

Research methods to assess the acceptance of EVs - experiences from an EV user study

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1 EVs as examples for `green technologies` in the automotive sector

Even though they started off promisingly, electric vehicles (EVs) could never be permanently established in the transportation system. In the last decades EVs were rather seen as niche products - which were strongly supported by the dedicated community - than as serious competitors for internal combustion engines (ICEs).

Following increasing demand and decreasing supply of fossil fuels, this mindset has gradually changed. The growing awareness for CO₂-emissions has stirred the public's interest in alternative propulsion systems. The fact that car-traffic is responsible for 14% of Germany's overall CO₂-emissions clearly emphasizes the importance to develop new concepts for transportation. Similar pictures can be seen all over Europe and in the US as well. Therefore within the EU ambitious efforts are undertaken to further reduce CO₂-emissions. According to a recent regulation by the European Commission, car manufacturers are required to reduce their average fleet emission of newly registered cars to 130 g/km by 2015. The implementation of innovative concepts like electric vehicles in the fleet will be accounted for by up to 7 g / km as credits (European Parliament and Council of the European Union, 2009).

Additionally Germany – similar to initiatives in the UK and US – has defined the goal that by 2020 one million electric cars should be driven on German streets. The initiative by the German government to further support research and development of electric vehicles was the framework for the present field study.

2 Framework of the field study

2.1 Aim of the study

Aim of the present study is to assess the challenges and potentials of EVs for everyday mobility. The German research group led by Josef Krems has developed key elements of the methodology for the world's largest field study on electric vehicles to date. Vehicles are tested in Germany, the UK and the USA. Through similar methodological standards and the close cooperation between Chemnitz University of Technology, the University of California at Davis and the Oxford Brookes University it is possible to compare results on an international level.

In the US 600 vehicles are used in the metropolitan New York City area and the metropolitan Los Angeles-Orange County Area in California. Apart from that 40

vehicles are tested in the UK, whereas 20 vehicles are used in the so called 'fleet setting'. Within the fleet setting a considerable number of drivers has access to each car, so the suitability for fleet usage can be evaluated as well. In the 'private setting' the access to the vehicle is limited to members of the household. Similar to the framework in the UK the German study contains also fleet and private usage.

2.2 Vehicle specifics

The EVs in the present study are MINI Coopers which are converted to an electric power train with a 220 Nm torque and a maximum speed of 152 km/h. The vehicle is equipped with 150 kW / 204 HP and reaches a nominal range of 240 km.

2.3 Renewable energy as key element

One key element of the study is the usage of renewable energy to charge the vehicles to maximize their environmental impact. The fact that renewable energies are available only at certain times of the day makes it necessary to develop strategies to match supply and demand. To do so a procedure called 'timed charging' has been developed by the energy supplier. This procedure is also evaluated with respect to user acceptance and usability.

2.4 The application process

Like in the other two countries, the application was accessible via Internet, more than 700 people from the Berlin metropolitan area applied for the first period of EV-usage. Several criteria (e.g. willingness to take part in interviews, willingness to pay the monthly leasing rate, suitable connection for power supply) had to be fulfilled by the applicants. Apart from that numerous questions about demographics and prospective car use had to be answered. This procedure enabled the accompanying researchers to balance the scientific sample according to relevant factors. The first factor included the expected kilometers driven with the car during the usage period. The second factor defined the type of household (Turrentine et al., 1995): either the EV would be the only car in the household or the EV would be integrated in the household's fleet of vehicles ('hybrid households').

3 Methodology

In the present study an extensive package of methods is applied to take all relevant issues into account, which affect the acceptance and suitability of EV for everyday mobility. Like in the UK the German study consists of a 'private setting' and a 'fleet setting'.

Within the private setting, users are interviewed three times throughout one study period. The application of a longitudinal research design allows drawing valid conclusions about changes in attitudes and behavior. Nevertheless comparisons between subjects in the degree of change can also be made and linked to certain attitudes or personality traits.

For the fleet setting the research package only involved questionnaires and a conjoint analysis as the number of users per vehicle is higher and thus the intensity of vehicle usage per person is less. Therefore especially adjusted methods for fleet usage are administered. Nevertheless comparable methods are applied to identify differences in acceptance and suitability for different usage scenarios.

3.1 Interviews

Telephone interview:

When officially included in the study, the participants were interviewed by phone. Main issues were the qualitative assessment of motivation to participate in the study, the attitudes towards e-mobility and environmental topics. Main background of the interview was to rate the motivation for participation and to get in personal contact with the participants.

Face to face interviews:

These interviews were conducted right before the participants drove the vehicle for the first time, after three months and at the end of the usage period. Of special interest was to discuss expectations and experiences of the participants concerning the vehicle, charging / batteries and the usage of the charging infrastructure. By that mental models of the participants about relevant topics could be qualitatively identified. Interviews have already been employed to explore usage patterns and recommendations for future plug-in hybrid vehicles (Kurani et al., 2007).

Think aloud:

During the test drive of the car, users were asked to verbalize their thoughts when operating the vehicle for the first time. Ericsson and Simon (1993) point out that the closest connection between thinking and verbal comments can be identified when people are asked to verbalize their thoughts while completing a task. This procedure, also called `think aloud` is a valuable tool to qualitatively measure the usability of prototypes.

3.2 Diaries

Travel diaries:

A prominent method to assess mobility patterns are so called travel diaries (e.g. Golob & Gould, 1998). Normally administered over a week, the participants are asked to log their daily mobility behavior. In the present study relevant variables included time, duration and purposes of trips over the whole day. The diary is administered three times: before receiving the vehicle, after three months and before

returning the vehicle. The baseline measurement is especially valuable as changes to the mobility behavior with conventional vehicles can be reliably detected.

Charging diaries:

In addition to the travel diaries, so called charging diaries were administered during the weeks mentioned above (except for the baseline measurement). These diaries included the number of charging processes per week, kilometer reading at start / end of charge and the motives to charge at that particular time. The charging diaries are an important supplement for the objective data as motives for charging and their influence on behavior can be measured.

3.3 Experimental tasks

Trip Decision Task:

Aim of the task is to estimate the comfortable range and subjective buffers set by the users. In that context users are asked to do a trip of 60 km, but different levels of remaining range being displayed on the dashboard. Through an iterative process the level of comfortable range is narrowed down to an accessible span. As the limited range is a very prominent characteristic of an EV, it is necessary to quantify possible concerns about the remaining range.

Conjoint Analysis:

During the last decade stated preference methods, especially conjoint analyses have become very popular quantitative instruments in Marketing Research. Based on the work of Luce & Tukey (1964) this method allows to measure individual preferences of users for certain product features. This procedure is especially valuable before market launch as the prototype and its relevant characteristics can be evaluated in detail. In the present study users were asked to participate in a choice-based conjoint experiment dealing with EVs. The task was to choose an appropriate vehicle or refuse all alternatives, which were displayed on a computer screen. The different versions of an EV were defined along four characteristics whose specifications were randomly assigned by the computer. The definition of relevant product characteristics is usually done by product experts, e.g. through a focus group. The defining variables of an EV were as follows:

- Range (100 km, 200 km, 300 km, 400km)
- CO₂-emissions (5 g/km, 50 g/km, 90 g/km, 130 g/km)
- Duration of charging 0-100% (½ hr, 4 hrs, 8 hrs, 12 hrs)
- Monthly leasing rate (200€, 400€, 600€, 800€)

The present procedure allows the identification of the attached importance of the relevant variables and trade-offs. Conjoint analyses significantly contribute to the identification and the importance of key elements of EVs and have been used successfully in past research on EVs (Cheron & Zins, 1997).

3.4 Questionnaires

The largest share of subjective data comes from questionnaires, which were also administered three times throughout the study. The questionnaires also involved qualitative elements, which allowed the interaction between users and researchers in more complex issues like questions about timed charging and the handling of batteries. In addition to that questions about attitudes towards electric mobility, renewable energy and energy sources were asked. Apart from that questions were adapted from questionnaires dealing with e.g. environmental attitudes (Preisendörfer, 1996), affinity for technological innovations (Goldsmith & Hofacker, 1991), need for change (Wood & Swait, 2002), usability (Brooke, 1996) and driving style (French et al., 1993).

3.5 Dataloggers

Another key feature of the present study is the use of onboard data loggers, which continuously record variables such as trip length, speed and acceleration. These loggers are decisive to validate subjective data collected in the interviews and questionnaires. Moreover the loggers also record the frequency of charging, the status of the battery and the duration of different charging cycles. Matched with the data from the diaries, it is possible to paint a valid picture of travel and charging patterns.

4 Preliminary results

4.1 Limited range sufficient for everyday needs

The majority of the users expected to be constrained by the limited range before receiving the vehicle. After three months of usage, 94, 3 % of the users agreed that the range of the vehicle (approx. 140-160 km) is sufficient for everyday needs. 67, 7 % of the users feel as flexible with an EV as with a conventional internal combustion engine (ICE). According to the users about 80 % of the daily trips could be done with the EV. If the cargo space was not limited due to the size of the battery, participants expect to be able to do more than 90 % of their trips with the EV. Data of the travel diary point in same direction: only 14 % of the total number of trips driven in a week could not be done by an EV due to its restrictions (limited cargo, limited number of passengers and limited range).

4.2 Maximum distance: 150 km

When asked for the maximum distance driven with their EV, users report about 150 km on average. As target values for range, less than 100 km would not be sufficient, 200 km would be sufficient and 250 km would be the optimum according to the participants of the present study.

4.3 Preferences for renewable energy

More than 95 % of the users are of the opinion that renewable energy should be used for charging EVs. Especially wind (95%), water (98%) and solar energy (98%) are suitable energy sources for electric mobility. Only 33 % of the users approve of nuclear energy to charge EVs, solely 8 % would accept to charge with energy from coal-fired power plants.

5 Discussion

Due to self-selecting processes and other limiting factors (e.g. income), the sample in the study might not be representative for the whole population, but for the target group, which is interested in progressive technologies such as EVs. Preliminary results of the study indicate that EVs are already suited for the usage in metropolitan areas such as Berlin. Concerns about the limited range expressed by the users at the beginning of the study have not become real after three months. Users also repeatedly point out that they consider purchasing an EV in the future, but suitable business concepts are to be developed. The utilization of renewable energy to charge the EVs plays an outstanding role for the users. According to the users, this is a precondition for EVs on a large scale. In general there appears to be a high acceptance for EVs among the participants of the study but necessary infrastructure and adequate services still have to be created.

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