Transportation Research Part F 40 (2016) 119–129

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Fast-charging station here, please! User criteria for electric vehicle fast-charging locations

R. Philipsen *, T. Schmidt, J. van Heek, M. Ziefle

Human–Computer Interaction Center (HCIC), RWTH Aachen University, Campus-Boulevard 57, 52074 Aachen, Germany

ARTICLE INFO

Article history:
Received 17 June 2015
Received in revised form 1 March 2016
Accepted 30 April 2016
Available online 14 May 2016

Keywords:
Fast-charging
Electromobility
Battery electric vehicles
Infrastructure planning
Evaluation criteria
User requirements

ABSTRACT

The present research reports an empirical study targeting the analysis of evaluation criteria for fast-charging locations regarding both position and concrete realization. Involving both current and potential users of electric mobility technology discovers criteria for public acceptance as well as a description of possible drawbacks. A questionnaire study was carried out in which participants were asked to provide information about desired locations as well as their requirements for both the charging process and charging stations. In a second step, the evaluation criteria based on earlier studies were ranked. An overall consensus could not only be detected in previous focus group discussions but also in this quantitative approach. Outcomes show that motorway service stations, shopping facilities, and traditional fuel stations can be visualized as potential fast-charging station locations. It is shown that users' willingness to accept waiting times or detours cannot be expected. Dual use, reliability, and accessibility prove to be very important criteria for site evaluation of charging locations. In relation to user diversity, significant differences in terms of both prior use of battery electric vehicles and gender as well as occasional variations for age were found.

1. Introduction

Major challenges like global warming mark the reduction of CO_2-emissions as a highly important goal (The Royal Society, 2005). The production of greenhouse gases is caused and accelerated by humans; e.g., air pollution is partly based on people's use of combustion engines (Umweltbundesamt, 2014). New technologies can provide an opportunity to change running systems and define new strategies to create a healthier and more sustainable way of living without limiting the full range of mobility we need every day.

With the help of technological development, the opportunity emerges to reduce greenhouse gas emissions by adopting new ways of traveling. One possible solution that obtained considerable support is traveling by battery electric vehicles (BEVs). The federal government of Germany postulates in its "National Electro Mobility Development Plan" of 2009 that the number of electric cars in use should be increased to at least 1 million vehicles by 2020 (Bundesregierung, 2009). Sustainable mobility and electric cars did receive a mostly positive assessment from the public, as several surveys show (Hoffmann, Hinkeldein, Graff, & Kramer, 2014; Ziefle, Beul-Leusmann, Kasugai, & Schwalm, 2014). It is expected that this technology will progressively gain market share in the next few years (Plötz, Gnann, & Wietschel, 2012; Kihm &

* Corresponding author.
E-mail address: philipsen@comm.rwth-aachen.de (R. Philipsen).

http://dx.doi.org/10.1016/j.trf.2016.04.013
1369-8478/

Trommer, 2014). The car industry has seen the potential of this solution and already addressed it by developing a new generation of battery electric vehicles that provide a range of up to 150 km, like the BMW i3, the VW e-Golf, or the Nissan Leaf.

Recent research did elaborate the potential of electric mobility from different angles like the technical (Frischknecht & Flury, 2011; Werther & Hoch, 2012), economic (Kley, Lerch, & Dallinger, 2011; Hackbarth & Madlener, 2016), environmental (Sourkounis, Ni, & Broy, 2011), and psychological (Ziefle et al., 2014) point of view. Unfortunately, there are still challenges that need to be taken care of such as the time needed to recharge the batteries (Hidrue, Parsons, Kempton, & Gardner, 2011) and the limited range of BEVs in comparison to conventional vehicles with combustion engines (Jarass, Frenzel, & Trommer, 2014; Barth et al., 2016). Another barrier stems from the currently still fragmentary charging network (Egbue & Long, 2012; Halbey, Kowalewski, & Ziefle, 2015). Both the limited range of BEVs and the limited charging options are presently still major impediments to a fast adoption of electromobility and contribute to the so-called range anxiety, a form of psychological stress, which is the object of research in several studies, dealing with driving BEVs in critical range situations (Rauh et al., 2015), the concept of range comfort zones (Franke, Günther, Trantow, Rauh, & Krems, 2014), or the user's charging behavior (Franke and Krems, 2013; Bühler et al., 2013).

Nevertheless, electric vehicles can be valid alternatives for traditional automobiles (Claas, Marker, Bickert, Linssen, & Strunz, 2010; Winter, Kunze, & Lex-Balducci, 2010). In Germany, the average range driven is 43 km per day, which matches the possible range of BEVs (Follmer & Lenz, 2008). This implies that daily trips to work, grocery stores, or visits to a nearby city are covered by current battery capacities (Jarass et al., 2014). Other studies showed similar results on the range of BEVs being sufficient for average daily travels (Morrow, Karner, & Francfort, 2008; Pearre et al., 2011). This means that users could already replace their combustion engine vehicle with an electric vehicle with limited range without substantial adjustments of their mobility behavior. However, long-distance traveling beyond the usual daily trips is still a major challenge for battery electric vehicles, because it requires recharging during the trips.

Therefore, fast-charging, which allows the driver to recharge the battery to 80% of its capacity in less than 30 min, might be a good solution to cope with both the necessity to travel long-distances and long recharging times. However, especially in Germany, there is still a lack of fast-charging opportunities since the implementation of the charging network is still in its infancy. Additionally, there is yet a lack of knowledge about user requirements related to the expansion of said network and the positioning of specific charging stations in particular. Previous approaches to factor in the user during the planning process of charging networks are usually limited to discrete-choice and origin–destination models (Bernardo, Borrell, & Perdiguero, 2013; Namdeo et al., 2014) or activity-based approaches (González et al., 2014; Shahraki, Cai, Turkay, & Xu, 2015) that cannot fully cope with the users' needs and requirements regarding concrete location decisions.

Concerning the location evaluation by users, it is necessary to take user diversity, especially prior experience with BEVs, into account for several reasons: For example, Bühler et al. already revealed that experience with electric vehicles has a significant, positive effect on the general perception of electromobility (Bühler, Cocron, Neumann, Franke, & Krems, 2014). Furthermore, Rauh et al. showed that BEV driving experience reduces range anxiety (Rauh, Franke, & Krems, 2014) and users become more comfortable with both the lower range levels of BEVs and undertaking longer trips with their electric vehicles (Franke, Cocron, Bühler, Neumann, & Krems, 2012; Franke, Rauh, Günther, Trantow, & Krems, 2015), which is likely to impact the users' requirements for the locations of charging stations. This may result in problems regarding the planning of charging infrastructure: On the one hand, the locations and concrete arrangement of charging stations should encourage users, who are accustomed to cars with combustion engines, to switch to BEVs. That is, the charging network should be structured in such a way as to ensure the charging infrastructure is no longer perceived as an impediment to adoption by potential users. On the other hand, the charging stations have to fit the requirements of experienced BEV-drivers and those may differ from the needs and wishes of prospective users. These possible differences regarding the evaluation of charging locations have to be explored to plan and construct a both demand-driven and technology disseminating charging network that satisfies both user groups.

Also, effects of age and gender have to be addressed, because previous studies revealed that these user factors, among others, have effects on users' technology acceptance in other infrastructure contexts, like the placements of electric pylons (Zaunbrecher, Arning, Özalay, Natemeyer, & Ziefle, 2015) or communication network masts (Arning, Kowalewski, & Ziefle, 2014), and on decision-making processes in general (de Acedo Lizarraga, de Acedo Baquedano, & Cardelle-Elawar, 2007). Although age and gender effects are often mediated by underlying factors, it is reasonable to consider them directly in this context, since normally, next to vehicle ownership and traffic data, only basic demographic data on the population within regional areas are available and provide the data basis during city and transport planning processes.

In order to identify at which locations users would expect and prefer fast-charging stations and to reveal the underlying evaluation criteria, qualitative research studies have been carried out. Halbey et al. tried to contextualize the topic in focus group studies by concrete placements of stations on maps (Halbey et al., 2015). Further, subsequent discussions were conducted to disclose reasons for the placement. Thereby, eight main evaluation criteria for fast-charging locations regarding both position and concrete realization were identified: dual use of time and route, habit compatibility, accessibility, visibility, reliability, safety, connection to the public transportation network, and necessity (Philipsen, Schmidt, & Ziefle, 2015).

However, a quantitative analysis of the identified criteria and their relative weighting was still pending. Therefore, the present study aims at both exploring which evaluation criteria are important and necessary for localization decisions during the planning and establishment of a fast-charging network and revealing the criteria's relationships to user diversity in terms of the variables gender, age, and experience with BEVs.