PEV-Charging in Rural and Business Environments

A User Behaviour and Demand Comparison

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***Abstract* — In order to accelerate the further development of electromobility and to achieve a demand-based, user-friendly charging infrastructure, profound studies on the EV user behaviour and needs are still necessary.** *To fill this gap, the research consortium Fraunhofer IAO and IAT University of Stuttgart combined the approaches of classical data mining with sociological research methods in order to achieve a holistic view on the actual situation and therefore to receive profound answers: On the one hand, typical charging behaviour patterns of PEV users in rural and business environments have been derived by analysing more than 15,000 charging events. Load profiles of specific charging locations in public and semi-public places were obtained in order to serve as rough sizing guidelines for future charging infrastructure. On the other hand, more than 130 regular EV users have been questioned by means of standardised surveys and qualitative in-depth interviews. The questioning aimed to capture the participants' perception regarding the usage of electric vehicles and the existing charging infrastructure in public places. By matching both user behaviour and demand, detailed recommendations for political and economic actions can be provided. Therefore, attractiveness and cost efficiency of public charging infrastructure can be increased, which encourage further development of e-mobility. In the following, the paper presents the combined interpretation of the results from the classical data analysis of PEV-charging events and those of the sociological research work.*

Keywords — electric vehicle; charging infrastructure; field study; rural and business environments; user behaviour; user demand

I. Introduction and Data Base

The increased environmental awareness and growing concerns over topics such as climate change or carbon footprints have led to an accelerated development of electromobility. Nevertheless, within the last years, e-mobility has not gained acceptance on a large scale since challenges as the customer oriented planning, cost-effective maintenance and user-friendly handling of (semi-)public charging infrastructure still exist. In order to accelerate the further development of electromobility, it is essential to assimilate electric vehicles as well as the charging infrastructure according to users' needs. Two EV-field-tests in urban-business and rural-public environments have been carried out and scientifically analysed by the research consortium in order to identify the main fields of action in future.

As part of the project *charge@work* a large-scale installation of charging infrastructure at 16 Daimler sites within the urban surroundings of Stuttgart has been established. With the provision of more than 220 Smart ED, the company enabled its employees to test EVs for commuting purposes. In contrast to this, the project *e-GAP Intelligente Ladeinfrastruktur* has its focus on the analysis of user-friendly, public installed charging stations in rural environments. Here, seven charging stations have been installed within the area of the Marktgemeinde Garmisch-Partenkirchen (in the following named as GaPa).

For both mentioned projects specific charging behaviour patterns and load profiles have been derived in [9], by analysing measured charging durations, energy amounts per load, start times of load processes and the frequency of those variables. Beyond that, Daimler employees and local EV users in GaPa participated in different sociological surveys regarding their actual mobility and charging behaviour as well as their satisfaction with electric vehicles and existing charging infrastructures. Here, the main objective was to capture the perceptions and suggestions of the interviewees in order to improve further steps to a sustainable and user-friendly e-mobility respectively charging infrastructure. Within the present paper the results of the sociological research are presented in detail and matched with those of the measured charging data (for more details about the latter see [9]).

II. State of Art

In order to gain profound knowledge about the behaviour and demands of EV users, several sociological methods can be applied. Most studies capture information by carrying out online surveys exclusively [1], [2], [3], whereas some include in-depth interviews and vehicle logs for a deeper insight [4], [5]. The papers focus on different aspects of electromobility and the majority of the researches deals with pros and cons of e-mobility out of a user's perspective. For example, the user's attitude towards investment costs, driving pleasure and sustainability is shown in [1]. Other studies illustrate correlations between driving experience and range anxiety [4], derive typical characteristics of potential customers [2], [5] or deal with the smart combination of car sharing and electric vehicles [6].

In general, the majority of papers focuses on the analysis of the EV users' behaviour and demand in urban areas, instead of rural ones as done in [7], [8]. There is also an absence of scientific researches, which describe the demand for charging infrastructure and focus on rural areas. Further, a lack of studies that deepen the results of surveys with the help of in-depth interviews and/ or measured charging data is obvious.

To overcome this evident lack und to gain a holistic view of the EV user behaviour and demands, survey and interview results have to be matched with the results of the analysed measured charging data. The present paper fills this gap by comparing sociological surveys and in-depth interview conclusions with results of two different field tests. Therefore, the demand and the potential for improvement with respect to (semi-)public charging infrastructures can be analysed which provide a solid basis for reasonable recommendations.

III. Charging in Business Environments

A. Research Methodology

Within the project *charge@work* a standardised survey was developed and handed out to Daimler employees who tested the Smart ED as commuters. Since most of the participants did not own an EV on their own and used primarily Daimler sites to recharge the vehicle, the questioning mainly focused on the handling of the company-owned charging infrastructure, the vehicle's driving properties and the customers' experiences with the EVs. A special feature of the survey was that the employees were questioned online at three different points in time:

- T0 – Two weeks prior to the vehicle leasing field test, the participants were questioned for the first time in order to gain information about the customers' expectations. Out of 135 addressed persons, 99 answered the survey completely.
- T1 – Two weeks after the beginning of the field test, the participants were questioned for a second time in order to capture the first impressions. 95 out of 135 questionnaires were filled completely.
- T2 – At the end of the field test and the vehicle leasing (leasing period was freely chosen by employees), the survey was carried out for a third time to get the impressions and the final conclusions of the customers. Out of 114 addressed persons, 86 have answered the survey completely.

In addition to the above mentioned standardised online survey, twelve qualitative in-depth interviews took place between February 11th and March 23rd 2015 in order to get a more detailed insight into the user behaviour. Before each interview, the customer's anonymity was ensured and the permission of recording was obtained. Moreover, the resulting interview material was not transcribed word by word but insofar as the sense and purpose remained unaffected. Pauses, the pitch of the voice and other non-verbal elements were not objects of the interpretation.

B. Description of the sampled population

Considering the sampled population of the standardised survey a significant higher representation of males (88 %) than females is obvious. The average online survey participant is a 43 year old Daimler employee, which has at least one car on his own and travels approximately 39 km per day to work (one way). Nevertheless, 8 % of the participants state to commute more than 100 km in one direction to reach their place of employment. The sample population is not representative on a general level since (1) it was limited to the participants of the field test and (2) not randomly chosen but selected by a Daimler contact person. Further, the sampling might slightly be influenced by the fact that the participants had to pay leasing costs for the EV why not all interested employees might have took part in the field test. Nevertheless, the sampling methods seemed to be acceptable in this specific case since a high interest in mobility matters was assumed in general for all employees at the different Daimler sites due to their work activity for an automotive company. Further, the present sample population confirms the general opinion and states the fact that users of electromobility are almost exclusively "middle-aged, well-educated men with a technical background, who live in an urban multi-person household and earn above-average" [10].

Considering the interpretation of the following results it has to be mentioned that all participants of the field test had to pay for (1) leasing and (2) charging the Smart ED.

C. Results: User demand in comparison with user behaviour

This section is divided into three parts. First, the results of the sociological research (online survey, in-depth interviews) considering charging infrastructure are presented. Then, the participants' view on the EV properties, in this case Smart ED, is discussed. Finally, results considering public image improvement and altered mobility behaviour are presented.

❖ Result I: Charging infrastructure

Although it is partly used to charge prototype vehicles in addition, the Daimler charging infrastructure with more than 530 charging stations at 11 sites was in general fairly oversized. The charging points assigned to the participants' EVs had a charging performance of 22 kW in consequence of the specific Smart ED charging characteristic. Further, 84 % of the online survey participants had the possibility to charge their EV at home. The survey shows that only 42 % of the participants actually used the charging infrastructure at work on a daily basis, whereas 28 % has not used it at all. Nevertheless, the opportunity to charge at work represents a precondition to buy an EV for the majority of participants (Fig. 1).

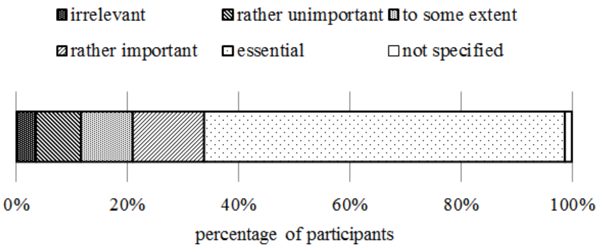

Fig. 1 Importance of charging possibilities at work in case the participants would possess an electric vehicle on their own [online survey: end of leasing period T2, 86 participants]

According to the twelve in-depth interviews, every single person made use of the opportunity to charge at home. In two cases, the power socket at home was the only frequented charging point.

Most of the interviewees made negative experiences with public charging infrastructure. E.g. the lack of information concerning the handling and location of public charging stations prevented many persons to make use of it. There exists a need to improve the provision of information considering the real-time charging state and location of (public) charging stations. Furthermore, charging stations that did not function or were blocked by conventional vehicles were an additional annoyance for most test persons. Another negative aspect relates to the charging procedure in different regions, where various types of access media were required. Different, local/ regional specific charging cards were mentioned as a not acceptable option and nationwide charging cards as well as roaming solutions were named as desired alternatives. Further, it was mentioned that simplified charging processes would lead to an increasing usage of public charging infrastructure.

A semi-public infrastructure at work was considered of vital importance, especially in case private charging is not possible. Having the above mentioned negative aspects of public charging infrastructure in mind it even seems to be the only acceptable possibility to overcome this lack. Further, it is mandatory for those participants with long commuting distances as a consequence of the limited battery range, especially during winter season. Some participants criticized the opening hours of the semi-public charging stations which made charging processes in the evening and at the weekend more or less impossible. The general process of fault repair was not satisfying since e.g. a central contact point, clear error messages and active feedbacks of the devices were missing. Further, plug and charge did not work numerous times. Higher prices for electricity at Daimler sites, in comparison to the regular electricity price at home, were also criticized. For this reason, some persons charged at work as little as possible.

Since the availability of charging stations varied between the different Daimler sites some participants reported about having problems with finding a free parking place or charging station depending on the given time of a day. In contrast to this, some interviewees always found a free charging slot immediately. In order to overcome the parking slot problem a possible solution would be to exchange fully charged EVs with uncharged ones. However, the willingness to move the car after the charging process during the working time varied between the participants. As some of them already moved their cars on several occasions, it would have been an option for others if alternative, but also attractive parking slots were accessible close by. For most of the participants such a rotation model would make sense in combination with fast charging and if the costs are linked to the parking time and not to the loaded energy amount. Nevertheless, some interviewees are in general not willing to move the car due to long distances at the working site. To overcome this issue, the participants asked for (1) more attractive parking slots next to the charging stations and (2) technical solutions via smartphone app in order to get real-time information about the status of the charging stations. To underline the above mentioned difficulties from an objective point of view Fig. 2 [9] shows the distribution of the relation R = *charging time / connect time* for all measured charging events at all Daimler locations. A small R indicates a very high occupancy rate, which leads to the assumption that many EV parking slots are blocked by already fully charged EVs. It is obvious that almost 50 % of the R values are smaller than 20 %. This means, that in almost every second case the charging time was significantly small in comparison to the connect time and, therefore, the EVs have blocked the charging stations most of the time without charging. In consequence, others EV drivers were not able to charge although the charging capacity would have been available in general.

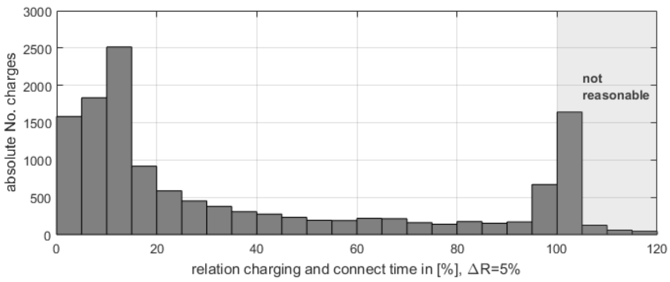

Fig. 2 Distribution of the relation R = *charging time / connect time* (10/2013-12/2014; charging events: in whole 13,524 considering all Daimler sites) [9]

For the improvement of the planning process of charging infrastructure, the participants were additionally asked to rate different functionalities of the charging points: A) connector locking device, B) feedback regarding the successful completion of the authentication process, C) feedback regarding state of charge, D) feedback regarding remaining charging duration and E) feedback regarding electricity price/ costs. As it can been seen from Fig. 3 all five mentioned functionalities of the charging points are of significant importance and have to be integrated into the planning process.

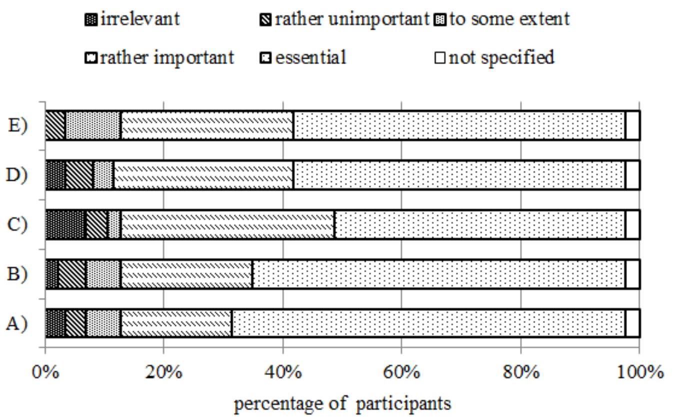

Fig. 3 How important are the following functionalities for the operation of the charging point? A) connector locking device, B) feedback regarding the successful completion of the authentication process, C) feedback regarding state of charge, D) feedback regarding remaining charging duration and E) feedback regarding electricity price/ costs [survey: end of leasing period T2, 86 participants]

To summarize the results of the sociological research (online survey, in-depth interviews) it can be said, that in general the theme charging infrastructure whether it refers to private, semi-public or public charging still plays a very important role. Currently, charging at home is the most important and comfortable option. Nevertheless, the results also indicate that over the survey period, the demand of (semi-) public charging infrastructure increased significantly. The results shows that as long as there is no possibility to charge at home, the willingness to buy an EV was denied by 62 % at the beginning of the sociological research work (T0) and even by 81 % at the end of the field test period (T2).

❖ Result II: EV properties

The driving enjoyment of the Smart ED was assessed very positively. All participants agreed on this and emphasized the good dynamics. The increased driving pleasure arises from the fact that Smart ED users were able to compete with sports-car drivers now, instead of those having a small vehicle of similar size. All interviewees highlighted the great torque, which results in good acceleration and spontaneous agility. Additionally, the possibility to drive eco-friendly was emphasized by several participants. Beside the great acceleration, the interviewees praised the silence of the electric motor, sometimes mentioning both aspects in one sentence.

In contrast to the positive qualities of the Smart ED, several negative aspects were mentioned, as shown in Fig. 4. In particular, investment costs, range and charging duration of the EVs could not meet the participants' requirements. Although, the actual driven distance was in average about 57.8 km a day, most participants still considered the EVs' range as the biggest handicap of electromobility (Fig. 5). Especially the reduced range in winter was criticized all over again, since many participants reported a considerable reduction of maximum range due to low temperatures.

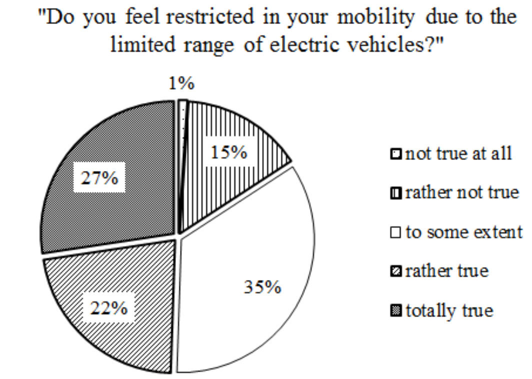

Fig. 5 Mobility limitations felt by the participants due to the limited range of EVs [survey: during the field test T1, 95 participants]

Regarding the charging duration, most participants were satisfied (42 %). Further, 37 % assessed the charging duration as moderate and 21 % even as negative. These impressions lead to the assumption that not all Daimler sites support a load performance of 22 kW. With reference to [9], the Smart ED battery capacity is limited to 17.6 kWh and the majority of the vehicles sustains a charging power up to 22 kW. Therefore, most charging events should have been terminated within one and a half hour. As shown in Fig. 6, this fact can be verified for most charging operations. Nevertheless, a fractional part of charging events was performed at 3.7 kW or even less, which could have caused the test persons' dissatisfaction.

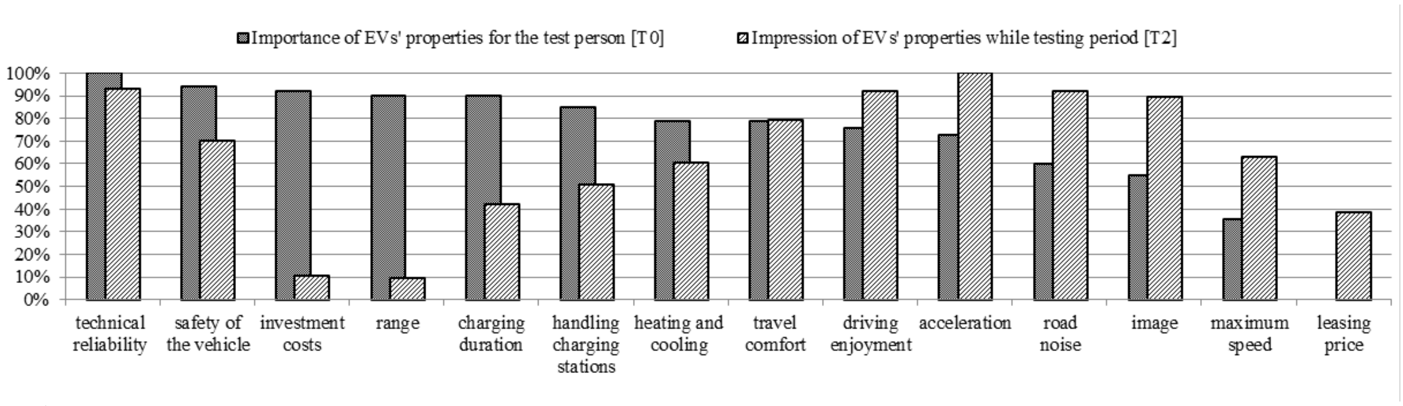

Fig. 4 Importance of and satisfaction with Smart EDs' properties [survey: before (T0, 99 participants) and after the field test (T2, 86 participants)]

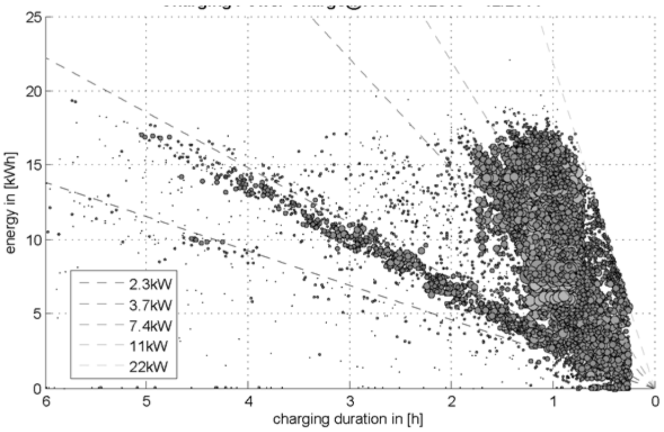

Fig. 6 Load performances in business environments (10/2013-12/2014; charging events: in whole 13,524 considering all Daimler sites)

Although an increase of the EV acceptance was expected during the field study, the survey did not confirm this assumption. For example the willingness to buy an EV decreased during the project (Fig. 7). Looking deeper into the twelve in-depth interview results the high investment costs are still considered as a major barrier, no matter how positively the vehicle's properties are described.

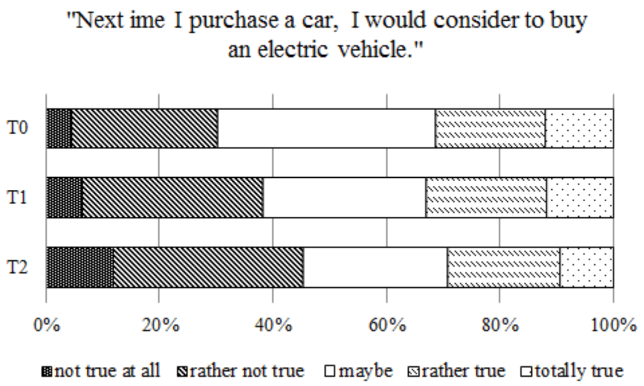

Fig. 7 Time-variant development of the participants' willingness to purchase an electric vehicle [survey: at the beginning T0, during T1 and at the end T2 of the field test; 99/ 95/ 86 participants]

Further, the sociological data analysis revealed a high demand for information and explanation concerning the EV usage even after the end of the field study (Fig. 8). The initial vehicle instruction itself plays an important role in this context, followed by a detailed explanation of charging infrastructure and general advices to an adequate driving behaviour. Here, most mentioned aspects are the temperature-depending fluctuation of range, the functionality of recuperation, the handling of auxiliary devices and the preconditions of (public) charging. Almost every person praised the vehicle's initial instructions, although very few were briefed on electromobility in general.

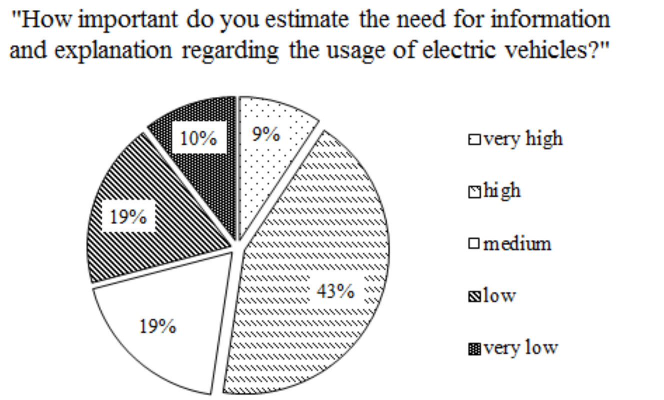

Fig. 8 Need for information and explanation regarding the usage of EVs [survey: end of leasing period T2, 86 participants]

❖ Result III: Public image and altered mobility behaviour

For most participants the connection of e-mobility with renewable energies is important (Fig. 9). One of the interviewees even made use of his own photovoltaic system to charge his Smart ED at home. Another participant plans to integrate solar panels, should he build a new house.

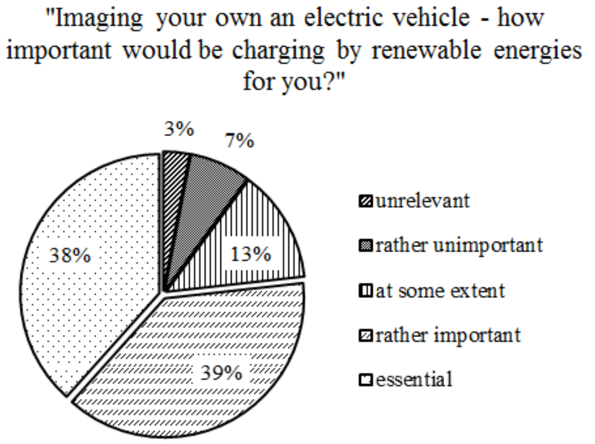

Fig. 9 Importance to connect electric vehicles with renewable energy [survey: at the beginning of the field test T0; 99 participants]

The emotions rising by driving an EV play a major role in order to increase the acceptance of electromobility. Many survey participants consider themselves as pioneers and ambassadors of electric vehicles. Over 80 % emphasized that persons from their circle of friends reacted positively to the EV and even 50 % of them were contacted by unknown persons. In addition, the interviewees described the public interest as very pleasantly. Some of the participants even acted as multipliers by enabling test drives for further interested people. It is due to this pioneer spirit that most of the participants dealt so well with the insufficiency of EVs (e.g. range, investments cost, charging processes).

Furthermore, EVs have the potential to change the driver's mobility behaviour. As a positive effect the more conscious driving style has to be mentioned. Instead of using the breaks most of the participants tried to maximize the effects on recuperation in order to extend the EV range. In some cases this behaviour even resulted in competitions between the participants. Nevertheless, also not intended negative effects occurred. There are some indications for general throwbacks due to an increased usage of the EV car. Several interviewees mentioned that EVs sometimes substitute those distances which otherwise might have been covered non-motorized or by means of public transport. Fig. 10 illustrates (A) the altered consciousness of driveability on one side and (B) of the daily mileage on the other side due to the usage of electric vehicles.

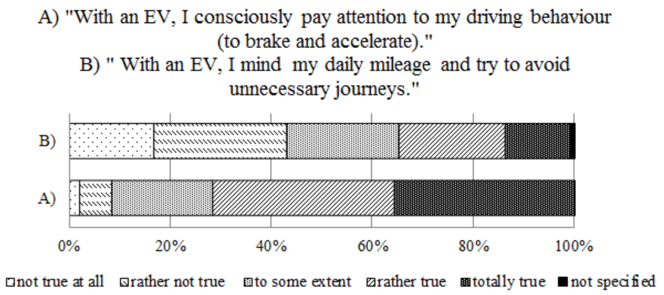

Fig. 10 Influence of driving an EV on (A) driving behavior and (B) altered mobility behavior [survey: end of leasing period T2, 86 participants]

IV. Charging in Rural Environments

A. *Research Methodology*

Within the project *e-GAP Intelligente Ladeinfrastruktur* 113 owners of the e-GAP-RFID card were contacted for a written survey by post and mail in September 2015. By means of a standardised questionnaire, the participants were questioned about their (1) personal data, such as gender, age or profession, (2) actual charging and mobility behaviour, (3) satisfaction with the local charging infrastructure as well as (4) about their opinion regarding the procedure of the charging itself (authentication, payment, case of failure, reservation).

Since a standardised questionnaire was used no (subjective) interview effect could occur as in the case of the Daimler in-depth interviews. Therefore, a (objective) comparability of the given answers could be achieved which facilitated further statistical analyses. Out of 113 conveyed surveys, 59 have been returned completely, which is a relatively high return rate for mailing surveys. It reflects the large interest in electromobility aspects and the need of further discussions and actions. At this point it has to be mentioned that a further written survey, contacting now 155 owners of the e-GAP-RFID card (113 old ones, 42 new ones), is currently running with more than 70 returns so far.

B. *Description of the sampled population*

The survey mainly focused on owners of the e-GAP-RFID card, a local EV-charging card, which is issued by the Gemeindewerke GaPa. Further, questionnaires had been laid out at the local tourism office, several car dealers and hotels in order to address electromobile tourists in addition. The average survey participant is male, 49 years old, lives in a three-person household and has an median household income over 4,000 € net. Out of 10 surveyed persons, one would drive a Plug-in Hybrid Vehicle, two a Range Extended EV and seven would use a Battery EV on a regular basis, mainly for private usage.

C. *Results: User demand in comparison with user behaviour*

In the following, the results of the sociological survey in GaPa are presented and discussed in more detail. To assess the outcomes, the EV users' view is matched with the actual charging behaviour measured by the local charging infrastructure [9]. The evaluation focuses on three essential parts: the existing charging infrastructure, the technical aspects of the charging process and the services attributed to the charging operation.

❖ Result I: Charging infrastructure

Within the Marktgemeinde GaPa and its close surroundings seven public charging stations (L1 to L7) are located for electric vehicles (Fig. 11). Three out of seven charging locations in GaPa are situated in the inner city (L1 to L3). The remaining four charging stations are located further away from the inner city (L4 to L7). In general, the charging stations have been installed next to shopping malls, tourist attractions and in commercial or residential areas on public parking areas with different maximum parking times (between 2 hours and 3 days). All charging locations are equally equipped with two charging poles having respectively a 3.7 kW (SchuKo) and a 22 kW (Type II) connection. On each location two EVs can charge simultaneously.

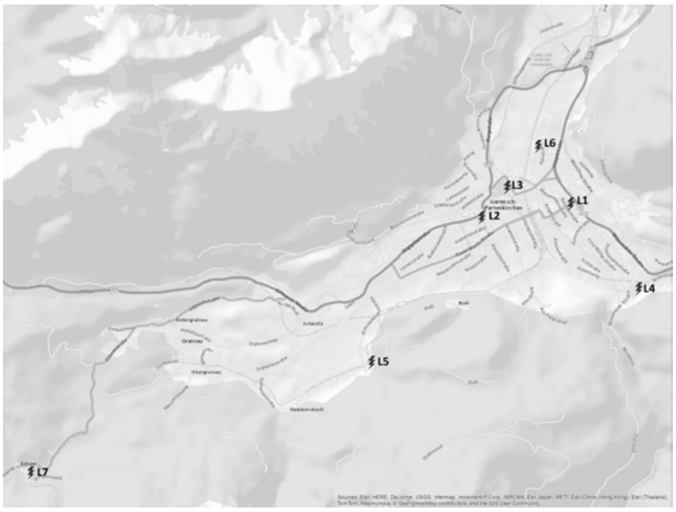

Fig. 11 Location of the seven public charging stations (L1 to L7) within the Marktgemeinde GaPa and its close surrounding

Regarding the general availability of public charging infrastructure, Fig. 12 shows the percentage of participants who have access to charging infrastructure at home and at work in addition. Furthermore, Fig. 12 presents that most of the participants prefer to charge their vehicle at home instead of using business and public charging infrastructures. Therefore, it confirms the results of the *charge@work* project in general.

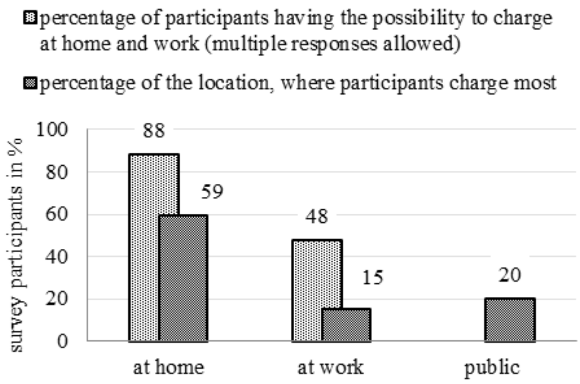

Fig. 12 Comparison of the availability of charging station with the actual charging behaviour [59 participants]

Since the *charge@work* project identified some negative aspects concerning the usage of the semi-public charging infrastructure, the participants were also asked about the general offer of the installed public charging infrastructure in GaPa. As shown in Fig. 13, the surveyed EV users are predominantly satisfied with (A) the offer as well as with (B) the placement and (D) handling of the public charging infrastructure in GaPa. Nevertheless, some of the participants expressed the wish for further charging stations, especially in public parking areas with shopping possibilities, near mountain railway stations, at the hospital or further tourist attractions (not shown). The necessity of a CCS-charging station at a through road or the inner city was mentioned trice.

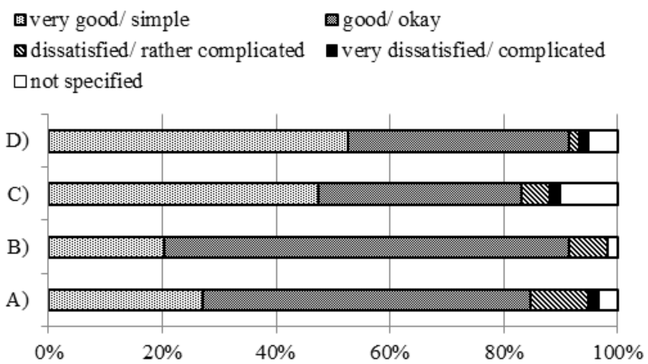

Fig. 13 Participants' satisfaction with A) the offer of public charging stations in GaPa, B) the charging stations' placement, C) the rules and regulations for EVs concerning parking in urban areas and car parks, D) the handling of the authentication process on frequently used charging stations [59 participants]

Regarding the occupancy rate of the installed charging infrastructure in GaPa, Tab. 1 provides information about the frequency one, two or more EVs are charging simultaneously at those stations. According to Tab. 1, there have never been more than five parallel charging sessions at all seven locations together from January 2014 till August 2015, even though 14 connectors are available. But having a closer look at the locations situated in the centre of the city, it becomes apparent that in roughly 4 % of the cases, when a vehicle charges, a second one does as well. It has to be emphasised that Tab. 1 provides no information about the overall occupancy rate, since it accounts only for charging EVs and not for vehicles (both electric and conventional) that simply block the charging slot. Considering this occupancy time as well, it can be assumed that the occupancy rates are even slightly higher. Therefore, temporary shortages of charging slots are possible at the inner city charging locations, which means that a third EV cannot charge at its preferred chosen location, and therefore has to look for another available charging location.

Table 1 Occupancy rate for different charging station locations in GaPa (considering only actually charging vehicles without those EVs parking at a station but do not charge; charging events: in whole 1,673)

Charging stations location	**Percentage of the time the charging location is occupied by one, two or more EVs (January 2014 – August 2015)**					
	0 EVs	***1 EV***	***2 EVs***	***3 EVs***	***4 EVs***	***5EVs***
L1 (inner city)	93.4	6.5	0.2			
L2 (inner city)	96.3	3.6	0.1			
L3 (inner city)	93.5	6.2	0.3			
L1+L3	87.8	10.9	1.2	0.1	0	
L1+L2+L3	84.9	13.1	1.9	0.2	0	0
L1-L7 (all)	80.8	15.5	3.2	0.5	0.1	0.01

❖ Result II: Technical aspects

This section deals with the participants' feedback concerning charging plug types, charging durations and performances. It has to be mentioned that those answers are not restricted to the public charging infrastructure in GaPa but to the participants' charging experiences in general (home, work, GaPa or further public places).

As to the charging plug, the participants considered the Typ II connection with 52 % the most important one. Roughly further 25 % of the answers relates to the Schuko plug, followed by CCS (12 %) and CHAdeMO (7 %). Regarding the measured charging performances in GaPa, a different picture to the survey answers is presented (Fig. 14). Even though, the EV users indicated to use the Typ II connection most, they barley take advantage of high loading performances up to 22 kW since the majority of charging events in GaPa occurred at 3.7 kW. The main cause for this is not the infrastructure's deficiencies, but simply the fact, that most EVs are not designed to charge with higher than those performances. But exactly these higher charging performances are wished by the survey participants as shown in Fig. 15.

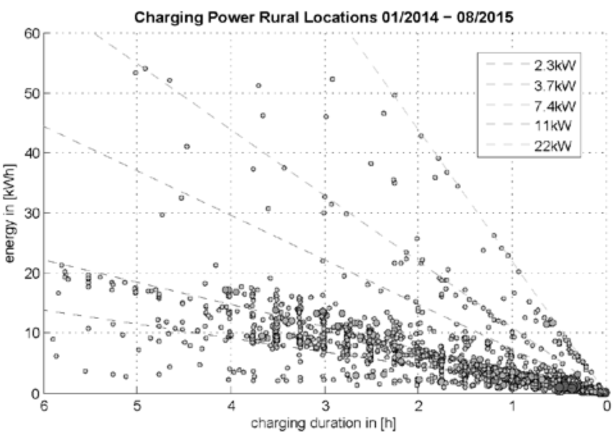

Fig. 14 Measured charging performances of charging events in GaPa (01/2014-08/2015; 1,673 measured events)

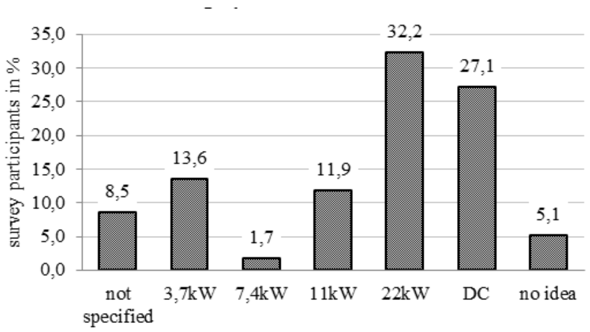

Fig. 15 Requested charging performance of the surveyed participants [59 participants]

Considering the survey results (Fig. 15), around one third of the surveyed participants preferred to load at 22 kW, whereas further 27 % even indicated the need for DC-charging. The need for higher charging performances becomes also apparent from the actual and requested charging durations (Fig. 16). In case the vehicles are charged at home or at work, charging durations of up to 8 hours are just about acceptable (not shown). However, when it comes to public charging, the charging time has to be reduced considerably in order to heighten the comfort and attractiveness of public charging infrastructure as shown in Fig. 16. However, without the car manufactures' support this cannot be accomplished.

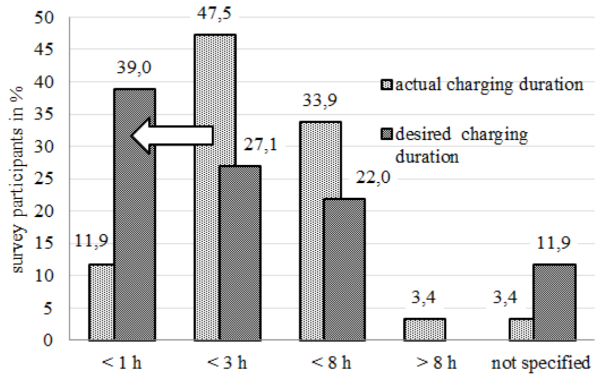

Fig. 16 Comparison of the actual charging durations with those requested by the surveyed participants [59 participants]

❖ Result III: Charging operation services

The focus of the sociological survey in GaPa was in particular on the participants' perception regarding services attributed to the charging processes themselves.

Before charging at unknown public infrastructure, 42 % of the participants sought for information about possible charging options via Internet beforehand. Further, one third preferred smartphone apps to inform themselves and only 14 % of the participants searched possible charging stations on-site. Being asked, which information they would like to obtain of each charging station in advance, the participants primarily named (1) the requirements for access and (2) the real-time information about the station's availability (Fig. 17). This includes the knowledge of supported plugs and charging performances, available slots in real time as well as payment and authentication methods. In addition, EV users wish to be informed about the charging price in advance for cost-saving and transparency reasons. Additional information concerning the station's close surroundings, its distance from the current location and GPS coordinates are considered less important.

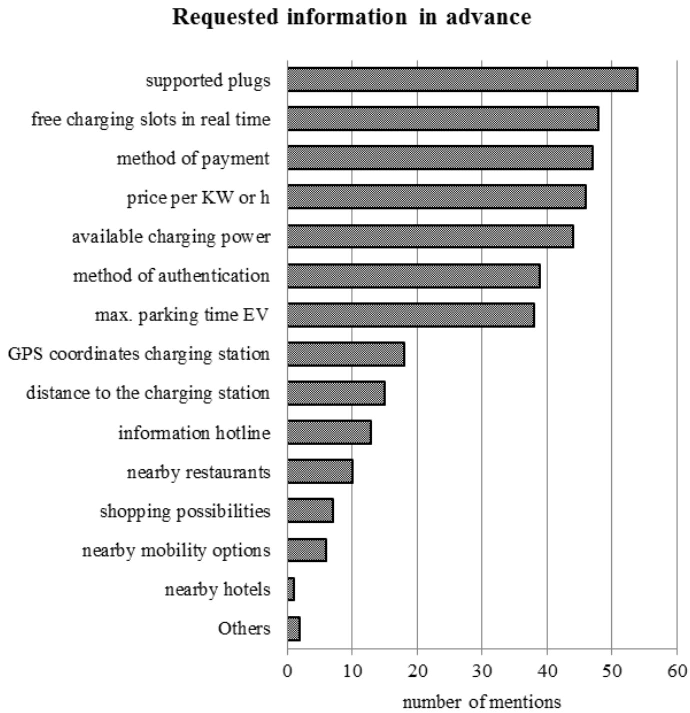

Fig. 17 Requested information the participants wish to get in advance for each charging location [59 participants]

In order to simplify the charging process, 76 % percent of the participants would welcome the possibility to reserve charging slots half an hour to three hours in advance. According to the EV users' view, the reserved slot ought to be released after 10 till 30 minutes after nonattendance to avoid the blocking of an otherwise usable charging point. A cancellation of the reservation, without worrying about consequences, should be possible 10 till 60 minutes prior to the predetermined charging event.

In case the reserved charging slot is not been used and no cancellation has been done, 98 % of the questioned EV-users vote for restriction measures as shown in Fig. 18. Most surveyed participants would consider it to be fair if those EV drivers were banned for a limited period of time from reservation options (44 %) or if their charging fees were more elevated (22 %).

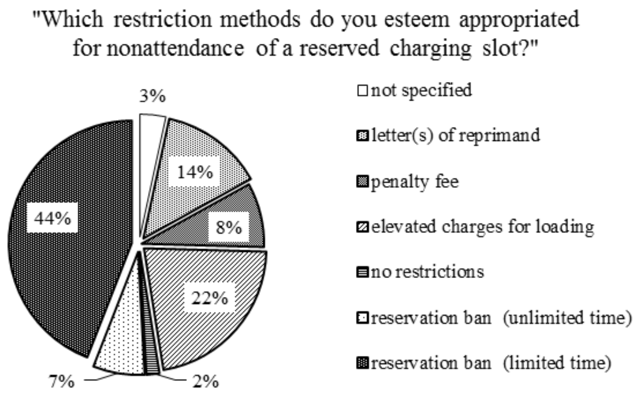

Fig. 18 Restriction methods favoured by the surveyed participants by nonattendance of a reserved charging slot [59 participants]

Considering the failure of charging stations, most participants expressed the wish to reset the charging station on their own (36 %) or to have access to an emergency hotline (28 %). Others preferred the instalment of talk buttons on each charging station in order to talk directly with a remote maintenance. One in six surveyed participants is satisfied with an additional routing option to another available charging station.

As an important field of action the authentication and payment themes were identified. Many participants criticised the wide range of different authentication and payment methods at public charging infrastructure in general. Instead of being bound to register at different mobility providers depending on the charging infrastructure provider behind, nationwide charging cards as well as roaming solutions were desired alternatives. This confirms the survey results of the *charge@work* project. Fig. 19 shows the currently used authentication methods and those requested by the surveyed EV users. Even though, the RFID card is widely known and in use, the EV users expressed their wish to extend the usage of EC and credit cards for authentication purposes. By doing so, both authentication and payment processes could be merged, which facilitates the charging process significantly. Due to the widespread usage of EC and credit cards the administrative burdens to access public charging infrastructure would disappear and render the expensive testing and instalment of other authentication or payment methods unnecessary. Nonetheless, by providing the means of cashless card payment, additional fees are charged by banks, which infrastructure operators are most likely to transfer to the customers themselves. Another acceptable option to authenticate the EV user on the charging stations is the usage of smartphone apps. In terms of payment modalities, a lot of EV users currently do not pay for their loaded energy amount (Fig. 20). This might be due to research reasons or special offers from infrastructure operators in order to increase the customer loyalty. Up to now, most payment transactions were processed by means of invoice and direct debit, followed by mobile and card payment. As expected, the need of EC and credit card payment was again stated the most often. Alternatively, the customers ask for more cash and online payment possibilities.

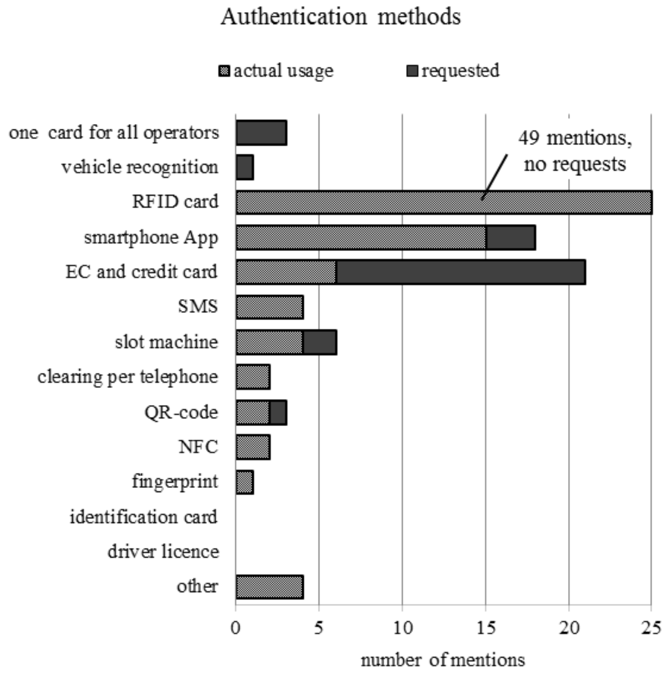

Fig. 19 Authentication methods currently used and requested by the EV users [59 participants]

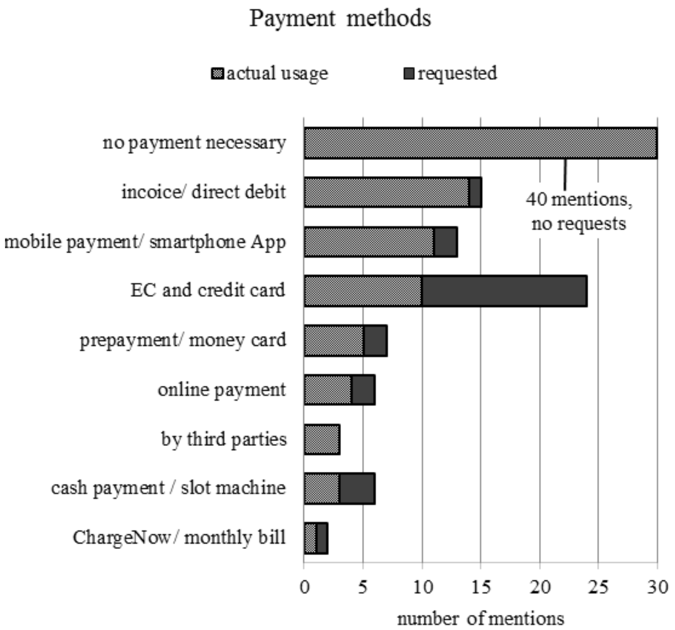

Fig. 20 Payment methods currently used and requested by the EV users [59 participants]

V. Summary and Recommendations for Actions

This chapter summarises the results of the sociological research in comparison with those of the classical data analysis (for latter compare [9]). It provides recommendations for political and economic actions as well as guidance for planners. By following them, the attractiveness and cost-efficiency of (semi-)public charging infrastructure can be increased which encourage the further development of electromobility.

As shown

- The *relevance of charging infrastructure at work is of increased importance* compared to public charging infrastructure. To heighten the occupancy rate (1) parking management/ car rotation concepts should be improved and (2) opening hours should be extended for the evening and weekend.
- *Simple authentication and payments methods are still required for (semi-)public charging infrastructures* in order (1) to ensure energy price transparency and (2) to be an attractive alternative for charging at home.
- *The establishment of one nationwide charging card as well as roaming solutions are still desired* alternatives. Nevertheless, EV users expressed their *wish to extend the usage of EC and credit cards for authentication purposes*.
- *More (real-time) information about (semi-)public charging infrastructures and its preconditions in advance are still wished* by the participants. Those include the knowledge of supported and free plugs, charging performances, charging prices, payment and authentication methods.
- *More information about the EV in general is also required.* To overcome the costumers' psychological barrier, it is essential to provide more information about the EV handling, recuperation, charging performance, range dependencies and range extension.
- The *troubleshooting management of technical problems is still not satisfying* for EV users whether considering semi-public or public charging infrastructure.
- *Reservation possibilities* which include car rotations concepts in some cases *have to be developed for (semi-)public charging infrastructure.* In this context, *user-friendly cancellation conditions as well as acceptable sanction models have to be derived*.
- The *performance of the AC (semi-)public charging infrastructure is in general satisfying* concerning charging duration. The bottle-neck for faster AC charging processes is currently caused by existing limiting conditions on the EV side.
- *Fluctuations of the estimated and actual range availability are still a restriction for many people to buy an EV.* Especially the temperature-affected range fluctuation represents a significant problem.
- The *multiplier effects of positive personal experiences should be picked up* within multichannel marketing efforts *in order to emotionalise electromobility.* Thereby, the vehicle's acceleration, acoustic, eco-friendliness and recuperation represent unique selling propositions of EVs.

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