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Why are individuals likely to change to sustainable modes of transport like carsharing and electric vehicles? An empirical analysis

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Abstract

Replacing conventional vehicles by electric vehicles (EVs) and increasing the use of carsharing are two strategies to reduce the environmental impact of car driving. However such a societal transition towards the use of more sustainable modes of transport will strongly depend on citizens' willingness to support this process. For this reason, this paper tries to identify factors which are related to the individual likelihood to change to more sustainable modes of transport. It draws on an adapted version of Rogers' diffusion of innovation model (DOI) and earlier work by the authors. It presents new findings from an online survey (n=1548) in one of Germany's show case regions for electric vehicles. Findings point out that relatively small shares of respondents already use these sustainable modes of transport (.6% for EV ownership and 5.3% for carsharing). Similarly, the shares of individuals who are very likely to use them in the near future (4.2% and 4.6% respectively) are also small. Much more individuals are interested in EVs (55.9%) than in carsharing (21.2%), and large groups are not interested (37.7% for EVs, 68.9% for carsharing). There are several significant sociodemographic differences between the respective four adoption groups. Furthermore, consistently, evluations are significantly more positive the higher the likeliness of adoption across groups. Based on regression models, it turns out that perceived compatibility with daily life is the most important factor influencing the attitudes towards EVs or carsharing across all groups.

Keywords: Electric vehicles, Carsharing, Adoption, Diffusion of Innovation

Table of Contents

Page

1 Introduction 1

2 Study Background 2

2.1 Acceptance of Innovations 2

2.2 Acceptance of EVs 3

2.3 Acceptance of Carsharing 4

3 Methods 5

4 Results 8

4.1 Adoption groups 8

4.2 Evaluation of EVs and carsharing 9

4.3 Regression analyses 9

5 Discussion 12

References 15

1 Introduction

In the light of climate change and declining resources of fossil fuels sustainable modes of transport are more in the focus of many governments than before. A societal transition towards the use of more sustainable modes of transport depends on citizens' willingness to actively support this process. Today, individual transport is dominated by car-driving; therefore, this paper focuses on two alternatives to car-driving which have the potential to make car use more sustainable: using electric vehicles (EVs) and carsharing.

Both modes of transport have received increasing attention and also public funding in the past years in many countries, also in Germany where the empirical data for this study was collected. At the beginning of 2016 25'502 battery electric cars[1] were registered in Germany, nearly half of them has been newly registered in 2015 [1]. This signifies both, on the one hand, the number of individuals driving an EV is increasing rapidly; however, it is still a tiny share of the overall market with over 45 millions of cars that are registered in Germany. The situation is similar for carsharing: In 2015, over one million individuals were members of 150 carsharing organisations across Germany [2]. This means an increase of 37% compared to 2014. However, although constantly growing, individuals who use carsharing are still a minority – only 1.9% of the individuals holding a driving licence in Germany.

This paper aims at contributing to identifying which factors influence individual likelihood to change to more sustainable modes of transportation in the future. This paper draws on an adapted version of Rogers' diffusion of innovation model (DoI) [3] in order to identify and analyse consumer groups varying in their likelihood to adopt those two modes of transport. It further analyses beliefs which influence attitudes towards the two modes of transport within these adoption groups also drawing on [3]. It builds on earlier work by the authors on EVs [4, 5] but presents analysis of new original data that has not been published before. Additionally, it now extends the approach developed earlier for EVs to carsharing which allows for comparisons between those two modes of transport.

[1] This paper focuses on battery electric cars as the most radical form of electrified cars.

2 Study Background

2.1 Acceptance of Innovations

Consumers' willingness to adopt (technical) innovations has been research applying the concept of technology acceptance. Acceptance of a new technology has been defined as 'behavior that enables or promotes (support) the use of a technology, rather than inhibits or demotes (resistance) the use of it' [6]. Applied to the areas of interest in this paper, this includes purchasing and using an EV as well as subscribing to carsharing and then using it. Theories on technology acceptance aim at explaining how and when individuals adopt innovations, and thus why some innovations successfully diffuse through the market, while others do not. Rogers' model of DoI [3] is well established as a framework in this field and has been frequently applied. It outlines the process and determinants of the individual adoption decision. Accordingly, the decision to adopt or reject an innovation is influenced by the individually perceived attributes of the innovation: (1) the *relative advantages* (RA) (and disadvantages) of an innovation compared to conventional alternatives on the market, (2) the *compatibility* with the adopter's values, experiences and needs, (3) the complexity, i.e. difficulty to understand and use the innovation ('*ease of use*'), (4) the *trialability*, i.e. the possibility to test the innovation before the decision to adopt and (5) the *observability* or visibility of an innovation and its consequences.

Other studies on user acceptance of new technologies have drawn on the theory of reasoned action (TRA) by Fishbein & Ajzen [7] (1975) and the Technology Acceptance Model (TAM) by Davis [8]. They share with [3] the reference to usability (ease of use) and the utility gained from the innovation (perceived advantages). The TAM model has been extended to include social norms, thereby adding an inter-individual factor [9]. In this paper we mainly build on Rogers' DoI, but add norms as an additional factor.

Rogers combines the set of predictors of adoption in his model with a categorization system. He distinguishes five consumer segments based on their relative timing of adopting an innovation. The first ones to adopt an innovation are called "innovators", the second group "early adopters". These early adopters are described as "typically younger in age, have a higher social status, have more financial lucidity, advanced education, and are more socially forward than late adopters." [3] The next group of adopters is the so called early majority, followed by the late majority. And the last ones to adopt an innovation, usually only due to the fact that the conventional solution is no longer available, are called laggards.

As indicated by the names, the two majority groups are assumed to cover a large part, about 70%, of the population. The other groups are expected to be smaller with innovators consisting of a very small share of individuals.

2.2 Acceptance of EVs

EV adoption and usage has received attention by researcher in recent years. Several studies have pointed out that amongst others the limited range and the higher prices compared to conventional vehicles are a barrier to EV diffusion [10, 11, 12]. However, further studies have shown that especially for early adopters the relationship between vehicle attributes and adoption is more complex [13, 14] and that factors of social influence also play an important role [12]. Especially Barth et al. [15] point out that social factors have been underestimated in research and in expert opinion.

Some studies have therefore addressed the issue of likely adoption groups of EVs. For example, a stated choice survey by Ziegler [16] indicates that the majority of potential car buyers still prefers conventional vehicles to EVs. Those who rate EVs and other alternative propulsion technologies as preferential are younger and more environmentally aware than the average participant. Plötz et al. [5] focus on describing early adopters in Germany in more detail. They find that that the most likely group of private EV buyers in Germany are middle-aged men with technical professions living in rural or suburban multi-person households. They state a higher willingness to buy electric vehicles than other potential adopter groups and their higher socio-economic status allows them to purchase EVs.

Peters & Dütschke [4] utilize the approach developed by Rogers and distinguish between four groups of adopters (users, individuals with purchase intention, interested, not interested) according to their likeliness to buy an EV. They partially use the same data as [5] and present a similar description of early adopters. Additionally they find that perceived compatibility is the most influential factor on stated willingness to buy an EV. For those interested or not interested in EVs social norm also plays an important role. Different aspects of relative advantages also play some role in predicting intention to purchase an EV. Furthermore, they find that strengthening environmental advantages of EVs and providing financial incentives for purchase are rated as important for the promotion of EVs and that vehicle performance characteristics seem to be less important. Similarly, also Petschnig et al. [17] use the approach from Rogers and combine it with measures for personal and subjective norms. They confirm the influence of norms as well

as of attitudes on the intention to use EVs. Attitude formation is amongst others influenced by relative advantages, compatibility and ease of use, no influence is found for observability and triability. In contrast to Peters & Dütschke [4] Petschnig et al. [17] do not differentiate between subgroups according to likeliness of adoption in their sample.

2.3 Acceptance of Carsharing

An important stream on research on carsharing has always focused on the environmental effect of carsharing which is closely related to the number of (private) cars that are replaced by carsharing vehicles and which modes of transport are replaced by carsharing (e.g. [18], and [19]. Recently, using EVs as part of carsharing programs has also received significant attention by researchers. Similar to EVs, it is found that costs play an important role as well as the necessary effort [20]. Early adopters are described to be similar to those of EVs – middle-aged working men with a high education and high income [21]. Compared to the purchase of electric or other alternatively fueled cars, carsharing seems to be less favoured [22]. Overall the research on carsharing acceptance seems to be less systematic and theory driven than the research into EV adoption.

3 Methods

For this analysis an online survey (N = 1548) was conducted in December 2014 in one of Germany's electric mobility showcase regions, i.e. the "LivingLab BWe mobil" around Stuttgart in the South-West of Germany. The showcase regions were funded by the Federal Republic of Germany with the aim of supporting the market uptake of EVs through local projects. This also implies, that in these regions, EVs are already a bit more part of everyday life than in other parts of Germany and that it is more likely that survey respondents have spotted them on the streets or heard about or even participated in public events from the local projects. One of the projects in the Stuttgart region is the highly visible car2go initiative, a carsharing project providing EVs all over the city to be booked via an app and which can be left on any public parking space available within a certain area in and around Stuttgart.

The survey was developed strongly drawing on Roger's diffusion of innovation theory [3]. It included items on socio-demographic characteristics, likeliness of adopting EVs or carsharing, usual modes of transport, evaluations about EVs and carsharing respectively (for more detail see below). The questionnaire was developed based on earlier work by the authors [4, 5] and also includes a segmentation into four groups according to the likeliness of adoption: People who confirmed that they own an EV are classified as users (group 1). Further items assess the general interest in EVs on the one hand and the intention to buy an EV within the next 3 years on the other hand. If both items are answered positively, the participant is assigned to the intending to use group (group 2). If only the interest item is affirmed, the participant is classified as interested (group 3). Participants affirming none of the above are classified as not interested (group 4). The two majority groups of Rogers are merged into one group (group 3) as we assumed that this differentiation is hard to draw in such an early stage of market development. Group 1 is conceptualised as being the innovator group, group 2 corresponds to the group of early adopters and group 4 to the group of laggards.

Participants for the survey were recruited from an online panel by a market research company specialised in such surveys. To ensure a regional focus a set of postal codes were defined that are situated within and around the show case region. The study was conducted in November 2014. Originally, the data set included more than 2200 respondents, however, data cleansing processes e.g. deleting participants that strongly deviated from the sample in time spent on the questionnaire reduced it to the above mentioned number of 1535.

It was tried to assemble a sample that is representative regarding gender, age and postal code regions; however as no specific official statistics for the area under study are available it is not possible to judge whether this is fulfilled. The age of the actual participants ranged from 18-86 years with a mean age of 43 years (SD=14). 52% of the respondents were female and the average household size was 2.4 individuals. 70% of the participants are working; more specifically 54% stated to work full-time, 16% part-time. 29% claimed to have a university degree. 94% of the respondents have a car driving license, with an average of 1.4 cars per household; 10% do not have a car.

At the core of the analyses presented in this paper are i) attitudes, towards EVs and carsharing and a combination of both (EVs in carsharing); constructs based on Roger's DOI, i.e. ii) compatibility with daily life, iii) observability, iv) social norms, v) triability, and vi) ease of use as well as vii) ratings of perceived relative advantages. All constructs were measured with several items; most of them were developed in an earlier study by the authors which focused on EVs [4]. Based on those earlier findings, few adaptations were made and additionally the list of items was added twice to the questionnaire, first asking about EVs, and then in a second version adapted to carsharing. The two lists were kept as similar as possible. Before aggregating items into scales by averaging across them we analysed whether the measurement is consistent by applying factor analysis and estimating Cronbach's α.

Items on attitudes and on EVs: In a first step, for each of the constructs i-vi a separate explorative factor analysis with varimax rotation was conducted. This led to the expected one-factor solution for constructs i-v. However, the items for vi formed two factors, so two items were excluded from further analyses. In a next step, the items for the DOI constructs ii-vi were added to an factor analysis simultaneously which nearly led to the expected structure (varimax rotation, pre-defined number of factors extracted; items were expected to have factor loadings of >.6 on the relevant factor and no factor loading >.4 on other factors). The analysis indicated that three of the four items intended to measure iii) observability did not show major factor loadings on a common factor. Thus, they were excluded and the factor analysis was repeated now leading to the expected results.

Items on carsharing: An identical procedure was applied for the items for scales ii-vi on carsharing. The results were also identical, with one exception. An additional item intended to measure ease of use of carsharing also had to be excluded in the final step due to ambiguous factor loadings.

Although the items have been used before the measures for vii) relative advantages did not show a factors structure in line with expectations. Therefore, they do not play a role in further analyses.

Finally, internal consistency was estimated for all items aggregated into scales which led to good results with $\alpha>.7$ for all scales.

4 Results

4.1 Adoption groups

Participants were categorized according to their likeliness of adopting EVs or carsharing based on the segmentation described above (cf. table 1). The data points out that the share of individuals who already uses these sustainable modes of transport is low and the number of EV owners is much lower than the one of carsharing users (.6% for EV ownership and 5.3% for carsharing). Also the shares of those individuals who are very likely to use them in the near future (4.2% and 4.6% respectively) are small. Much more individuals are interested in EVs (55.9%) than in carsharing (21.2%), and large groups are not interested in either (37.7% for EVs, 68.9% for carsharing). Group affiliation is not independent (significant Chi2 test, $p<.01$): On the one hand, those who are intending to buy an EV are also more likely to be interested, intending or actually using carsharing; on the other hand, those interested in carsharing, are more likely to state that they are owning, intending to own or interested in an EV. On top of this more people than expected are interested in neither, EVs nor carsharing.

Table 1: Adoption groups for EVs and carsharing

	(1) Users		(2) Intending to use		(3) Interested		(4) Not-Interested	
	EV	CS	EV	CS	EV	CS	EV	CS
N	9	81	64	70	858	326	579	1058
Share	.6%	5.3%	4.2%	4.6%	55.9%	21.2%	37.7%	68.9%
Age (m)	36.3	38.1	43.0	38.1	43.1	42.2	44.3	44.7
Household size (m)	3.0	2.4	2.7	2.7	2.5	2.5	2.3	2.4
Cars per household (m)	2.2	1.0	1.6	1.2	1.4	1.3	1.3	1.5
Share female	33.3%	44.4%	32.8%	38.6%	49.1%	57.4%	57.3%	51.0%
Share university degree	11.1	37.0	39.1	38.6	32.8	39.0	23.7	25.1

The adoption groups also differ in some socio-demographic criteria (tested with ANOVA and Chi2 tests, results categorized as significant if $p<.05$). According to EV adoption, groups do not differ in age on average, but group 4 lives in significantly smaller households than groups 2 and 3 and car-ownership is significantly higher in group 1 compared to 3 and 4. Additionally, men and respondents with a university degree are overrepresented in groups 1-3 and underrepresented in group 4. Due to the very small number of group members all results involving

group 1 for EVs have to be treated with caution. For carsharing, group 4 is significantly older than all other groups and owns more cars than group 1 and 3. More men are part of group 1 and 2 while the share of women is disproportionately high in group 3. Respondents with a university degree are overrepresented in groups 1-3 and underrepresented in group 4.

4.2 Evaluation of EVs and carsharing

In a next step we analysed in how far the adoption groups differ in their evaluations towards EVs and carsharing respectively. Figure 1 and 2 provide an overview over the descriptive findings. Generally, the results point out that the higher the likeliness of adoption the better the (average) evaluation of EVs and carsharing turns out to be across all constructs. Only the group of EV users shows a slightly less positive attitude and slightly lower ratings of compatibility than those intending to use an EV. However, it has to be noted that the group of EV users is extremely small.

The differences were also tested for significance applying MANOVAs for EV evaluations and carsharing evaluations respectively (not including the EV user group due to its small size). Both MANOVA models are highly significant ($p<.01$); post-hoc tests were used to identify mores specifically the relevant differences in ratings. Regarding EVs group 2 to 4 differ significantly for all constructs but for observability and triability. For observability only group 3 and 4 give significantly different rating and for triability only group 2 rates differently from the other groups. Regarding carsharing evaluations, the structure of significant findings is more complicated. Regarding attitudes towards carsharing only group 4 rates significantly different from all other groups, this also applies for attitudes towards carsharing including EVs, but in this case also group 3 and 4 differ. For compatibility all groups rate significantly different from each other but group 1 and 2. For ease of use, group 4 differs from all other groups but group 1. Again, for social norm, group 4 differs from all other groups. Finally, for triability group 1 differs from groups 3 and 4 as well as group 2 from 4.

4.3 Regression analyses

In a final step of analyses within this paper, we regressed the constructs from Roger's model on attitudes towards EVs and carsharing. The regression models are estimated for the overall sample as well as for the adoption groups. Results are displayed in tables 2 and 3.

For attitudes towards EVs, the model including all participants is highly significant as are the models for groups 2 to 4 and they explain between 24-41% of the variance. No significant model can be estimated for group 1 due to the small group size. The factor showing the highest relationship in the overall sample with the attitude is compatibility, this also applies for group 3 and 4 and compatibility also tends to have a significant relationship with attitude in group 2. Social norm turns out to be the other significant factor in the overall model and similarly in groups 3 and 4. An unexpected significant relationship is detected for ease of use which shows a significant negative relationship with attitudes in groups 3 and 4.

Table 2: Regression on attitude towards EVs

	All respondents	(1) Users	(2) Intending to use	(3) Interested	(4) Not-Interested
Compatibility	.519**	-	.272#	.425**	.446**
Ease of use	-.039	-	.168	-.124**	-.099*
Observability	.025	-	-.232	-.031	.102**
Social Norm	.188**	-	.035	.157**	.179**
Triability	.026	-	.300#	.048	.003
R	.639**	n.s.	.544**	.487**	.564**
R2	.408		.295	.237	.318

Note. Cells give standardised regression coefficients if not indicated otherwise.
** - p<.01; * - p<.05; # - p<.10;

When regressing on the attitudes towards carsharing, all of the estimated models are highly significant explaining 17-41% of the variance. Again, compatibility turns out to be the most relevant predictor in the overall sample and the construct is also significantly positively related to the attitude towards carsharing in all other groups (at least showing a tendency in group 2). Ease of use and social norm also turn out to be significantly predictive for the overall sample and in groups 1 to 4 and 3 to 4 respectively. Again, a somewhat unexpected relationship is also identified, in this case for triability which is negatively related to the general attitude towards carsharing in the overall sample and for groups 3 and 4.

Table 3: Regression on attitude towards carsharing

	All respondents	(1) Users	(2) Intending to use	(3) Interested	(4) Not-Interested
Compatibility	.349**	.312*	.293#	.254**	.192**
Ease of use	.186**	.230#	.317*	.163**	.167**
Observability	.011	-.145	-.056	-.032	.012
Social Norm	.284**	.203	-.003	.150*	.340**
Triability	-.146**	-.039	-.257**	-.126*	-.169**
R	.639**	.549**	.484**	.410**	.504**
R2	.408	.302	.235	.168	.254

Note. Cells give standardised regression coefficients if not indicated otherwise.
** - p<.01; * - p<.05; # - p<.10;

5 Discussion

The aim of this paper was to enhance the understanding of factors which are related to the individual likelihood to change to more sustainable modes of transportation. It draws on an adapted version of Rogers' approach and combines the identification of influencing factors with a segmentation of adopter groups. It applies this approach to two sustainable modes of transport, namely EV purchase and carsharing. In earlier work, the authors have already applied this approach to the case of EVs, however, the recent study presents new empirical data on this issue. What is special about the data is that it was collected in an area of Germany that is already more advanced regarding EV diffusion as many state funded EV projects. Furthermore, the approach is extended to carsharing for the first time.

Findings point out that relatively small shares of respondents already use these sustainable modes of transport (.6% for EV ownership and 5.3% for carsharing); the shares of individuals who are very likely to use them in the near future (4.2% and 4.6% respectively) are also small. Much more individuals are interested in EVs (55.9%) than in carsharing (21.2%), and large groups are not interested (37.7% for EVs, 68.9% for carsharing). Compared to another study which used a sample that is representative for Germany [23] group 1 and 2 are bigger. This other study classified .4% as group 1 and 1.0% as group 2. Also group 3 is bigger in our sample (46.0% in the earlier study).

In line with [3] as well as earlier empirical work [4, 5, 21] we find that those more likely to adopt the two innovations under study early on are more often men than women and have a higher socio-economic status. Moreover, consistently with the segmentation of respondents, we also find that attitudes and evaluations on EV purchase and carsharing are more positive the higher the likeliness of adoption this innovation.

However, not all of these factors are relevant for prediction attitudes towards EV purchase and carsharing. In line with earlier work on EVs [4, 17], we find that compatibility is a highly relevant factor. Additionally, social norms are also important, especially for later adoption groups, as was assumed by [15] and also found in earlier studies on EVs [4, 12, 17]. Interestingly, a very similar pattern of results regarding compatibility and social norm is found for EVs and carsharing. This implies that similar strategies can be applied for supporting both new modes of transport.

In our survey, the measurement of compatibility referred to a congruence of the mode of transport with (daily) habits and the individual personality, thus it captures a mixture of self-identity and mobility patterns and requirements. This implies, that on the one hand perceived compatibility is likely to be influenced by issues like whether a respondent has to commute to work or which modes of transport are (likely to become) available at his/her place of living. Thus, it is shaped by situational and contextual factors. On the other hand, it taps on personal factors and seems to be related e.g. by personal values. Leaving it to debate which of these can be more easily changed it should be noted that this means the mere technical progress would not necessarily enhance compatibility.

Social norms refer to the opinions and expectations of others. Thus, their relevance points out that the adoption of an innovation is a social process. This implies, that the more certain modes of transport are perceived as normal the more they are likely to be adopted, i.e. accelerating the adoption process with increasing rate of adoption. Additionally, social norm are subject to societal influence, e.g. likely to rise if important societal actors publicly adopt an innovation.

For ease of use the identified relationship across adoption groups seems to be more complicated in the case of EVs. For carsharing its influence is straightforward positive and therefore as expected. This leads to the obvious recommendations that carsharing concepts that provide a high usability e.g. by including simple structure for booking, getting and returning vehicles are more likely to be adopted. However, for EVs, the relationship with attitudes is negative in groups 3 and 4. This finding is in line with an earlier result [4]. It could point to an adverse effects that those who are more positive about EVs in these groups expect them to be more different from conventional cars and therefore less easy to use.

Overall, the effect of observability seems to be negligible. This is especially noteworthy as the study was conducted in an area where many respondents are likely to have noticed EVs and / or carsharing vehicles. However, due to lack of internal validity, the measurement of this concept only relied of one item in the analysis. So it is possible that in case of a more comprehensive measure the results might be different.

For EV adoption, triability did not seem to have an effect and the effect on attitudes towards carsharing is negative. This finding is unexpected and not easy to explain. Again, as only two items were used to measure triability, it may be a problem of operationalisation.

That some of the variables included in this study have unexpected effects that are difficult to explain is one of the limitations of this study. This points out the need of a deeper analysis of the data to find out whether these unexpected findings remain stable if some variance is controlled for by other factors. Furthermore, the insight could be extended by combining the analyses presented in this paper with an analyses of actual mobility patterns and habits in order to pin down their relevance for perceived compatibility.

Overall our study points out the need for a combined analyses of technical and economic attributes of an innovation as well as the individual and subjective factors that need to be taken into account. This leads to the conclusion that to support the diffusion of the innovations under study measure on technological improvement should be combined with communicative elements which emphasize individual values and strengthen social norms.

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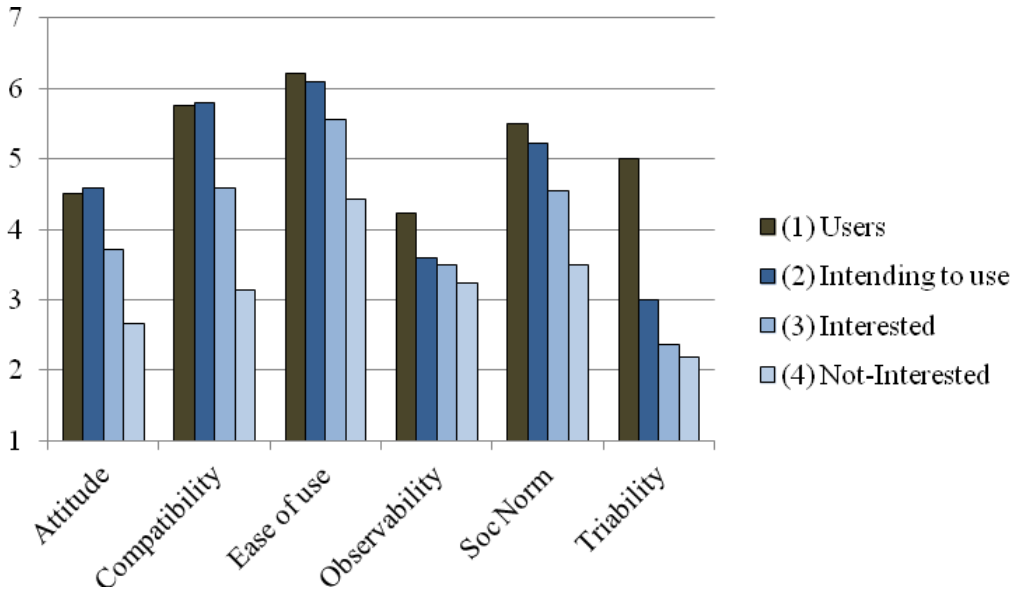


Figure 1: Evaluation of EVs by adoption groups
Note. Ratings for attitudes range from 1 to 5, for all other constructs from 1 to 7. Higher numbers indicate a more positive evaluation.

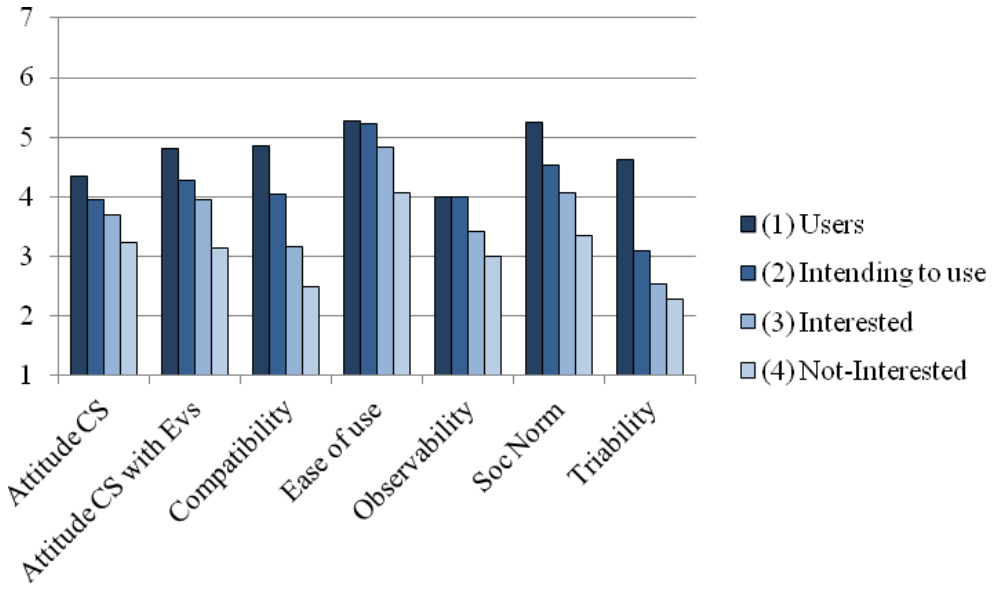


Figure 2: Evaluation of carsharing by adoption groups
Note. Ratings for attitudes range from 1 to 5, for all other constructs from 1 to 7. Higher numbers indicate a more positive evaluation.

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