Identifying EV drivers' needs for information communication technology to ease the EV charging process

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ABSTRACT

Known barriers of Electric Vehicles (EVs) include their limited range and, to some extent, the underdeveloped charging infrastructure. This position paper presents initial results from a field study investigating the experience of EV drivers who are supported by a newly developed charging concept (ELVIIS) consisting of a web, smartphone and in-vehicle application. By connecting power grid owner with the telecom and vehicle industry such a solution can be achieved. Presented are the self-reported experiences of 11 EV drivers using Volvo C30 electric, captured via open-ended interviews after the completion of the trail. Highlighted are the user needs for information communication technology (ICT), in particular remote access. It should be noted that the ELVIIS charging concept is used in this position paper as an example to illustrate the need of ICT (e.g., remote access) rather than an evaluation of the overall ELVIIS concept. Further analysis will be performed to evaluate the concept in detail.

Categories and Subject Descriptors

H.5 [**Information interface and presentation**]

General Terms

Design, Human Factors,

Keywords

User experience, Human machine interaction, electric vehicle, information processing, automotive interface, decision making

1. INTRODUCTION

The ELectrical Vehicle Intelligent InfraStructure project (ELVIIS) is a cross-industry project with the goal to ease the charging process of electric vehicles (EVs) by means of Information Communication Technology (ICT), see [1-3, 19]. Two field-studies, in which drivers experienced EVs for one month each, investigated the value of driving EVs (Study 1) and the potential added value of information technology in EVs (Study 2). Reported are initial findings from the second field study (Study 2) performed in 2013, in which the proposed ELVIIS charging concept was tested. The field study focused on 3 aspects of the charging experience, (a) the consumer value of ELVIIS charging concept (i.e., benefits/sacrifices), (b) the experience of range anxiety, and (c) the Human-machine-interaction. In this position paper, initial findings related to the need for ICT are explored, rather than the overall evaluation of the ELVIIS concept.

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1.1 The ELVIIS charging concept

The ELVIIS charging concept provides ICT support that enables EV drivers to use any outlet and automatically get the cost added to their own bill (Figure 1), see [1-3,17, 18]. It is hypothesised that the barrier for using private (e.g., a friend's) and public outlets can thus be decreased by providing the driver an easy way to pay for the electricity used (cf. [4-5]). It is also hypothesised that the uncertainty regarding the EV as a limited resource vehicle decreases by allowing drivers to access and control information related to the charging of the EV, via a web, smartphone and in-vehicle application (cf. [6-7]). More specifically, the mobile telecom network is used to coordinate the charging of vehicles, which increases the efficiency of the grid [18]. The driver decides when the car should be fully charged, the minimum range required to charge immediately, and the current to be used for the charge. The information is sent over the mobile network to a system that determines the best time for charging, based on the lowest cost and current demand on the grid. After that, the cost is added to the driver's bill, no matter which power outlet is used.

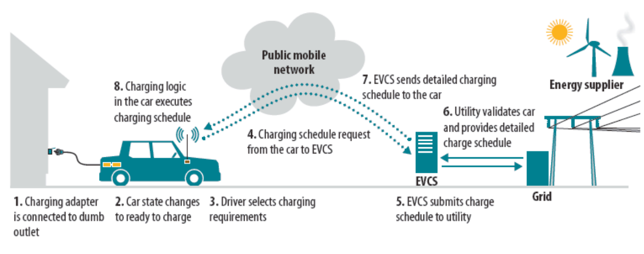

Figure 1. Overview of the ELVIIS concept, illustration inspired by illustration by Ericsson [18]. Step 3 illustrates the role of the driver. The EV driver interacts with the system in three ways: (1) via the in-vehicle application, (2) the web application, or (3) the smart-phone application.

As an EV driver you are typically aware of the range you need for a day. Imagine that you drive about 50 km á day, and you typically leave home roughly about the same time. The ELVIIS system then enables the EV driver to set up a charging schedule accordingly, that determines the minimum range (e.g., 50 km) and the time it should be fully charged (e.g., 08:00). This provides flexibility to the system; the vehicle is charged as fast as possible until the minimum range is reached - then starts charging according to the grid/personal preference on price/demand. The driver can change, update, or stop a charging schedule (remotely) when necessary (e.g., you need to leave earlier due to a re-scheduled meeting) via the smart-phone, the web or in-vehicle application, explained below.

1.1.1 *In-vehicle application*

The in-vehicle application (touch screen) can be used to adjust users' personal charge profile, minimum driving range that should be charged immediately, time for when the EV should aim to be fully charged by, and maximum charging current (cf. Figure 2).

Figure 2. Illustration of the in-vehicle system that the driver uses to adjust current charge settings.

1.1.2 *Web application*

In the web application, it is possible to view the EV's status of charge (SOC), estimated range and the charging schedule (cf. Figure 3). It is also possible to alter the user's personal charge profile, force the vehicle to start charging immediately, and to see statistics over previous charging, including the monthly charge reports. In addition, the users can see a map with their latest charging places as well as notifications issued by the system (e.g., the cord is disconnected).

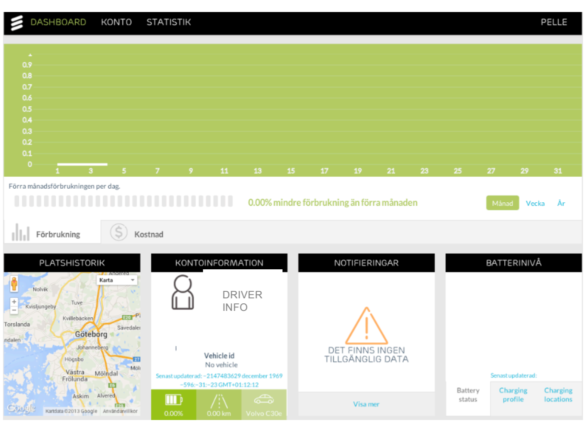

Figure 3. Illustration of the web application. The driver can access information regarding charge history, billing information amongst other.

1.1.3 *Smartphone application*

The smartphone application provides similar functionality as the web application; it is possible to force the EV to start charging immediately and to view its SOC and estimated range as well as to receive notifications related to the charging. However it is not possible to see the charging history or monthly reports there.

Figure 4. Illustration of the smart phone application. The user can access, via different tabs, charging schedule, and charge profile. The user can also decide to start the charging directly.

2. METHOD

2.1 Data collection

This study is based on the data from the second trail within the ELVIIS project (Study 2). Collected are the self-reported experiences of 11 EV drivers using the ELVIIS charging concept for one month in a Volvo C30 electric (a battery electric vehicle). The participants were given the task to use the EV as their main vehicle of the household. In total, 11 in-depth interviews were performed at the end of the EV trail period; 6 women and 5 men. The age ranged between 31 and 66 years. All had experience of participating in the previous one-month trail using EVs without having access to the ELVIIS charging concept. The follow-up session consisted of semi-structured interviews divided in two parts. Part 1: the drivers' perceptions and attitudes towards using the charging concept. This included open-ended questions regarding value creation together with the explanation model of critical incidents [8-9]. Part 2: the drivers' interaction with the EV. This included open-ended questions regarding the usability and functionality of the interface using probes in the format of reaction cards [10-11]. The reaction cards consisted of a list of adjectives, which can be used to describe user experiences of EVs. The lists consisted of 100 randomised adjectives (40% positive, 40% negative, 20% neutral). Each interview lasted for about 60 minutes.

2.2 Analysis

All interviews were transcribed using a third party. A qualitative assessment of the transcripts was performed in which a process of data reduction [12] and "open coding" were performed [13]. The identified citations were grouped and their meaning was analysed form the perspective of consumer value, the trade-off between the benefits and sacrifices perceived by the customers in the offering of a supplier [9,14, 16]. Furthermore, all material was analysed from the perspective of distributed cognition [cf. 15] to identify the emergent properties of the interaction between the driver and the interface; thereby being able to differentiate the functionality, information provided and role of the interaction. The activity of interest was constrained by the decision: "I will/will not drive to destination A" and how that activity influenced the daily life of the participant.

3. RESULTS AND ANALYSIS

Presented is the initial analysis of identified value drivers (i.e., the first level of data reduction). Here, value is not constrained by the value of the physical product, but also the service and relational dimensions of value is considered (cf. [14, 16]). All material has been analysed and citations were grouped as either a benefit or sacrifice. Here, a benefit is considered to be something that would increase (positive driver) or decrease (negative driver) the value of the newly developed ELVIIS concept. The following sections present seven emergent themes ("needs") from the data of which 3 emerged from the list of "benefits" and 4 emerged from the list of "sacrifices": (1) Need of remote access (benefit), (2) need of information availability (benefit), (3) need of limited range control (benefit), (4) need of synchronisation (sacrifice), (5) need of feedback (sacrifice), (6) need of personalisation (sacrifice), and (7) need of integrated functionality (sacrifice).

In the following sections, the number in brackets after identified value driver shows the number of participants who expressed a certain statement.

3.1 Need of remote access

Most frequent benefits with the used ELVIIS charging concept are those opportunities that emerge by accessing information about the charging process remotely via the web and smartphone applications (e.g., receive notifications about the progress and interruptions of charging). Examples of value drivers/benefits within this category are as follows:

- Remote access to information (11)
- Accessibility (8)
- Ability to show others (3)
- Check charging progress (5)

3.2 Need of information availability

Another emergent theme is related to the fact that having access to information at multiple places open up for opportunities that ease the charging process. Examples of identified value drivers/benefits:

- Availability (9)
- Confirm settings (6)
- Feedback (3)
- Multiple access points (4)

3.3 Need of limited range control

Many of the identified benefits are related to the ability of the ELVIIS charging concept to address issues related to the limited range of the vehicle. Examples of value drivers/benefits are:

- Information to use as decision support (9)

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- Control the charging process (6)
- Access to private/other outlets (5)

3.4 Need of synchronisation

The importance to show the same time-stamp as well as the same data was highlighted. Also, the information in these applications should be presented and visualised in the same way, e.g. the graphs should have same layout (i.e., provide familiarity). Some basic functionality should be available in all applications, e.g. one should be able to see details about the latest charge in all applications, but the full charging history may be available only via the web application. Examples of the value drivers that would increase the value of the proposed concept:

- Time (5)
- Data (6)
- Presentation (3)

3.5 Need of feedback

Many negative value drivers concerned a lack of feedback in terms of lack of usability and trust. Many participants actively looked for confirmation. It is for example highlighted that the applications need to confirm that a change is registered. Also, the concept should provide functions that enable feedback on driving style to be able to encourage the user to drive more "green" (e.g. inform the user how to drive to save energy). Examples of the value drivers that would increase the value of the proposed concept:

- Confirmation (8)
- Encouragement (4)

3.6 Need of personalisation

A need for personalisation was highlighted. Respondents expressed a need for setting own preferences regarding the content on the overview page. Also, it should be possible to set own preferences regarding the optimisation of the charging (e.g. if one wants to charge with "green" energy only then he/she could select this as the optimisation criteria). Examples of value drivers that would increase the value of the proposed concept:

- Own overview (3)
- Own charge optimisation (3).

3.7 Need of integrated functionality

Generally, the participants are satisfied with the functions available in the concept (given that these are error-free), but they would like to get access to more (integrated) functions. Examples of the value drivers that would increase the value of the proposed concept:

- Amperage control (8)
- Charging spots (7)
- Trip planning (6)

4. DISCUSSION AND CONCLUSION

The presented results highlight the need for extra support regarding the charging process of EV. By evaluating the benefits and sacrifices associated to the ELVIIS concept the initial analysis highlights 7 emergent themes that ease the experience of charging EVs. When participants compared their experiences when charging without support (Study 1) and charging with the support of ELVIIS, several participants (7) stated that charging with the developed ELVIIS charging concept was easier. Indeed, the results show that a great majority of the participants (9 of 11) stated that they would recommend the ELVIIS concept to a friend using an EV, or use it self in an EV. Interestingly, it is noted that the attributes of the information technology used (smartphone, web, in-vehicle application) for presenting the ELVIIS charging concept influence the experience of the concept (e.g., remote access). It is also noted that the charging experience extends time and space and the physical boundary of the vehicle itself. Further studies will evaluate the overall experience of the proposed concept and its possibilities for minimising known barriers of full-scale adoption of EVs.

5. ACKNOWLEDGMENTS

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