public transport available in many areas, making it more attractive to choose alternatives to private cars. While the use of these new options is increasing, particularly in combination with each other, they are still not familiar to many people. For example, in the beginning of 2017, only 1.7 million carsharing-users were registered across Germany [3]. Additionally, not all trips are necessarily easy to replace; car-sharing tends to be used for irregular trips rather than for routine travel such as commuting [4]. The same applies to other alternative means of transport; it is rather complicated, expensive, and time-consuming to gather information about the various means of transport and how to combine them [5–7]. Therefore, to confront the challenges facing modern transport systems, solutions are required that make using the

alternative transport options more attractive to the public. In increasing the use of these alternative options, such solutions will significantly contribute to sustainable development, specifically, the United Nations Sustainable Development Goal 11—Sustainable Cities and Communities [8].

1.1. Integrated Multimodal Mobility Platforms

Different means of transport are available in most areas, and each option has its own advantages and disadvantages, depending on both the users' circumstances and preferences and the routes they want to travel. Consequently, it would be ideal if users could choose one or a combination of different transport options based on the specific requirements of a particular route they wish to travel. This is the concept behind multimodal mobility—the flexible and barrier-free combination of different means of transport [9].

Usually, it requires considerable effort to search for different transport options, compare them and then choose the most appropriate for a specific route. This is where integrated multimodal mobility (IMM) platforms come into play; they allow users to enter the two points between which they wish to travel and then suggest possible routes and the transport combinations available for them. Users can then compare the results based on pre-specified criteria, like the cheapest, fastest or most environment-friendly route and, ideally, can pay for the entire route at once [10]. A concept very similar to IMM is offered by "Mobility as a Service" (MaaS) platforms, which seek to replace the need for owning the mean of transport (e.g., a private car) with the possibility of buying the service of transportation—a shared vehicle or public transportation from within an integrated platform [11]. As such, MaaS platforms can be seen as a subset of IMM platforms, which allow the combination of any means of transport. IMM platforms specialize in facilitating intermodal mobility—the combination of different means of transport within a trip [12]. The umbrella term multimodal mobility is used in this paper to encompass the broad range of information and trip planning services provided by IMM platforms, and to include various specialized concepts including MaaS platforms.

There are several IMM platforms currently available to consumers, with rapid market development. Most platforms offer partly integrated multimodal mobility, for example facilitating an effective search function of different modes of transportation, but only limited payment and ticket services. In the following, we will present a few examples of platforms that have concentrated on different aspects of integration. Since this paper focuses on the overarching concept of an IMM platform rather than the effectiveness of any particular platform currently available to customers, we will not include a comprehensive review on currently available IMM platforms. Such reviews are, however, available to the reader elsewhere [10,12].

One example of an IMM platform that has been trialled and analysed extensively is UbiGo, a service offered in Gothenburg, Sweden [13]. UbiGo is a "one-stop, monthly, paid subscription service for the entire household" [14] (p. 58), combining already existing transport options in one app to facilitate an easy and efficient booking process for any combination of public transportation, sharing services, taxi and rental cars. As such, UbiGo focuses on payment and ticket integration. The service was tested by 195 participants for six months and evaluated using both qualitative and quantitative methods, showing that a noticeable change towards sustainable behavior did indeed occur. The service was received positively among all user groups, with almost all participants wanting to continue using the platform [14–18]. Following the successful pilot, UbiGo is currently relaunching in Stockholm in cooperation with various platform and transport providers [19].

An interesting example of an IMM service that aims to integrate both informational and payment services is Radiuz [20], who provide a platform to plan, book and pay for multimodal journey. Based on this platform, various MaaS services can be launched in cooperation with local partners and employers, who can offer employees a "budget" of multimodal transportation that they can plan and pay for from the app. Transport options currently include public transport, car- and bike sharing, private car fuel and parking, electric vehicle charging and taxis. A similar approach is taken by the Whim smartphone application [21], an IMM platform offered by MaaS Global [22], first in the city of Helsinki, Finland,

and now in the UK and Europe. It covers public transport, taxis, and car and bike sharing, and allows planning, booking and paying in one app. Unfortunately, while Radiuz and Whim are operating successfully, they have not yet been evaluated systematically.

Among the scientific publications which have researched IMM platforms specifically, few have done so from a consumer perspective. As hinted above, researchers evaluating the platform UbiGo found that test subjects were not only highly satisfied with the service, but also felt more positive towards sustainable modes of transportation and less positive towards their private car. The results also suggested that simplicity, increased accessibility to additional means of transport, flexibility and added value were the main motivations for participants to take part in the trial and were the most influential towards the positive final evaluation. In addition to the studies described above, a number of other projects have been evaluated around Europe. For example, researchers in Lyon have found that users initially evaluated an IMM application positively, but struggled to permanently change their mobility patterns [23]. Portouli et al. [24] report similar results after a cross-European study, with actual behavioural change only found in some areas. Kamargianni et al. [11] give a further review of studies that have investigated partially integrated services; studies on fully integrated concepts are, however, lacking as of yet. Most of the published studies that include IMM platforms cover the concept rather superficially [2,9,25] or focus on the technical implementation of IMM platforms [26–30], which is challenging due to the necessary integration of multiple transportation systems and complex user preferences. Others have analysed the usage and users of intermodal transport in general, finding that a small percentage of citizens are using those opportunities of intermodal travel that are already available, but that intermodal trips are usually longer and of a routine nature compared to unimodal trips [31,32]. So far, the literature lacks a systematic and theory-driven investigation of (potential) users' perceptions, requirements and acceptance of IMM platforms. If diffusion theories are implemented, they are only used for evaluating a few aspects or to put results into context (e.g., [14,16]). A theory-based study could provide valuable insights to help understand the drivers for and barriers to using IMM platforms. This could also help identify potential target groups for measures to promote IMM platforms. Our paper aims to close this gap in the literature. A study is reported to explore factors that might influence the intention to adopt IMM platforms and to identify potential target groups for IMM platforms.

1.2. Diffusion of Technological Innovations

The distribution of technological innovations in society is often explained by theories focusing on innovation acceptance or diffusion. The framework of this study was based conceptually on the Diffusion of Innovations Theory (DoI) by Rogers [33]. DoI is one of the most prominent theories in diffusion research and is empirically well established. Importantly, it offers a comprehensive framework to study the adoption of innovations that incorporates factors related to adopters, the innovation itself, and society, and therefore avoids a singular perspective on the diffusion of an innovation. DoI has been successfully used to study innovation diffusion in a great variety of fields, including IT innovations [34–36], service organisations [37] or AIDS programmes [38]. In the context of mobility, DoI has been used to study the acceptance and diffusion of electric vehicles [39], alternative fuel vehicles [40] and car-sharing models [41]. So far, however, little research has looked into IMM platforms from an innovation diffusion theory perspective. The present study aimed to close this gap in the literature. DoI was chosen as the theoretical framework for its successful application to a wide variety of research fields, as well as its comprehensive look at potential influences on the adoption process.

In DoI, an *innovation* is defined as "an idea, practice or object that is perceived as new by an individual or another unit of adoption" [33] (p. 12). Because it can be assumed that IMM platforms are still relatively unknown in society, it is reasonable to classify them as an innovation in the context of DoI. The degree to which an innovation is adopted in society is measured by the prevailing intention to adopt it. This intention is largely determined by the so-called attributes of an innovation, as perceived

by potential adopters: *relative advantage* describes "the degree to which an innovation is perceived as being better than the idea it supersedes"; *complexity* is "the degree to which an innovation is perceived as difficult to understand and use"; *compatibility* is "the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters"; *observability* "the degree to which the results of an innovation are visible to others", and *trialability* "the degree to which an innovation may be experimented with on a limited basis" [33] (pp. 15ff). All attributes are assumed to have a positive influence on the intention to adopt an innovation except for complexity, which is assumed to have a negative influence.

System norms are another factor influencing a person's intention to adopt. These are defined as "established behavior patterns for the members of a social system" [33] (p. 24). An innovation that is compatible with the norms of the social system is assumed to be adopted faster than one that is incompatible.

Finally, a person's intention to adopt an innovation is also positively influenced by his or her own *innovativeness*, which describes "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than the other members of a system" [33] (pp. 15f). People who score high on innovativeness tend to adopt innovations earlier. This means that innovativeness can serve as a basis for the definition of adopter categories to classify a community based on its general willingness to adopt innovations. Innovativeness is assumed to be normally distributed, and adopter categories can therefore be defined using means and standard deviations. *Innovators* (2.5%, Min to $M - 2SD$) are the most innovative subgroup: They tend to be strongly interested in modern technology and are usually among the first to try out technologies themselves. *Early adopters* (13.5%, $M - 2SD$ to $M - SD$) tend to be the biggest opinion leaders. This group of adopters is followed by the *early majority* and *late majority* (34%, $M \pm SD$, respectively) and finally the *laggards* (16%, $M + SD$ to Max), who are usually among the last to adopt innovations. Thus, over the course of an innovation's diffusion through a society, only relatively few people (innovators and early adopters) adopt an innovation, followed by more and more as time goes on (the majorities). Once everyone who is willing (and able) to use the innovation for his or her needs has adopted it, diffusion eventually decelerates and stops [33]. This insight can be used to define target groups as well; once it is known how far in the diffusion process an innovation has progressed, the next groups to be addressed can be identified. This specific adopter category can then be analysed regarding its socio-demographic characteristics, as well as the prevailing perception and requirements of the innovation. Effective measures for the target group can be designed on this basis.

1.3. Research Questions and Hypotheses

Based on the assumptions of DoI, the following research questions were chosen to guide the present study:

1. How well known are IMM platforms (at the time of the survey) and how large is the interest in and intention to adopt IMM platforms?
2. Which factors influence the intention to adopt IMM platforms?
3. What are the potential target groups for IMM platforms?

Research question 1 was exploratory and, thus, no specific hypotheses were formulated. Regarding research question 2, the following hypotheses were proposed:

Hypothesis 1 (H1). *Relative advantage is positively associated with the intention to adopt IMM platforms.*

Hypothesis 2 (H2). *Complexity is negatively associated with the intention to adopt IMM platforms.*

Hypothesis 3 (H3). *Compatibility is positively associated with the intention to adopt IMM platforms.*

Hypothesis 4 (H4). *Observability is positively associated with the intention to adopt IMM platforms.*

Hypothesis 5 (H5). *Trialability is positively associated with the intention to adopt IMM platforms.*

Hypothesis 6 (H6). *System norms are positively associated with the intention to adopt IMM platforms.*

Hypothesis 7 (H7). *Innovativeness is positively associated with the intention to adopt IMM platforms.*

In several studies related to IT innovations, another factor has surfaced as a significant predictor of the diffusion of innovations: the *perceived technology security* [42–44]. For the context of IMM platforms, a working definition of perceived technology security was derived from Salisbury et al. [42]: the extent to which one believes that the technology is secure for transmitting sensitive information. Because this factor is not represented in DoI and can be assumed to influence the adoption of IT innovations such as IMM platforms, we proposed an additional hypothesis:

Hypothesis 8 (H8). *Perceived technology security is positively associated with the intention to adopt IMM platforms.*

We suggest that target groups for IMM platforms can be identified (research question 3) by grouping people into adopter categories based upon their innovativeness. As this is a highly explorative process, no hypothesis was formulated.

2. Materials and Methods

An online-questionnaire was designed and distributed among car-sharing users in Germany in October and November of 2016. This chapter describes the participants, data collection, and measurement instruments, as well as data handling and analyses. Additionally, a summary of the technical data can be found in Table A2.

2.1. Participants and Data Collection

In general, it may be difficult for consumers to state their expectations and preferences towards novel technological concepts without some degree of experience. At the time of the data collection, few prototypes of IMM platforms were available on the market (In Germany, the best-known platforms were moovel and Qixxit, belonging to Daimler AG and Deutsche Bahn Vertrieb GmbH (the German national rail company) respectively. Moovel integrates information on travel routes and payment for transport throughout Germany and cooperates with car-sharing, bike-sharing, taxi, bike and public transport providers [45]. Qixxit also operated throughout Germany, but was limited to providing information on the different means of transportation (recently, Qixxit has changed its business model to cover long-distance travel and is no longer an IMM provider [46]). Google Maps, while recently having advanced to include multimodal transportation planning in many countries, did not provide these options in Germany at the time of the study.) It could therefore be expected that few participants would have concrete associations with the concept of IMM platforms. A lack of previous experience may enable an unbiased response from participants and encourage them to freely state their preferences towards their ideal of such a platform, without pre-existing opinions based on current schemes. Nevertheless, care had to be taken that participants would be able to understand the concept, its potential and the challenges involved in multimodal travel.

Among the population of road users, those who are already organizing and booking their journeys via online tools, as well as those who are already familiar with the decisions concerning the use and combination of different means of transport, were assumed to be more capable of stating their preferences and intentions towards IMM platforms than other groups of road users. In light of these criteria, it was decided to conduct the study among a sample of car-sharing users. Furthermore, it seemed reasonable to assume that car-sharing users would be among the first to use IMM platforms on the market, which is why documenting their requirements and attitudes towards IMM platforms is

very valuable to decision-makers in managing both private and public transport services. Because the reasons underlying our sampling decision applies to users of both free-floating and station-based car-sharing schemes, no distinction was made between these two user groups.

During October 2016, all 122 car-sharing providers of the Bundesverband CarSharing e.V. (national German car sharing association) were contacted via e-mail and asked to distribute the questionnaire among their members. One week later, those car-sharing providers who had not replied were additionally contacted by phone. Of those 122 car-sharing providers, 20 explicitly agreed and 15 explicitly declined to send the questionnaire to their customers. The remaining 87 did not respond or chose not to give a definite answer, and therefore might or might not have sent the questionnaire to their customers. During this pre-data collection phase, preliminary access to the questionnaire was given to the providers to familiarize them with the study. Furthermore, social media channels and blogs related to the topic of the study were used to post a link to the questionnaire. During the actual data collection, the questionnaire was available to respondents for a total of 3 weeks in October and November of 2016.

The gross sample contained responses from 992 participants. Cases with missing data on the focal constructs as well as people who were not car-sharing users were excluded, which led to a net sample of 711 respondents. Their ages ranged from 18 to 82 years with a mean of 46 years, and 46% of them (n = 319) were women. Almost three quarters of respondents (73%, n = 519) had a university or higher degree and half (50%, n = 356) lived in central areas of medium or large cities. Regarding their choice of transport, 90% (n = 640) had access to a private bike, and 38% (n = 270) had access to a private car in addition to their car-sharing membership. While 63% (n = 451) already had a Bahncard (discount subscription programme for national rail transport in Germany) and 42% (n = 298) had a subscription for public transport, only 4% (n = 29) subscribed to a programme combining several means of transport.

2.2. Questionnaire

This section describes the selection and operationalization of the relevant measures included in the questionnaire.

2.2.1. Measures of DoI Variables and Perceived Technology Security

Several steps were taken in designing the questionnaire. First, studies implementing a comprehensive DoI model in a technology or mobility context [34,35,39,41], as well as studies using perceived technology security [42], were selected and compared regarding the validity and reliability of item scales. Items were then chosen from those studies based on item quality and applicability to the IMM context. The main module of the questionnaire contained 37 items to measure the constructs of DoI and perceived technology security. All items were adapted to the topic of IMM platforms and (if necessary) translated into German. Some additional items had to be constructed specifically for this study, because certain aspects of existing instruments could not be adapted to IMM platforms. Finally, the items were tested in a pilot study asking four participants from different backgrounds to fill in the questionnaire while "thinking aloud". Based upon the insights gained from this pilot study, a few items were then revised to erase ambiguity and increase ease of understanding.

Relative advantage and innovativeness were measured with six items, the intention to adopt IMM platforms with one item, and all other constructs with four items. All items comprised of statements that asked participants to rate their agreement ranging on a scale from 1 (completely disagree) to 5 (completely agree). For an English version of the items, see Appendix A Table A1.

A brief description and a concrete example of the possible use of an IMM platform were provided for all participants to make sure they would be able to rate the items. In the description, participants were asked to imagine the following situation (translated from German):

> You are planning to visit friends who live in a town nearby. Several options for completing
> this trip are available to you: There is a bus stop near your house, but you also have access

to a car-sharing vehicle. Alternatively, you could combine several means of transportation. Mobility platforms, for example in the form of a smartphone app, can assist you in combining these means of transportation. You are able to receive information about possible combinations, compare them and book the desired option right away. This is referred to as "integrated multimodal mobility" (IMM).

Depending on the service provider, different functions could be available to you on such a platform. In the following part of the questionnaire, we would like to know whether you would be interested in using an IMM platform and, if so, which features you would prefer.

Care was taken particularly with two aspects of the phrasing of the description. Firstly, emphasis was put on the combination of different means of transport within a trip (intermodal mobility) to distinguish innovative solutions (like Moovel) from platforms that only provide multimodal mobility (like Google maps), which are more readily available and not the focus of this study. Secondly, the description was held concrete enough to ensure that participants would understand the possible use cases of an IMM platform, but also general enough that participants would respond to those aspects that most actual platforms will have in common, thereby making the results applicable to a wide range of services. Concrete aspects that will differ between platforms, such as the specific information on display, the method of payment, and other features, were investigated in a separate part of the questionnaire (see Section 2.2.2).

All the items used to measure constructs with a hypothesized influence on the intention to adopt IMM platforms (relative advantage, complexity, compatibility, trialability, observability, innovativeness, system norms and perceived technology security) were included in a principal component analysis (PCA; oblimin rotation, eigenvalues greater one). The Kaiser-Meyer-Olkin measure confirmed the sampling adequacy for the analysis (KMO = 0.94) and Bartlett's test of sphericity, χ^2 (630) = 10,027.12 and $p < 0.001$, indicated that inter-item correlations were suitable for a PCA. For factor (cross) loadings, a criterion level of 0.3 was selected. Seven components with an eigenvalue above one were extracted, which explained 64% of the total variance. After inspecting components for meaningful content, five of the seven components were retained that together explained 57% of the variance. A list of items and the respective factor loadings after rotation can be seen in Appendix A Table A1.

Items belonging to one component were combined into an index variable for that component by computing the mean across the respective items. Negatively-phrased items were recoded to include them in the indices. The constructs relative advantage and compatibility were combined into one component called *advantage and personal compatibility* (34% variance, $M = 3.39$, $SD = 0.89$, Cronbach's $\alpha = 0.94$). Innovativeness (7%, $M = 2.88$, $SD = 0.99$, $\alpha = 0.90$) and perceived technology security (5%, $M = 2.83$, $SD = 0.90$, $\alpha = 0.81$) were represented as separate components, while the other three constructs were summarized in the two components *observability of use in the personal environment* (8%, $M = 1.94$, $SD = 0.96$, $\alpha = 0.82$) and *ease of learning the usage* (3%, $M = 2.98$, $SD = 0.85$, $\alpha = 0.74$). The reliabilities of these components were all satisfactory, as indicated by Cronbach's α values of 0.74 and above.

Additionally, separate PCAs and reliability analyses were conducted with items of the original DoI constructs and perceived technology security. The results indicated that the components of the PCA presented in Table A1 had better reliability than the original DoI constructs. These were chosen for use in subsequent analyses due to their superior reliability and because the empirically identified components had sensible content and were supported by the data.

The hypotheses proposed in Section 1.3 then had to be revised to match the new indices:

Hypothesis 1b (H1b). *Advantage and personal compatibility is positively associated with the intention to adopt IMM platforms.*

Hypothesis 2b (H2b). *Observability of use in the personal environment is positively associated with the intention to adopt IMM platforms.*

Hypothesis 3b (H3b). *Innovativeness is positively associated with the intention to adopt IMM platforms.*

Hypothesis 4b (H4b). *Perceived technology security is positively associated with the intention to adopt IMM platforms.*

Hypothesis 5b (H5b). *Ease of learning the usage is positively associated with the intention to adopt IMM platforms.*

2.2.2. Other Measures

Another section of the questionnaire contained supplementary items to measure familiarity with IMM platforms as well as preferences regarding various features of IMM platforms. Here, participants were asked about any IMM platforms they were already familiar with, as well as their preferred method of payment and use. They were also asked to rate their preferences regarding specific information and other features potentially offered by an IMM platform (e.g., map view, navigation mode, live traffic information etc.). These items were measured on a scale ranging from 1 (=not important at all) to 5 (=very important).

Although these measures provide additional opportunities to analyse the preferences regarding transportation options and the interest in IMM solutions, the focus of this paper is on the "diffusion of innovations perspective" of IMM platforms. Therefore, the analyses mainly comprised the measures described in Section 2.2.1. However, examples are provided in the Target Groups Section and the Discussion Section of this paper on how these additional data can be used to design effective IMM platforms and measures to promote them among potential target groups.

More detailed results regarding these measures can also be found in the supplementary materials to this article, Tables S1–S5.

The use of different means of transport was also assessed, including access and subscription to mobility programmes. These items were created specifically for this study.

Further to these measures, socio-demographic data were collected including the participant's year of birth, gender, household size, place of residence with the number of inhabitants, personal living situation, education, job, flexibility of work schedule, and income.

2.3. Data Handling and Analysis

The data set contained 9.5% missing values. In light of this relatively high percentage, the distribution of missing values was tested using Little's MCAR-Test [47]. A statistic of χ^2 (11,231) = 11,255.96 and p = 0.432 indicated that values were missing completely at random. Considering this result and the large sample size of respondents (n = 711), it was decided to delete cases listwise to ensure comparable analyses.

All the analyses were conducted using IBM SPSS Statistics Version 21. Correlations and linear regression analyses were used to test the hypothesized associations with the intention to adopt IMM platforms. Descriptive statistics were used to define adopter categories, and *t*-tests were used to test for group differences between the defined target group and the other categories.

3. Results

3.1. Descriptive Results

Most participants (72%, n = 506) stated that they had not heard of IMM platforms prior to taking part in the study. Of the remaining participants, 19% (n = 131) had heard of, but never used IMM platforms, and 10% (n = 68) had personally used IMM platforms before (percentages are rounded). In total, 29 different platforms were named by the respondents, the most frequent being Qixxit (n = 21 known, n = 14 used) and moovel (n = 19 known, n = 9 used). Many participants who had already heard of or used IMM platforms were able to name several local platforms in addition to

the larger competitors. Of those who had never heard of the concept of IMM platforms before, 74% (*n* = 369) expressed a general interest in using an IMM platform in their everyday life. However, there was no clear tendency visible in the intention to adopt IMM platforms (*M* = 3.09, *SD* = 1.15).

3.2. Associations with the Intention to Adopt IMM Platforms

First, bivariate correlations and multiple linear regression analyses were calculated to test the hypothesized associations with the intention to adopt IMM platforms. Either Pearson's *r* or Spearman's *ρ* were used to calculate correlations, depending on the distribution of the respective variables. All indices correlated positively with the intention to adopt, providing support for all five hypotheses. The highest correlation coefficient was found for advantage and personal compatibility (*ρ* = 0.75, *p* < 0.001), and the lowest coefficient for the observability of use in the personal environment (*ρ* = 0.35, *p* <.001). Between indices, a large correlation could be observed between advantage and personal compatibility and innovativeness (*ρ* = 0.52, *p* < 0.001), and moderate or small correlations between all other indices (effect sizes according to [48]).

Second, linear regression analyses were used to test the hypothesized associations with the intention to adopt IMM platforms. The assumptions of multiple linear regression analyses [49] were met for all models reported in this paper. A first multiple regression model was calculated including the five indices. This model (see Table 1) was significant with *F*(5) = 239.18 and *p* < 0.001 and explained 66% of the observed variance (R^2 and adjusted R^2).

Table 1. Linear regression model 1: regression on the intention to adopt [1].

Criterion Variable: Intention to Adopt IMM Platforms				
	B	β	*LCI*	*UCI*
Constant	−0.85 **		−1.15	−0.56
Advantage and personal compatibility	0.79 **	0.61	0.72	0.87
Observability of usage in the personal environment	0.18 **	0.16	0.13	0.24
Innovativeness	0.20 **	0.17	0.14	0.27
Perceived technology security	0.08 *	0.06	0.01	0.15
Ease of learning the usage	0.01	0.01	−0.06	0.09
R^2	0.66			
Adjusted R^2	0.66			
F	239.18 **			

[1] Note. *n* = 617. *LCI/UCI* = lower/upper confidence interval (95%). Listwise case deletion. * *p* < 0.05 ** *p* < 0.001.

Four out of five indices were significant predictors of the intention to adopt IMM platforms (all positive associations). By far the strongest predictor was advantage and personal compatibility, with a standardized regression coefficient β = 0.61, while the weakest significant predictor was perceived technology security with β = 0.06. Ease of learning the usage was the only index that was not significantly associated with the intention to adopt. Consequently, this first linear model provided support for hypotheses H1b, H2b, H3b and H4b, but not for hypothesis H5b.

Another multiple regression was computed by hierarchically comparing a second model including the five indices and sociodemographic variables (sex, age, household size, size of city of residence, location of house, education, job, job hours and income) to the first model described above. All categorical variables were converted to dummy variables in order to be included in this second linear model. After listwise deletion, *n* = 489 cases were retained for the analysis. Both models were significant with *p* < 0.001. The first model explained 68% of the observed variance (R^2 and adjusted R^2), and the second model 70% (R^2) or 68% (adjusted R^2). In the first model of this second multiple regression, three of the five indices were significant predictors of the intention to adopt IMM platforms. Again, advantage and personal compatibility showed the strongest association (*B* = 0.82, 95% CI [0.74, 0.91], β = 0.62), followed by innovativeness (*B* = 0.22, 95% CI [0.14, 0.28], β = 0.19) and the observability of usage in the personal environment (*B* = 0.18, 95% CI [0.12, 0.25], β = 0.16).

These three predictors remained significant in the second model that included the sociodemographic variables, with advantage and personal compatibility once again showing the strongest association ($B = 0.83$, 95% CI [0.74, 0.92], $\beta = 0.63$). Additionally, the dummy variable housewife/househusband showed a significant negative association ($B = -0.45$, 95% CI [-0.81, -0.09], $\beta = -0.07$), indicating that housewives and househusbands tend to have a higher intention to adopt IMM platforms compared to other job groups. Overall, the second regression analysis provided support for hypotheses H1b, H2b, and H3b in both models. Complete results of the second regression can be found in the supplementary materials Table S6.

An additional third regression was computed which included data on participants' mobility context and behaviour, that is, subscription to public transport or a ticket that combines multiple means of transport, as well as perceived proximity to a tram stop, bus stop, train stop, car-sharing station, free-floating car-sharing vehicles, bike-sharing, and free-floating bike-sharing. However, since the regression model did not explain any additional variance ($R^2 = 67\%$, adjusted $R^2 = 66\%$) as compared to the above models, and none of the mobility variables showed significant associations with the intention to adopt, detailed results of this final regression are omitted.

3.3. Target Groups

Adopter categories were calculated based on the innovativeness index as described in Section 1.2. Innovativeness was roughly normally distributed, so that the sample could be divided into the adopter categories defined by Rogers [33]: 1% of the sample ($n = 8$) were innovators, 14% ($n = 92$) were early adopters, 38% ($n = 242$) were part of the early majority, 30% ($n = 190$) were part of the late majority, and the remaining 17% ($n = 107$) were laggards. Because the size of the categories was very similar to Rogers's [33] dimensions (2.5%, 13.5%, 34%, 34% and 16%), this categorization was deemed successful and used to define target groups. Table 2 shows a demographic description of the different adopter categories.

Table 2. Key demographics of adopter categories [1].

	Age (*M*)	Sex (Male)	City of Residence	Experience with IMM (Yes)
Innovators	26 to 57 (40.38)	63% (*n* = 5)	71% larger city (*n* = 5)	38% (*n* = 3)
Early adopters	21 to 69 (38.81)	77% (*n* = 70)	49% larger city (*n* = 45)	46% (*n* = 42)
Early majority	19 to 76 (46.01)	62% (*n* = 147)	39% larger city (*n* = 94)	36% (*n* = 86)
Late majority	19 to 83 (48.07)	42% (*n* = 78)	36% larger city (*n* = 68)	23% (*n* = 44)
Laggards	19 to 75 (49.23)	33% (*n* = 35)	32% larger city (*n* = 34)	10% (*n* = 11)

[1] Note. Categories for city of residence: larger city (100,000 or more inhabitants), medium-sized city (20,000 to 100,000 inhabitants), small city or town (5000 to 20,000 inhabitants) and village (smaller than 5000 inhabitants).

The mean age of respondents rose with the affiliation to later adopter categories (resembling lower levels of innovativeness). While most innovators, early adopters and the early majority were male, the late majority and laggards were predominantly female. As might be expected, members of earlier adopter categories were more likely to live in a larger city than members of later adopter categories, and also tended to have more prior experience with IMM platforms.

Figure 1 shows the values of the DoI indices and the intention to adopt across the different adopter categories. There is an approximately linear relationship between all indices and the adopter categories, with some exceptions for the innovators. The intention to adopt is also strongest for the innovators and decreases with later adopter categories. The variance of the observability of use in the personal environment is noticeably small, with values on the lower half of the scale. This was to be expected, since IMM platforms were still unknown to most people at the time of the study.
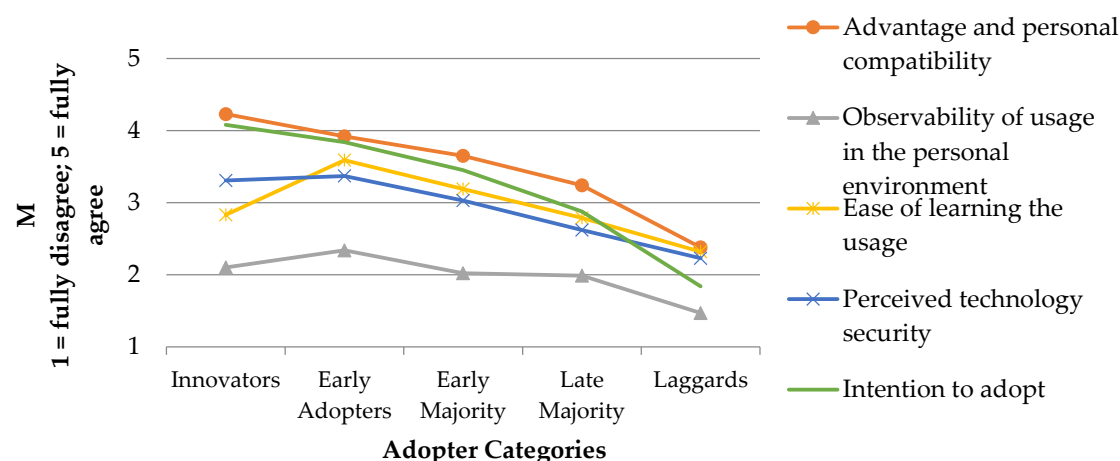
Figure 1. Relationship between the indices and adopter categories.

To answer research question 3 (what are the potential target groups for IMM platforms?), these results were used to define a target group to be addressed during the first phase of IMM platform promotion. Considering that the diffusion of IMM platforms is still in a rudimentary stage, it makes sense to select a target group of people that are already interested in IMM platforms and already have a medium to high intention to adopt them. Following this approach, one could achieve an initial diffusion of IMM platforms with an efficient and effective use of resources. Afterwards, additional target groups could be contacted more easily due to the increased publicity of IMM platforms and stronger system norms. Therefore, the adopter categories were split into two subgroups: those adopter categories whose respective mean intention to adopt was larger than three were combined into the *target group* (innovators, early adopters and early majority) with a resulting mean intention to adopt of $M = 3.58$ ($SD = 0.98$); and those adopter categories whose respective mean intention to adopt was smaller than three were combined to form a second group (late majority and laggards) with a resulting intention to adopt of $M = 2.51$ ($SD = 1.06$). The two groups were approximately the same size and their mean difference for the intention to adopt was significant, $t(619) = 13.07$, $p < 0.001$.

Figure 2 compares the means between the two groups. The target group shows significantly higher values for all indices compared to the second group, consisting of the late majority and the laggards ($p < 0.001$).
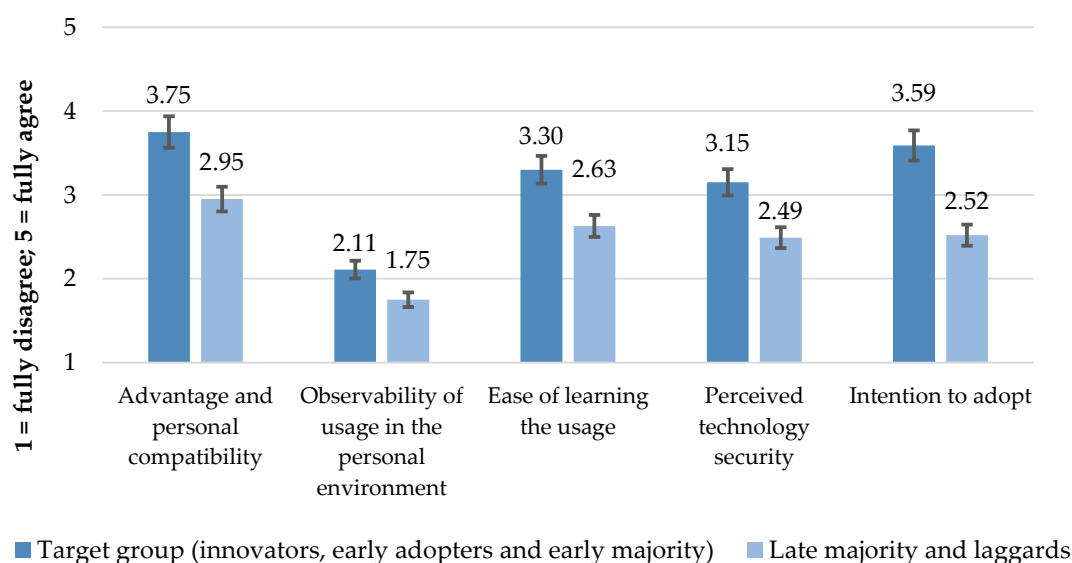

Figure 2. Index mean values and 95% confidence intervals for the target group of innovators, early adopters and early majority and a second group consisting of the late majority and the laggards.

The participants were also asked to indicate personal preferences and requirements concerning an IMM platform (cf. Section 2.2.2). For both the target group and the second group, the most important items of information were the duration of an entire route (target group: *M* = 4.57, *SD* = 0.74; second group: *M* = 4.43, *SD* = 0.90) and the cost of the entire route (target group: *M* = 4.5, *SD* = 0.78; *M* = 4.28, *SD* = 0.95). These were followed in third place by information about different combinations of transportation for the target group (*M* = 4.23, *SD* = 0.99), and by the length of an entire route for the second group (*M* = 3.59, *SD* = 1.12).

Besides providing information, the most important features of an IMM platform, as indicated by the target group, were: the display of available car-sharing vehicles (*M* = 4.43, *SD* = 0.85); transparency about the use of personal information (*M* = 4.28, *SD* = 1.07); and a navigation mode (*M* = 4.21, *SD* = 0.99). The second group showed similar preferences: the most important features of an IMM platform for them were transparency about the use of personal information (*M* = 4.29, *SD* = 1.12); the display of available car-sharing vehicles (*M* = 4.13, *SD* = 1.01); and a map view (*M* = 3.93, *SD* = 1.07).

Regarding the booking and payment process on an IMM platform, the target group and the second group agreed on the three most important aspects: data security (target group: *M* = 4.60, *SD* = 0.79; second group: *M* = 4.62, *SD* = 0.91), ease of usage (target group: *M* = 4.56, *SD* = 0.72; second group: *M* = 4.64, *SD* = 0.81), and the option to cancel a booking (target group: *M* = 4.42, *SD* = 0.80; second group: *M* = 4.38, *SD* = 0.93).

More detailed results regarding the specific preferences concerning IMM platforms can be found in the supplementary materials to this article.

4. Discussion

In sum, the present study found that few members of car-sharing schemes have used IMM platforms before. However, interest in those platforms is generally high. The intention to adopt IMM platforms was most strongly associated with the perceived *advantage and personal compatibility*, with *innovativeness, observability of use* and *perceived technology security* as additional significant predictors. Furthermore, a defined target group was established based on adopter innovativeness, which can become the focus of efficient and effective promotion of IMM platforms in an early market phase. With regard to the theoretical foundation of the study, it can be concluded that DoI was successfully applied to the context of IMM. The main assumption of DoI, that the adoption of an innovation can be explained by its so-called attributes, was supported in the context of IMM. Additionally, the factor innovativeness was successfully used to define adopter categories as predicted within the DoI framework.

Section 4.1 details a discussion of the results, followed by a discussion of the limitations and strengths of the present study in Section 4.2 and implications and suggestions for the practical promotion of IMM platforms in Section 4.3.

4.1. Results

The results demonstrate that, at the time of the survey, IMM platforms were still largely unknown and only being used by a few members of car-sharing schemes. Since car-sharing users can be assumed to have a higher affinity than the general public towards digital solutions that support the combination of different means of transport, it seems likely that the distribution of IMM platforms has progressed even less in the general public. However, there is a major interest in IMM platforms even among those who had not heard of the concept prior to taking part in the study, and target groups could be identified that already indicate a medium to high intention to adopt IMM platforms.

Some, but not all, constructs of DoI emerged in the factor analysis of the data. Additional factors were identified that combine items from different DoI constructs. Similar observations were made by Moore and Benbasat [34] when developing an instrument to measure DoI constructs, especially regarding the grouping of compatibility items with relative advantage items, as was the

case in this study, too. Based upon the factor analytic findings, the original hypotheses were slightly modified to align with the content of the identified components.

Bivariate correlations and linear regression analyses supported most of the hypothesized associations with the intention to adopt. Hypothesis H1b (advantage and personal compatibility) was supported in all analyses, and advantage and personal compatibility consistently showed the strongest associations with the intention to adopt compared to the other indices. This is in line with previous studies indicating that relative advantage and compatibility have the largest influence on the intention to adopt (cf. e.g., a meta-analysis by Tornatzky & Klein [50] and Rogers [33]). Hypotheses H2b (observability of use in the personal environment) and H3b (innovativeness) were also supported by the results, whereas H4b (perceived technology security) was supported everywhere except for the models of the second, hierarchical linear regression. A possible explanation for this discrepancy is that far fewer cases were included in the hierarchical linear regression analyses compared to the single model regression analyses, due to the listwise deletion of missing values. Hypothesis H5b (ease of learning the usage) was supported only by correlations, but not the linear regression analyses. Similar results were found when studying the acceptance of information technology [35]. In general, the regression analyses demonstrated that a relatively simple regression model including the DoI indices and perceived technology security provide a good explanation of the intention to adopt, with explained variances of 66% or more. This is backed by the finding that socio-demographic variables did not act as significant predictors of the intention to adopt IMM platforms when added to the innovation attributes.

The definition of adopter categories based on an index of innovativeness was backed by the data collected, and resulted in groups of very similar relative sizes to the ones defined and predicted by Rogers [33]. Descriptive analyses showed that earlier adopter categories (e.g., innovators, early adopters, early majority) tend to live in larger cities, while later adopter categories (e.g., late majority, laggards) tend to live in smaller towns or villages. This suggests that IMM platforms might provide different kinds of advantages for these groups. In larger cities, they could support people in managing and optimizing the wide range of transport options in their area, and in smaller cities or rural areas, they could help people find any viable alternative to their private cars. Thus, the potential adopters in larger cities might see more advantages in IMM platforms and might be willing to adopt them earlier.

For efficient and effective promotion of IMM platforms in an early market phase, those adopter categories that indicated a high intention to adopt were combined into a primary target group. Once IMM platforms become widely distributed and used in this target group it should be easier to address and convince the general public, given that the observability of IMM platforms, which is associated with the intention to adopt IMM platforms, will be much higher than it is now. The target group identified in this study was shown to have significantly higher values in all focal indices than the other adopter categories. Nevertheless, the results indicate that there is still potential to improve the perception, and thus, the adoption, of IMM platforms in the target group. The specific characteristics and preferences of the target group (e.g., high concentration in bigger cities, the indicated relevant features of an IMM platform) enable the development of tailored measures for promoting IMM platforms. The implications for specific measures are described in the final section.

4.2. Limitations and Strengths

The aim of this study was to investigate IMM platforms from a DoI perspective. DoI was chosen as a theory for its successful application to a wide variety of research fields, as well as its comprehensive look at the innovation diffusion process—and found an apt approach to understanding the adoption of IMM platforms. However, other theories might be able to highlight different perspectives in understanding dissemination of such mobile platforms. For example, future studies might gain further insights from other psychological models focusing on behavior change in stages (e.g., [51]), normative motivation (e.g., [52]), or social learning (e.g., [53]). As IMM platforms are

a software innovation, some DoI constructs have limited applicability (observability in particular). For example, the probability of observing others using a smartphone app is lower than the probability of observing others driving a car or using a computer. This means software innovations have a longer diffusion time [33], which should be considered when designing measures to promote IMM platforms. Regarding the measurement instrument, it was not possible to adapt existing items to the IMM context for all the aspects covered in the questionnaire, which is why some items had to be newly developed. All items, in particular the self-devised ones, should be validated by further research.

Due to the nature of the recruiting process, we cannot guarantee that our sample is representative for car-sharing users in Germany. Sample descriptives are comparable to some, but not all, similar studies of German users. For example, the plurality of car-sharing users in Tübingen, Germany, were in the age bracket of 45–49 years [54], which is comparable to the mean age of 46 years in the present sample. Free-floating car-sharing bookings in Berlin have the highest correlation with the percentage of users in the 40–49 years bracket, while in Munich the highest correlation is with the percentage of users between 30 and 39 years [4]. Besides geographic dependency, demographics seem to vary with the service provider as well: Flinkster users were found to be of a mean age of 45 years, but DriveNow users to be of a mean age of 36 years [55]. Due to these inconsistencies in recent findings, future work should aim to replicate this study with additional samples to verify the generalizability of the present results. Of course, IMM platforms could be interesting and useful for people who are not yet involved in car-sharing. In order to draw conclusions regarding the general public, it is recommended to replicate the study using a sample representative of the general public. In particular, those using alternative means of transport such as biking or public transport (as opposed to motorized private transport) would be a potentially accessible target group for IMM platforms and therefore of interest for future studies.

Furthermore, the data presented, being correlational, cannot make inferences regarding the directionality or causality of the associations.

To the best of our knowledge, our work is the first to study IMM platforms systematically based on an established psychological theory, and it provides both valuable insights into the psychological factors influencing the diffusion of IMM platforms and practical implications for how to promote IMM platforms. A large sample of car-sharing users was consulted, providing results that can be combined for a variety of applications (see also supplementary materials available online). The study has expanded researchers' knowledge about applying DoI to study the diffusion of a new software innovation. For practitioners, measures to promote IMM platforms are suggested in the following section.

4.3. Practical Implications

IMM platforms are in the initial phase of the diffusion process. Further development of the currently available IMM platforms can be expected in the near future. If these are to diffuse successfully, it seems important to tailor their development and design towards the preferences and needs of promising target groups. Marketing campaigns should also consider the sociodemographic characteristics, knowledge and perception of such groups. This means that measures should be divided into two phases for the effective and efficient promotion of IMM platforms. During the first phase, those expressing a high interest and intention to adopt IMM platforms (the target group defined in this study) should be addressed to achieve a rapid diffusion of IMM platforms through the relevant groups of the population with an efficient use of resources. The results of this study can be combined and used to design effective promotional measures. For example, to boost advantage and personal compatibility, which showed the strongest association with the intention to adopt, one might look at which potential features of an IMM platform were most important to the target group (duration and cost of an entire route). When designing measures, the focus should be on incorporating these features into the IMM platform and communicating them in a medium tailored to the specific target group based on its socio-demographic characteristics. This should strengthen the advantage and personal compatibility

and consequently the intention to adopt IMM platforms. As another example, the observability of IMM platforms could be increased by enabling social media integration. Such initiatives should focus on those predictor variables which can still be strengthened in the target group (as indicated by lower mean values). At the time of the survey, this is the case for all significant predictor variables, but this might change as the diffusion of IMM platforms progresses and should be kept in mind when designing later measures. During the second phase of the promotion of IMM platforms, when these have become more familiar and more supported by social norms, features that are relevant to other groups (e.g., length of an entire route and map view) could be added to address additional and broader groups of society.

In general, the fact that IMM platforms are largely unknown at this point can be seen as an advantage. The general public does not yet have a strong mental image of an IMM platform. If care is taken to develop platforms that are attractive to (potential) user groups and to communicate these effectively, a positive image of IMM platforms can be generated from the very beginning, thereby effectively increasing the diffusion of IMM platforms through society. Cooperating with institutions might help to familiarize the public with IMM platforms: One possibility is to include the concept and utility of IMM platforms in the curriculum of car drivers' education classes, thereby encouraging young drivers to rethink their everyday mobility options. If all these aspects are considered, IMM platforms have the potential to help people everywhere access more sustainable means of transport.

Appendix A

Table A1. Principal component analysis of DoI and perceived technology security items [1].

Items	Components						
	1	2	3	4	5	6	7
Using IMM platforms means I can cover routes faster. (adv)	0.87						
Using IMM platforms to plan my daily routes saves time. (adv)	0.87						
Using IMM platforms means I am more flexible. (adv)	0.83						
Using IMM platforms makes it easier for me to plan my daily routes. (adv)	0.80						
Using IMM platforms improves my quality of life. (adv)	0.78						

Table A1. *Cont.*

Items	Components						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Using IMM platforms helps me to save costs. (adv)	**0.70**						
IMM platforms are a good match for my routines and habits. (compa)	**0.69**						
I think that using IMM platforms fits well with the way I like to travel. (compa)	**0.68**						
IMM platforms are compatible with my current situation. (compa)	**0.64**						
Using IMM platforms fits my lifestyle. (compa)	**0.57**						
I think I will get to try out IMM platforms in the future so that I can make up my mind about them. (trial)	**0.53**						
I think I will find it easy/I find it easy to use IMM platforms on a daily basis. (compl)	0.47					0.30	
I assume that the people around me will approve of me using IMM platforms. (socsys)	0.39				−0.34		
I have noticed others using an IMM platform. (obs)		−0.87					
People around me are already using IMM platforms. (socsys)		−0.86					
I have never seen others planning routes using an IMM platform. (obs)		**0.77**					
I know where I can find an IMM platform. (trial)		−0.69					
Among my peers, I am usually the first to try out new technology. (inno)			−0.92				
I like to experiment with new technologies. (inno)			−0.87				
I am always well informed about the latest technologies. (inno)			−0.83				
If I heard about a new technology, I would look for ways to experiment with it. (inno)			−0.82				
In general, I am hesitant to try out new technologies. (inno)			0.61		−0.30		
I would not like to share personal data with an IMM provider. (tech)				**0.87**			
I worry about creating a user profile on an IMM platform. (tech)				**0.81**			
I think my data are in safe hands with an IMM provider. (tech)				−**0.72**			
I don't worry about making payments via an IMM provider. (tech)				−**0.55**			
The idea behind IMM platforms is difficult to understand. (compl)					0.73		
People who are important to me do not approve of using IMM platforms. (socsys)					0.67		
I think/know that testing IMM platforms will take a lot of effort. (trial)					0.50		
IMM platforms have the potential to develop a positive image in society. (socsys)	0.37				−0.42		
It's easy for me to tell others what benefits I have from using an IMM platform. (obs)	0.34				−0.40		
I have to find out all about a new technology before I am willing to try it. (inno)							−0.79

Table A1. *Cont.*

Items	Components						
	1	**2**	**3**	**4**	**5**	**6**	**7**
I would have to/I had to invest a lot of time beforehand to be able to use IMM platforms. (compl)						**−0.72**	
I think it will be easy/it was easy for me to learn how to use IMM platforms. (easy)						**0.37**	
I don't think anybody would notice if I used an IMM platform. (obs)							0.90
I can try out IMM platforms with no obligations until I make up my mind about them. (trial)							0.33
Explained variance	34%	8%	7%	5%	3%		
M (Index)	3.36	1.94	2.88	2.83		2.98	
SD (Index)	0.89	0.96	0.99	0.90		0.85	
Cronbachs α	0.94	0.82	0.90	0.81		0.74	

[1] Note. Loadings of items used for computing indices appear in bold. Only factor loadings >0.3 are reported. Theoretical constructs of items in brackets: adv = relative Advantage, compa = compatibility, trial = trialability, obs = observability, socsys = system norms, inno = innovativeness, tech = perceived technology security, compl = complexity. Components: 1 = advantage and personal compatibility; 2 = observability of use in the personal environment; 3 = innovativeness; 4 = perceived technology security; 5 = not used; 6 = ease of learning the usage; 7 = not used (Components 5 and 7 were not used due to lack of meaningful content).

Table A2. Summary of Survey's Technical Data.

Element	Data
Type of survey	Online-questionnaire
Survey platform	Unipark by QuestBack (Version: EFS Survey Summer Release 2016)
Target group	Car-sharing users
Survey period	3 weeks in October and November of 2016
Sampling procedure	(1) 122 car sharing organizations (every member of Bundesverband CarSharing e.V., i.e., national German car sharing association) were contacted with the request of distributing the questionnaire among their members; if they didn't respond, they again contacted (via phone call) after a week - 20 car sharing organizations explicitly agreed to send out questionnaire; - 15 explicitly declined to send out questionnaire. (2) Additional distribution of questionnaire on social media channels and blogs related to the topic
Gross sample	992
Net sample	711
Participant's age	18 to 82 (mean: 46 years)
Participant's gender	46% (*n* = 319) women 54% (*n* = 392) men
Participants with a university or higher degree	73% (*n* = 519)
Participants who live in central areas of medium or large cities	50% (*n* = 356)
Participants with access to a private bike	90% (*n* = 640)

Table A2. *Cont.*

Element	Data
Participants with access to a private car in addition to a car-sharing membership	38% (*n* = 270)
Participants with a Bahncard (German rail discount card)	63% (*n* = 451)
Participants with a subscription for public transport	42% (*n* = 298)
Participants subscribed to a programme which combine several means of transport	4% (*n* = 29)

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