Acceptance of electric vehicles by commercial users in the electric mobility pilot regions in Germany

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Abstract

Electric vehicles (EVs) charged with electricity generated by renewable sources have the potential to make the transport system more sustainable. Due to their high share of new car sales commercial fleets are playing a crucial role for the diffusion of new technologies in the transport sector. Also there are further peculiarities of commercial vehicles (e.g. more stable daily routes, central overnight parking for recharging) which make commercial fleets likely early adopters of EVs. Nevertheless, most studies which issue user acceptance address private users of passenger cars. Our paper aims at contributing to close this gap of knowledge by (1) conducting a comparative analysis of commercial and private users of EVs and (2) comparing commercial users with a high acceptance of EVs to commercial users who have a lower acceptance of EVs.

What is at stake?

Electric vehicles (EVs) are often discussed as a way to make transport more sustainable: If the energy used to charge the battery is "green", i.e. generated via renewable energy sources, these vehicles are more environmentally friendly than conventional ones. Additionally, they have the potential to make transport more independent of fossil fuels. In recent years, national governments and automobile manufacturers in many countries have therefore increased their efforts to promote EVs and the necessary technology. So far, EVs are not able to face the challenge with conventional vehicles (CVs) with regard to battery capacity and charging times as well as costs. Thus, besides technological progress, analyses of promising usage scenarios are crucial. Up to now, valid scientific findings and practical experience on likely early users of EVs have been somewhat rare, as the market is still at a very early stage and only a limited number of EVs is available on the market or already driving on the streets. On top of this, most research on users of EVs focuses on private usage. However, an important market for EVs might be in the field of commercial usage.

Commercially used vehicles are often part of a fleet of several vehicles and – at least some of them – have a reliable driving profile of daily routes (Nesbitt & Sperling 1998). This also implies predefined times during which the vehicle is not used but rests at a predefined place where it can be recharged. Furthermore, EVs are characterised by higher initial costs of purchase but lower running costs for fuel. As, on average, the annual mileage of cars in commercial fleets is higher than that of privately used cars, they are more likely to be economically attractive in such a scenario (Nesbitt & Sperling 1998; Gnann et al. 2012). Furthermore, the larger pool of vehicles provides the possibility that CVs could compensate for the restricted range of EVs if necessary (Golob et al. 1997). For some companies, e.g. if the vehicles are used for delivery, the low noise emissions of EVs might also bring valuable advantages. Additional benefits for companies could be image effects by showing a green conscience.

In this paper we therefore want to take a closer look at EVs and the role they can possibly play in commercial transport focusing on the perspective of the actual users of the vehicles. We do this by analysing survey data from the pilot regions for electric mobility in Germany where several EVs were tried out

in a broad variety of everyday scenarios from mid-2010 until the end of 2011. As a first step we give an overview of the empirical literature on consumer research for EVs which has been published so far; as mentioned before, it mainly focuses on private consumers. Then we give a short review of existing studies on commercial usage which lead to the specification of two research questions: 1. How do private and commercial users differ in their evaluations of EVs? 2. Which features of EVs differ between commercial users with a high acceptance of EVs from those with a lower acceptance? Then we aim at providing answers to these questions based on our data. At the end we discuss our findings and point out the limitations of our study as well as further research questions.

Acceptance of EVs

Several studies have been conducted in order to analyse the acceptance of EVs and the influential antecedents on EV adoption. In this chapter we give an overview of this literature. As mentioned above, most of this work focuses on private customers. Thus we will first briefly discuss research findings on acceptance of EVs by private users, and then we focus on the few studies available for commercial users. Based on the literature analysis we derive the research questions of this paper.

ACCEPTANCE OF EVS OF PRIVATE USERS AND POTENTIAL EV BUYERS

In the last few years several studies assessing the user acceptance of EVs by private consumers have been published. They have used different approaches. In order to be able to compare the results adequately a short overview of the approaches is given. The studies can be divided into population surveys (Lieven et al. 2011), surveys of (potential) private car or EV buyers (Curtin et al. 2009, Götz et al. 2011, Peters et al. 2011), surveys of (potential) private car buyers which provided information on EVs (Anable et al. 2011) and surveys of private (test) users of EVs in short field trials from several hours to one week (Graham-Rowe et al. 2012, Skippon & Garwood 2011) and longer field trials up to several months (Knie et al. 2012, Schneider et al. 2013 i.pr[1]., Vilimek et al. 2012). In the following the most important results are described.

There are some characteristics of EVs which are perceived positively by private customers. EVs are associated with environmental friendliness – by non-users (Götz et al. 2011, Graham-Rowe et al. 2012, Peters et al. 2011) as well as by actual users (Schneider et al. 2013 i.pr.). Operational costs of EVs are evaluated positively (Peters et al. 2011, Schneider et al. 2013 i.pr., Skippon & Garwood 2011). The quiet motor is another factor which might be a driver for the diffusion of EVs (Götz et al. 2011, Graham-Rowe et al. 2012, Knie et al. 2012, Schneider et al. 2013 i.pr.). Furthermore, the private customers who took part in the survey like the driving pleasure and acceleration (Knie et al. 2012, Skippon & Garwood 2011, Vilimek et al. 2012) and using an EV even increases the evaluations of this aspects (Schneider et al. 2013 i.pr.). In contradiction with this, users in the study of Graham-Rowe et al. (2012) rated the power and performance of EVs negatively. Regarding the handling of EVs potential as well as actual users evaluate EVs as easy to use (Peters et al. 2011, Schneider et al. 2013 i.pr.) and charging is rated positively as well (Schneider et al. 2013 i.pr., Vilimek et al. 2012).

On the other hand, there are some EV features which might be a barrier to their adoption. Range is perceived as not sufficient – by actual (Graham-Rowe et al. 2012, Knie et al. 2012) as well as non-users (Anable et al. 2011). However, using an EV can influence the confidence in the indicated range positively (Schneider et al. 2013 i.pr.). Charging duration is perceived as too long (Skippon & Garwood 2011) – actual users perceive it as even worse than future users (Schneider et al. 2013 i.pr.). However, there are users who enjoy the possibility to charge at home and integrating the charging process into their daily routines did not pose any problems (Vilimek et al. 2012). Recharging is often done overnight (Skippon & Garwood 2011). Thus the charging duration – even when perceived as too long – might not be a major problem for some users. The purchase price of an EV is another factor perceived negatively by most of the consumers or users (Skippon & Garwood 2001, Schneider et al. 2013 i.pr.). Test users think the purchase costs of EVs are unjustifiable because they perceive an EV as inferior to a conventional vehicle; concerns about the lifespan of the battery can be a contributing factor (Graham-Rowe et al. 2012). Regarding security or storage capacity EVs are perceived slightly inferior to conventional vehicles (Graham-Rowe et al. 2012, Peters et al. 2011) and reliability of EVs and availability of service are further factors the users are uncertain about (Graham-Rowe et al. 2012). The availability of a charging infrastructure in public is perceived very negatively by users (Schneider et al. 2013 i.pr.). In line with this, MINI E users wish for public charging infrastructure. On the other hand, public infrastructure is only rarely used (Vilimek et al. 2012).

These disadvantages from a user's point of view might be a reason for the fact that only very few consumers are planning to buy an EV (Lieven et al. 2011). Graham-Rowe et al. (2012) found that one reason could be the conviction that EVs are at the moment an "ongoing project"; thus the potential users want to wait and see. Thus, the users can imagine buying a BEV only as a second car for short journeys (Graham-Rowe et al. 2012).

A factor which influences the likelihood of buying an EV is the evaluation of the range (Anable et al. 2011, Lieven et al. 2011). The social influence or social norm is also important for the intention to adopt an EV, i.e. family or friends who might be attracted to an EV (Anable et al. 2011, Peters et al. 2011). Further factors are the compatibility of the EV with own values, needs and experiences and – related to the EV itself – operational costs and driving characteristics (Peters et al. 2011). Curtin et al. (2009) found that, despite the relevance of economic factors, the likelihood of plug-in hybrid electric vehicle (PHEV) and hybrid electric vehicle (HEV) adoption is influenced even more by environmental and other non-economic aspects. Purchase price and running costs are considerable factors for the speed of the diffusion of EVs whereas range and duration of the recharge process primarily affect the ratio between BEVs and PHEVs within the diffusion process (Götz et al. 2011).

1. The majority of users (40 %) uses the vehicles in private usage scenarios, thus we decided to integrate this study into this chapter (20 % of the participants uses their vehicles commercially and 40 % had a mixed using scenario).

In sum, (potential) drivers of the diffusion of EVs can be lower operational costs, environmental friendliness and (the perceived) better performance. EVs are evaluated as easy to use and to recharge and the low driving noise is rated positively. On the other hand, the main barriers for an uptake of EVs might be higher purchase costs, lower range and long recharging times. When analysing the influence of several factors on the purchase intention some studies identified economic factors, like operational costs, others non-economic ones, like environmental influence, range or compatibility with own needs and experiences as well as social norms.

When comparing the results of the different studies on consumer acceptance of private customers it becomes apparent that the participants in the studies rate EVs similarly even though they have used different kinds of vehicles in different usage scenarios. Even non-users are mostly aware of the most important advantages and disadvantages of EVs.

ACCEPTANCE OF EVS BY COMMERCIAL USERS

Besides private car use there are commercial fleets of vehicles. This means that these vehicles are primarily used for commercial purposes und their owner is a corporate body (Gnann et al. 2012; Steinmeyer 2007; Zischler 2011). A hybrid form of private and commercial usage are company cars which are purchased or leased by the company, but can be used by the employee also for private purposes.

Importance of commercial fleets for the diffusion of EVs

There are several reasons why commercial fleets are seen as an adopter group which is crucial for the diffusion of EVs or, as discussed by Nesbitt and colleagues, for alternatively fueled vehicles (AFVs) in general (Gnann et al. 2012; Golob et al. 1997; Nesbitt & Sperling 2001, 1998; Carroll und Walsh 2010): From a societal perspective, the high share of commercial vehicles in the new sale market could accelerate the diffusion of EVs in the market. Additionally, in the case of commercial fleets a small number of decision makers decides on a large number of vehicles which is promising for the success of marketing efforts, customised policies to promote EVs and the establishment of made-to-measure solutions for the adoption of EVs. Thus this group could be targeted by specific product developments as well as suitable marketing measures. From a user perspective, fleet vehicles often have a reliable profile of daily routes and are parked at a central spot which provides good conditions for installing facilities for refuelling/recharging. Furthermore, EVs are characterised by higher initial costs of purchase but lower running costs for fuel. Therefore the higher annual mileage of cars in commercial fleets can constitute good framework conditions for an economic reasonable operation of EVs. Also it is assumed that a larger pool of vehicles provides better conditions in order to compensate for the restricted range of EVs by using them only for suitable routes while long distance trips can be covered by the conventional vehicles in the fleet. In the end organisations with a vehicle fleet can gain additional benefits for their image by using EVs as a corporate identity measure and for promoting their efforts in sustainability to their customers and the public. Nesbitt and Speling (1998) provide a comprehensive discussion of these specialties of commercial fleets with regard to AFV adoption and reconsider the relevance of these specialties.

User acceptance in commercial fleets

Few studies so far deal with the evaluation of EVs by commercial users; we were able to identify three (Carroll & Walsh 2010; Ehrler & Hebes 2012; Deffner et al. 2012). Deffner et al. (2012) conducted a study that included two groups of commercial users. One group used EVs of the organisational car pool (N=61) and another group used EVs as company cars (N=200). The second group used their EVs predominantly for private purposes like daily commuting. Main findings of this study with regard to the users of company cars have been that the low noise emissions and the overall driving experience were perceived very positive. Acceleration, top speed, vehicle safety and comfort got intermediate ratings whereas the range of the vehicles was assessed as not sufficient. Furthermore, it is reported that users are quite tolerant towards teething troubles of EVs. However, these user evaluations are based on a rather short period of usage (maximum: two times for one week). The car pool users also rated the low noise emissions and the overall driving experience the best, whereas safety, top speed, comfort and acceleration got intermediate ratings. Range was rated better by the car pool users than by the company car drivers but got also the least positive evaluation. Users (N=113) surveyed by Carroll and Walsh (2010) utilised EVs for business trips only. Key findings of this paper are that users rate their EVs overall as "good", especially with regard to driving noise and the environmental benefits of EVs. Due to the result that 58 % of the respondents stated that the experiences in the field trial made them feel more positive about EVs the authors conclude that the using experience results in a positive change in the evaluation of EVs. Ehrler and Hebes (2012) report results of a one year field trial with ten drivers of electric trucks and light duty vehicles. According to this study the drivers had concerns about the restricted range but also reported that driving those EVs is fun and elates them. With regard to this finding the authors conclude that the acceptance for EVs by commercial users is high.

With regard to the existing literature it can be stated that the acceptance of commercial users for EVs is underexplored compared to the number of studies dealing with private customers. Furthermore, the existing studies have different shortfalls. In the sample of Deffner et al. (2012) the users had overall only a short period for gaining experience with the EVs. Moreover, most of the participants used the EVs primarily for private purposes like daily commuting which makes it difficult to draw conclusions for a predominantly commercial user scenario. The questionnaire by Carroll and Walsh (2010) did not cover questions about the range of the tested vehicles and therefore misses a crucial part of the subject matter. The results of Ehrler and Hebes (2012) are based on a very small number of users. Thus, these studies provide a starting point for discussion, however, the issue needs to be further deepened.

SCOPE OF THE PAPER

To conclude, several studies have analysed the user perspective on EVs for private consumers. They come to similar results. Overall they point out that environmental friendliness, lower operational costs and better perceived performance can be drivers for the EV adoption. On the other hand, restricted range, charging duration and high initial costs are evaluated negatively and might thus be barriers from a customer's point of view. The

few studies who looked at the user perspective in a commercial usage scenario point to somewhat similar conclusions, e.g. users seem to have a positive attitude towards the vehicle (Carroll & Walsh 2010; Ehrler & Hebes 2012; Deffner et al. 2012), the low driving noise is evaluated positively (Carroll & Walsh 2010; Deffner et al. 2012) and vehicle range is a concern (Ehrler & Hebes 2012). However, based on these publications it is not possible to conclude whether users perceive EVs in an identical way if they use them privately or professionally. A closer analysis of this issue allows to check whether results from private usage scenarios can be transferred to commercial ones or not. Thus the first research question we look at in this paper is

1. how do private and commercial users differ in their evaluations of EVs after a long duration of usage?

The work published so far on commercial usage does not allow to draw conclusions which factors are related to a high or a low acceptance of an EV, i.e. to identify factors that are likely to be influential on overall user acceptance. Thus we also analyse

2. which features of EVs are evaluated differently by commercial users with a high acceptance of EVs from those with a lower acceptance?

Method

The data for our study were collected within the pilot regions for electric mobility and covers users of very multifaceted projects. This section describes how the data were generated and prepared for the analysis this paper is based on.

RESEARCH DESIGN AND PROCEDURE

The German Federal Ministry of Transport, Building and Urban Development funded a series of field trials of EVs, the "Electric Mobility in Pilot Regions" (in German: "Modellregionen Elektromobilität"). Eight pilot regions were initiated where different kinds of EVs, e.g. two-wheelers, transporters, and passenger cars were used. These vehicles were tested by several types of users (private as well as commercial) in a broad variety of usage scenarios: Private users used the vehicles in exclusive private use or via participation in car-sharing scenarios; commercial users had access to the EV as a company car or fleet vehicle. Every pilot region conducted several projects on electric mobility. The field trials varied in length and took place from summer 2010 to September 2011.

The Pilot Regions were accompanied by research projects which covered issues of overall interest; research on consumer perceptions of EVs was one of them (see Dütschke et al. 2012 for further information). For this purpose a longitudinal study design including three surveys was developed and the three questionnaires were – where possible – distributed to the participants of the field trials.

- Survey T0 assessed consumer expectations of electric mobility prior to vehicle delivery.
- Survey T1 assessed first impressions of the vehicles and electric mobility after one to eleven weeks of usage.
- Survey T2 assessed experiences after more than three months of usage.

The surveys includes questions on the vehicle types, usage, demographics, perceived advantages and disadvantages of the vehicles, and item batteries with general aspects of acceptance, e.g. the ease of use, as well as more detailed questions about specific attributes of the EV, e.g. the performance, and the infrastructure. The surveys were available online as well as in a paper version and participating took about 25 min per questionnaire. In sum, 2,306 EV users took part in the survey – 853 participants in the T0 survey, 781 in the T1 survey and 690 participants in the T2 survey (see Dütschke et al. 2012 for a detailed description of the overall sample). In the overall sample more than 75 % of the participants are men, the mean age is around 40 years and – as far as data is available – most of the participants are highly educated (around 65 % state to have an university entrance diploma).

In this paper we focus on evaluations on perceived usefulness of EVs (dependent variable) and vehicle characteristics (independent variables) measured at T2. More details about measures and the sample are provided in the following sections. The sample mainly includes users of BEV (battery electric vehicle).[2]

SAMPLE

With regard to the research questions of this paper the original data had to be edited in some way. First of all the database was restricted to the T2 survey. The users of the EVs in this third wave had used the EVs for the longest time (more than three months up to a full year) and could therefore base their judgments on extensive practical experience. The gross sample consists of 792 cases[3]. 149 respondents did not state at all whether they used their EV in a commercial or private context and were therefore excluded from the database. The remaining sample included 132 users who stated that they use their vehicle in a private as well as in a commercial context. The last group was assigned to the group of the private users if they stated that they use their EV in their private life as main means of travel and if they did not use the EV as their main means of travel with regard to their commercial mobility needs (n=14). The other way round respondents were assigned to the group of commercial users (n=16). If respondents who used their EV in a private and a commercial context stated either that they use the EV in both or in none of these settings as their main means of travel they were excluded from the dataset (n=102). Furthermore the sample was restricted to persons driving a passenger car or a light duty vehicle whereas users of e-bikes and electric motorcycles where excluded from the database. This decision was made as this analysis concentrates on evaluations of vehicle characteristics which are very different for these types of vehicles (cf. Reichardt et al., 2012, for the specifics of electric two-wheelers). However, by this constraint the sample was reduced to 58 private users and 82 commercial users. To make sure that the respondents can base their judgments on a sufficient base of experience all individuals were excluded who used their EV

2. Two drivers of PHEVs are also part of the sample. Drivers of hybrid electric vehicles without an external rechargeable battery were not accounted in this study due to the differences with regard to the need for charging infrastructure.

3. The difference to the number of participants reported for T2 is caused by the inclusion of participants of T1 who used their EV for more than 3 months at the time of the survey.

Table 1. Characteristics of the sub-samples of private and commercial users.

Sub-sample	Vehicles	Mean duration of usage	Intensity of usage
Private users	49 BEV passenger car 1 BEV transporter	7.0 months	28 almost every day 15 1–3 times a week 7 1–3 times a month
Commercial users	37 BEV passenger car 2 PHEV passenger car 11 BEV Transporter	5.6 months	19 almost every day 20 1–3 times a week 11 1–3 times a month

less than one to three times per month what spared 52 private users and 70 commercial users. Furthermore, to ensure a sufficient quality of data respondents who left more than 30 % of the items unanswered were excluded from the database. So the final sample consists of 50 private users and 50 commercial users. For the remaining sample, missing values were replaced by the mean of the respective variable. Due to privacy issues, especially in the case of commercial car users, items about demographic attributes were unfortunately not accepted by some project partners to be part of the questionnaire. Therefore no demographic parameters can be provided for this sub-sample. Basic parameters with regard to the vehicle usage are reported in Table 1.

MEASURES

Dependent variable: user acceptance

User acceptance is often defined as the actual (and frequent) usage of a technology or a product or the intention to use it (Venkatesh et al. 2003). However, as we deal with participants of field trials in an early market phase, this measure is not adequate. In many projects whose participants we surveyed users did not have the possibility to further use the EV after the end of the project. As EVs were hardly available on the market for permanent use at that point of time a question about future usage did not make sense. For the purpose of this paper, we therefore define user acceptance as the perceived usefulness of an EV. In several studies perceived usefulness proved to be the most stable antecedent for actual or intended usage of a technology (Yousafzai et al. 2007a, 2007b). Therefore it seems to be appropriate to use it as a proxy for technology acceptance. Perceived usefulness was originally defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis 1989, S. 320). Transferred to the context of EVs we specified it as the degree to which the EV allows to successfully meet the transport requirements of an individual in his or her everyday life. The concept was measured by a single item worded "The electric vehicle is useful for my everyday life.". The item was rated by the respondents on 6-point-scale (see next paragraph).

Independent variables

The independent variables of our survey are measured by items which cover different aspects of EV usage. The items were rated by the respondents on 6-point-scales ranging from 1 ("does not apply at all" or "not at all") to 6 ("applies perfectly" respectively "fully"). For the purpose of this analysis the items are aggregated to indices each summarizing similar items within a range of values from 1 to 6. Table 2 gives an overview of the used indices and items.

Results

This section starts with a descriptive presentation of our dependent variable. In the following two sub-sections we further present the data analyses addressing our two research questions. The distribution of the statements to the item "The electric vehicle is useful for my everyday life." is shown in Figure 1. The mean of private users is 5.2 with a standard deviation of 1.0 while the sub-sample of commercial users has a mean of 5.1 and a standard deviation of 0.975. The difference between the two groups is not significant[4].

The different independent variables show varying means: So ease of use of the EVs was rated very positive with a mean of 5.6. Less positive but still good was the rating to the item "positive reactions of others" (mean 5.2) as well as the evaluation of the environmental friendliness of the EV (mean 5.2). The indices of safety and driving experiences got intermediate ratings, each with a mean of 4.9. Reliability was evaluated with an average rating of 4.5 and the process of recharging got a rating of 4.3. Relatively poor ratings were given to the aspects of costs, range and comfort with a mean of 3.9 each. The rating of the availability and accessibility of charging infrastructure brings up the rear with a mean value of 3.4.

DIFFERENCES BETWEEN PRIVATE AND COMMERCIAL USERS' EVALUATION OF THE EVS

To address our first research question we used t-tests[5] in order to identify significant differences regarding the evaluation of the EVs between private and commercial users. The results of the analysis are shown in Table 3.

Out of the 12 tested indices and items 5 show significant differences between commercial and private users (see Figure 2). Most of these differences rely on a better rating of the private users, like charging infrastructure, costs, reliability and positive reactions of others. Commercial users only rate the index instrumentation and passenger compartment significantly more positively than private users.

4. T-value: 0.614.

5. Due to the small size of the sub-samples we also report p-values of lower than 0.1.

Table 2. Indices and items measured as independent variables.

index	Items
Ease of use	The use of the EV is easy.
	The handling of the EV was easy to learn.
Range	Sufficient range
	Trust in remaining range
Process of recharging	Short duration of recharge process
	Easy handling of recharge process
Charging infrastructure	Availability of charging spots at work
	Availability of charging spots at home
	Availability of charging spots at public places
	Accessibility of charging infrastructure at public spots
Driving experience	Great pleasure of driving
	Good acceleration
	Sufficient maximum speed
	Pleasant driving noise
	Comfortable driving
Costs	Low acquisition costs
	Low costs for service and maintenance
	Low operating costs
	The EV helps to save money
Safety	Safety of driving
	Safety of recharging
Reliability	High reliability
	Good service
Instrumentation and passenger compartment	The heating system of the EV has functional capability.
	The air conditioning of the EV has functional capability.
	The EV provides a lot of space.
	High transport capacity
	Clear arrangement of displays and good instrument readout
Environmental friendliness	The EV is environment-friendly
Social environment	Positive reactions of others

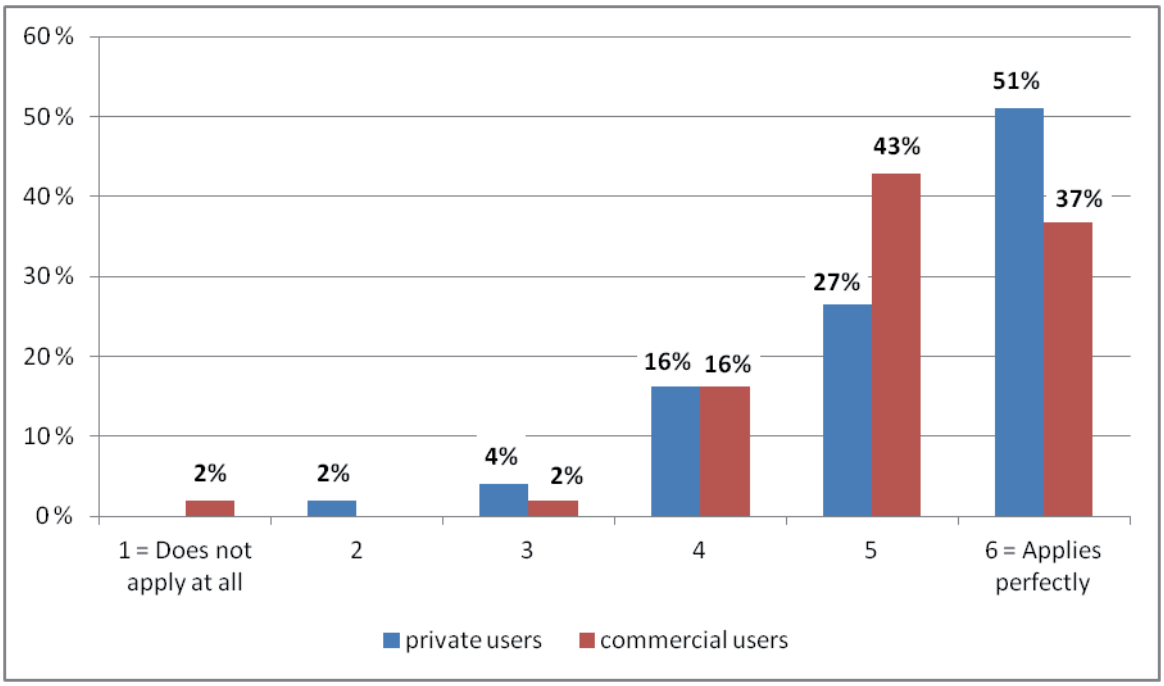

Figure 1. Perceived usefulness of EVs by private and commercial users.

Table 3. Differences between private and commercial users of EVs.

Index / single item	Mean private users	Mean commercial users	Difference	T-value
Ease of use	5.6	5.6	0.0	0.159
Range	4.0	3.8	0.2	0.716
Process of recharging	4.3	4.3	0.0	0.080
Charging infrastructure	3.7	3.0	0.7****	3.941
Driving experience	5.0	4.8	0.2	1.354
Costs	4.2	3.7	0.5****	4.837
Safety	5.0	4.8	0.2	1.225
Reliability	4.7	4.3	0.4***	2.639
Instrumentation and passenger compartment	3.5	4.3	-0.8****	-4.711
The EV is environment-friendly	5.2	5.1	0.1	0.303
Positive reactions of others	5.5	4.9	0.6***	3.349

Note: The Level of significance is reported the following way: p<.1, p<.05**, p<.01***, p<.001****.*

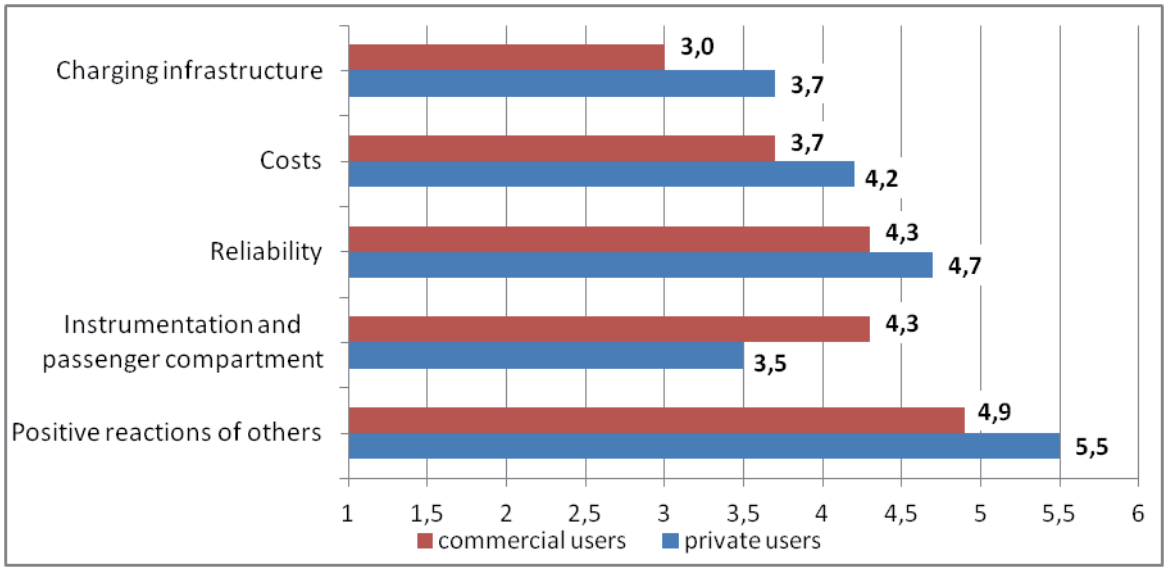

Figure 2. Means of items/indices with significant differences between commercial and private users. Note: The underlying items of the indices were rated by the respondents on 6-point-scales ranging from 1 ("does not apply at all" or "not at all") to 6 ("applies perfectly" respectively "fully"). The indices have the same range of values.

COMPARISON OF COMMERCIAL USERS WITH HIGH AND LOW ACCEPTANCE

Due to the small sample size the application of a multiple regression model is not a promising approach in order to identify influential factors on perceived usefulness. Thus, we use the comparison of two subgroups, one with low, one with high acceptance of EVs, in order to explore which factors are likely to be related to user acceptance of EVs. The first sub-sample consists of those respondents who reported on the six step likert-scale of the item "The EV is useful in my everyday life" a 5 or a 6 (signalling a strong agreement to the statement). This group consists of 40 respondents of whom 33 used a car and seven were drivers of a transporter. The average duration of usage is 5.5 months. The other group gave answers which signalised a weaker agreement to the statement (4 or lower). This group consists of ten people, four driving a transporter and six driving a car. The mean duration of usage is 5.7 months[6]. T-tests identify some differences between the high- and the low-acceptance-group (see Table 4).

6 of the 11 tested variables showed significant differences (see Figure 3). 5 out of 6 of these differences show a better rating of the group with a higher perceived usefulness. These are

6. The differences between the mean duration of usage are not significant; t-value: -0.349

Table 4. Differences between commercial users with a high and low perceived usefulness of EVs (N=50).

index/item	Perception of EV as very useful (n=40)	Perception of EV as less useful (n=10)	Difference	T-value
Ease of use	5.7	5.2	0.5*	2.079
Range	4.0	3.1	0.9*	1.867
Process of recharging	4.3	4.1	0.2	0.789
Charging infrastructure	3.1	2.7	0.4	1.584
Driving experience	4.9	4.4	0.5*	1.748
Costs	3.7	3.8	-0.1	-0.572
Safety	4.9	4.4	0.5*	1.889
Reliability	4.2	4.6	-0.4**	-2.056
Instrumentation and passenger compartment	4.4	4.2	0.2	0.455
The EV is environment-friendly	5.2	4.7	0.5	1.544
Positive reactions of others	5.1	4.3	0.8**	2.436

Note: The Level of significance is reported the following way: p<.1, p<.05**, p<.01***, p<.001****.*

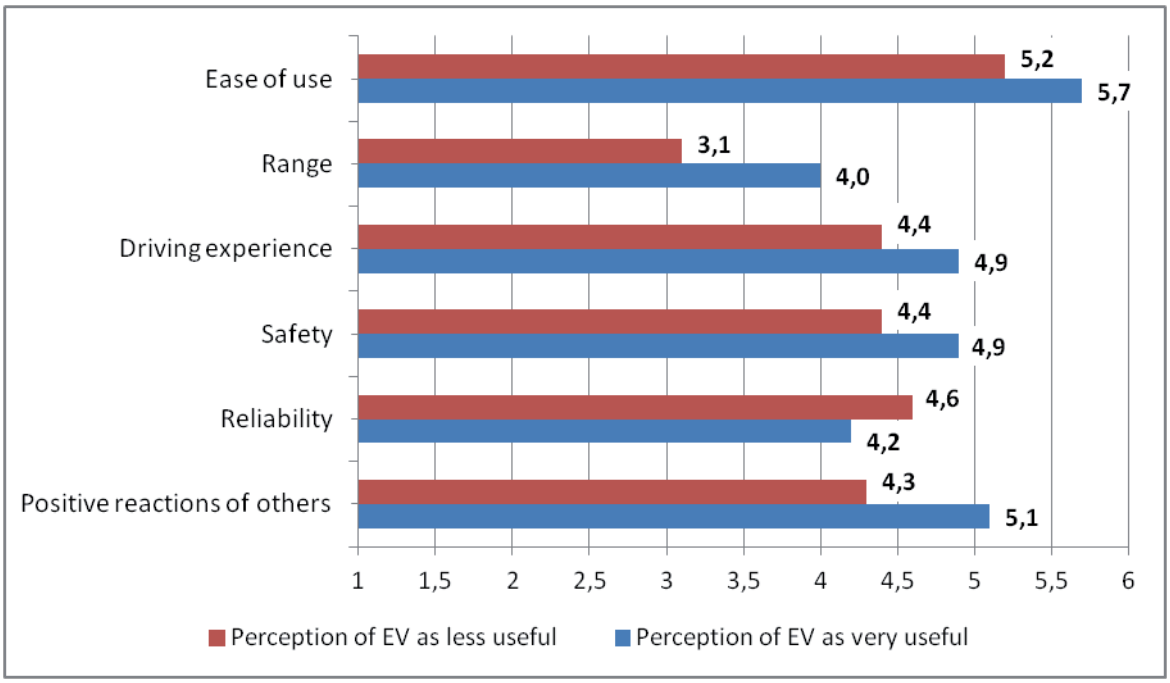

Figure 3. Means of items/indices with significant differences between commercial users with high and low perceived usefulness. Note: The underlying items of the indices were rated by the respondents on 6-point-scales ranging from 1 ("does not apply at all" or "not at all") to 6 ("applies perfectly" respectively "fully"). The indices have the same range of values.

the evaluations with regard to ease of use, range, driving experience, safety and the perceived reactions of other persons. The result for the evaluation of reliability of the EVs show a significant better rating of the group which perceive EVs as less useful in their daily life.

Conclusion and Discussion

For our analysis we measured different aspects which can be important for user acceptance of EVs and surveyed a sample of long-term users of EVs which consisted of private and commercial users of electric passenger cars and transporters. We aimed to learn more about possible differences between private and commercial users and the preconditions for user acceptance of EVs in a commercial context. Our ambition is to enrich existing knowledge by avoiding weaknesses of current studies, namely samples of users with little experience of EVs.

To summarize our findings, it can be stated that EVs are rated overall very positively in the whole sample. On the one hand, this can be exemplified by the positive ratings for perceived usefulness (mean 5.1). On the other hand, only range, the charging infrastructure, the costs for the EVs and instrumentation and passenger compartment have a mean evaluation below 4 whereas the mean ratings of all other aspects signalize positive evaluations. The conclusion that can be drawn from this finding is that the range restrictions and high costs seem to be the most salient barriers to user acceptance of EVs. Due to the rating of the index "instrumentation and passenger compartment" issues regarding the available space, the lucidity of displays and the functional capability of the heater and the air-conditioning also seem to be potential obstacles. The handling of the EVs (mean 5.6) and worries about the safety of the vehicles (mean 4.9) do not seem to be a barrier. Main drivers for the acceptance of EVs can be the positive reactions to EVs by the users' social environment (mean 5.2), the perception of EVs as an environmentally friendly innovation (mean 5.2) as well as the pleasure (of the experience) of driving an EV (mean 4.9). Reliability of the EVs (mean 4.5) and the process of recharging (mean 4.3) do not seem to be major obstacles to user acceptance.

PRIVATE VS. COMMERCIAL USERS

With respect to the comparison of private and commercial users it can be stated that there are no fundamental differences between these groups. Six out of eleven means of the tested indices/items do not show any significant difference. Except for the evaluation of instrumentation and passenger compartment, there is a stable trend that private users rate EVs better than commercial users. A possible explanation for this effect is that this difference in evaluation is partly a result of a process of self selection. Usually private users had to conduct more efforts in order to participate in the field trials and all of them decided to do so voluntarily whereas commercial users participated in connection with their occupation, and thus may be more critical.

A large, significant gap between the evaluation of private and commercial users is observed regarding the charging infrastructure (mean 3.7 vs. mean 3.0). These findings may be influenced by some project-specific circumstances. The index for infrastructure was built of items dealing with the availability and accessibility of charging infrastructure at home, at work and in public. Due to the different thematic focuses of the respective projects the availability of charging infrastructure at home or at work differed, i.e. projects focusing on commercial use usually mainly provided infrastructure at the workplace whereas projects for private users provided infrastructure at home.

Another large difference between private and commercial users can be found regarding the only aspect of EVs which is rated better by commercial than private users – instrumentation and passenger compartment (mean 3.5 vs. mean 4.3). It could be argued that this finding is influenced by the higher share of transporters in the sub-sample of commercial users. In fact, ratings for transport capacity and the provision of space in the EV provided by drivers of transporters are significantly better than those of the drivers of passenger cars[7]. However, the index still shows a significant better rating by the commercial users if these two items are excluded[8]. Possibly, the vehicles used for commercial settings were in general more spacious.

The significant better ratings of private users with regard to reliability (4.7 vs. 4.3) of the EVs are remarkable. This is of relevance because it is sometimes argued that commercial fleets are predestinated as adopters of EVs due to their better initial position in order to provide technical assistance and that they could therefore ensure a more reliable operation of the vehicles (Nesbitt & Sperling 1998). However, maybe the companies taking part in the projects under study could not deliver these services themselves due to the innovativeness of EVs. Moreover, the EVs used for commercial usage may have been in an earlier stage of technical development.

The costs of the EVs were rated better by the private users (4.2 vs. 3.7). This finding can be influenced by the structures of the different projects our data are collected from. While private users in these projects are voluntary early adopters who obtained their EVs by an individual decision making process commercial users are not expected to pay for their vehicles and therefore the outcomes of our analysis could be influenced by these different framework conditions. So the findings with regard to the costs can be biased by the process of self-selection within the sub-sample of private users as described earlier.

The perception of positive reactions of other people (5.5 vs. 4.9) seems to be a clear difference between private and commercial users. Therefore, the perceived affirmation by the social environment seems to be stronger in the private than in the commercial sphere.

HIGH VS. LOW PERCEIVED USEFULNESS

Regarding the comparison of commercial users with a high perceived usefulness with such users with a lower perceived usefulness it can be concluded that the sufficiency of range of the EVs plays a crucial role. Here the spread of the mean ratings (4.0 vs. 3.1) is quite large.

Ease of use (5.7 vs. 5.2) and positive reactions of others (5.1 vs. 4.3) also received different reactions from commercial users with a high perceived usefulness compared to commercial

7."The EV provides a lot of space": Mean passenger car drivers 3.2; mean of transporter drivers 5.3;
t = -7.343; p<.001. "High transport capacity": Mean passenger car drivers 3.2; mean transporter drivers 5.4; t = -6.641; p<.001.

8. Mean private users 3.9; mean commercial users 4.5; t = -3.083; p<.01.

users with a low perceived usefulness. Perceived ease of use is a crucial precondition for the usage of an innovation at all (Yousafzai et al. 2007a, 2007b). Positive reactions from the social environment in a commercial usage scenario can play a considerable role for the corporate image and therefore constitute a higher perception of usefulness.

The driving experience (4.9 vs. 4.4) and the perception of safety of the EVs (4.9 vs. 4.4) also constitute a distinction between commercial users with high and low perceived usefulness. The evaluation of the driving experience can rely on an emotional perception of the usage of the EV (e.g. fun by powerful acceleration) as well as on the conformance of practical needs (e.g. like sufficient top speed in order to travel quickly) by the EV. Concerns about the safety of a vehicle can undermine the acceptance of the vehicle.

However, our findings with regard to the reliability of EVs are somewhat not intuitive and therefore hard to interpret. It is possible that project specific circumstances which cannot be identified so far play a role in the formation of our data.[9] Thus the finding that there is a better evaluation of reliability by users with a low perceived usefulness is definitely a point which requires further research.

LIMITATIONS

To name further limitations of our study, it has to be kept in mind that the market for EVs is still in an early phase and our sample therefore covers a very specific group of early adopters. Therefore, further research will need to monitor in how far findings from this early phase will also be valid in later phases – with more developed vehicles, different types of users and a changed environment for EVs (e.g. with regard to infrastructure). As we described earlier, it is possible that voluntariness of early adopters leads to systematic better evaluations of the used EVs.

With regard to questions addressing possible diffusion scenarios of EVs in the market for commercial vehicles it has to be attended to that the users of EVs and the people who make adoption decisions in commercial fleets are not necessarily the same people. Therefore user acceptance and the adoption decision are not inevitably that closely connected as they are in the case of private car buyers it is therefore necessary to address the decision makers as well if propositions with regard to technology diffusions are to be made. However, studies regarding decision makers of vehicle fleets which adopt EVs in an early stage of the market will face the same methodological problems of early adopter samples as we mentioned above.

Most studies, including ours, find that EVs are well received by their users, however, that some important topics like range, price and infrastructure remain critical from a user point of view. Due to the early stage of the diffusion process, it cannot be forecasted whether EVs will gain ground in the market or not, because CVs are a matured technology and constitute a high standard of comparison. Users therefore make great demands on EVs and it is not clear if they can measure up to these expectations. Especially with regard to issues of financial costs and benefits it is likely that macroeconomic developments like the crude oil price will have a great impact on the future diffusion of EVs.

The identification of early adopters-applications for EVs remains a field in which more research is needed. Such applications could probably be found in certain branches or vehicle utilizations which are likely to be early adopters-applications for EVs, because they provide good original conditions by lower demands for vehicle ranges and still allow EVs to bring their low running costs to bear. Our data provides information about the purpose for which the EVs of commercial users were used.[10] However, none of these purposes is significantly related to the rating of the range-index. Therefore we cannot provide statistical evidence for certain usage scenarios which are particularly suited or unsuited for EVs due to lower or higher requirements for the driving range. Gnann et al. (2012) analyzed GPS-logged driving profiles and further data in order to identify branches with suitable original conditions for EVs. The authors conclude that commercial fleets in the public sector and social service have a higher potential for an economic (total cost of ownership) and technical (low number of long-distance trips) advantageous application of BEVs. However, due to their limited data-base it is not clear if general conclusions can be drawn from this study. Dudenhöffer and Leisten (2011) published survey results that indicate that the providers of social services have a particularly low willingness to pay with regard to vehicle purchase. Furthermore, the authors state that the driving profiles of vehicles in the public sector have a very heterogeneous path length and that the high purchase price remains a barrier even if the mobility-tasks fit the technical parameters of BEVs. So findings with regard to the issue of early adopters-applications are ambiguous.

However, commercial usage scenarios differ from private ones and can therefore enable operation scenarios of EVs in which the current limitations of EVs do not have a negative impact. Nevertheless, such usage scenarios demand further technical developments like new applications of information technology which help to integrate EVs into a general concept of a commercial fleet. Beside solutions by such technical approaches user acceptance remains a crucial point for the diffusion of EVs. Even if EVs can be integrated into fleets in a way that accommodates performance characteristics of EVs to usage scenarios, it is not clear if the users were to perceive such a solution as an adequate alternative. Thus, e.g. range restrictions could remain a barrier.

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9. T-tests whether the participants of the respective projects differ from the remaining participants with regard to our dependent and independent variables did not show obvious biases.

10. Respondents could choose six categories with regard to the type of use: 1. Visits/inspection/meetings; 2. customer service/job completion; 3. social service/care; 4. transport, collection and delivery of goods; 5. passenger transport; 6. miscellaneus; multiple choices were allowed.

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