Modes of fast charging

rolling out fast chargers in cities and along corridors to meet the heterogeneity of needs among EV drivers

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Rolling out fast chargers in cities and along corridors to meet the heterogeneity of needs among EV drivers

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Presented at the EVS 31 on Octobter XX, 2018

ABSTRACT: Fast charging is usually seen as a means to facilitate long distance driving for electric vehicles and roll-out therefore often happens with corridors in mind. Due to limited charging speeds, EV drivers usually tend to charge at home or work when the car is parked for a longer period to avoid unnecessarily time loss. However with increasing charging speeds and different modes (taxi, car sharing) also switching to electric vehicles, a different approach to fast charging is needed. This research investigates the different intentions of EV drivers at fast charging stations in inner-cities and along highways to see how usage at such stations differs to inform policy makers and charging point operators to accommodate an efficient roll-out strategy.

KEY WORDS: Electric vehicles, Fast charging

1. INTRODUCTION

Fast charging has mainly been considered as a means to accommodate long distance driving for electric vehicles. Many roll-out strategies have therefore focused on a corridor approach (1) (2). However with increasing fast charging rates, the time needed for fast charging could come closer to fossil fuel refuelling times (3). Such rates could reduce the need for lower speed charging stations that have a significant impact on public space and for which a business case is difficult due to lower charging speeds and therefore lower throughput. Charging point operators and policy makers are looking at fast charging to overcome these problems. Moreover additional modalities such as taxis (4)(5) and car sharing (6) are also switching to electric vehicles. Such modalities have different usage patterns and therefore also different needs for fast charging.

Policy makers and charging point operators are however struggling with the roll-out of fast charging stations as they are unaware of the intentions of those using fast charging infrastructure. Usage patterns (see result section Fig. 3 and Fig. 4) of fast charging stations and level 2 charging stations differ suggesting different intentions of EV drivers for recharging. For slow level charging infrastructure the intentions can be derived from charging patterns (7) but for fast charging this is more ambivalent. Analysis of level 2 charging behaviour has also shown the spatial heterogeneity is relevant Although various articles have looked into fast charging patterns (8)(9)(10) so far a systematic evaluation of the differences in intentions of EV drivers between fast charging in the city and along corridors is missing. Such information is however crucial for an efficient roll-out strategy to be able to make decisions about the speed and dimension of both level 2 and fast charging installations.

2. Methodology

This studies relies on two type of data collection. First we look at the actual usage of fast chargers within the four major cities within the Netherlands. Data is analysed and comparisons are made between user types.

Secondly we make use of a survey to collect more in depth information about the user's motive to charge at a particular fast charging station.

2.1. Charging data

First, usage patterns within the city of fast chargers and level 2 chargers are compared to illustrate the differences and similarities between these types of charging modes. This analysis is based upon a large dataset of 1.4 million charging sessions in four cities in the Netherlands, see (11) for a description of the

dataset. Data was collected between 2016 and 2018. Of those sessions 52.190 (3%) were collected at 7 (0,5%) different fast charging stations

Comparisons are performed on the timing of the sessions, amount charged and on the time connected. T-test is used to explore the differences between these types of charging sessions.

2.2. Survey

A survey is conducted among fast charge station users at both corridor and inner-city stations is performed to ask drivers about the reason they are charging. Inner-city charging stations users were asked in the city of Zaandam, Amsterdam and Haarlem. Fast charging users along the highway were asked at numerous places across the Netherlands. Regular fast charging stations have a power of 50 kW (both inner-city and highway). We surveyed at the Fastned station Bijleveld near the highway A12.

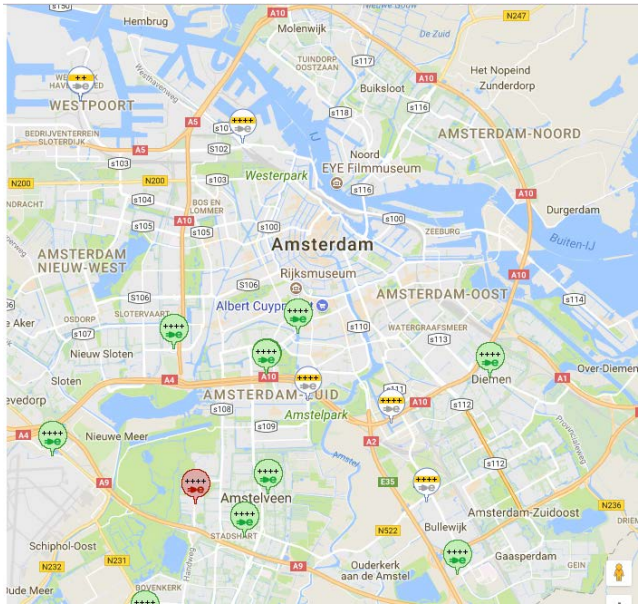

Fig. 1 Distribution of fast charging stations in Amsterdam. Source: oplaadpalen.nl

Fig. 2 Distribution of corridor fast charging stations in the Netherlands Source: oplaadpalen.nl

Users were asked about the type of vehicle, state-of-charge, if they could have completed their next trip, duration of the session, their reason to charge, and their type of mode (private, business, taxi, car sharing). Moreover users were asked why they preferred this charging station over others (i.e. possible other facilities). In total we have collected data from 100 EV drivers at the charging station.

3. Results

3.1 Charging Data

Time of Day

Figure 3 and 4 show the distribution of the start times of charging sessions at fast and slow (level 2) charging station respectively. The graphical representation shows that the timing of the charging sessions at these speeds is completely different. Charging sessions at fast chargers have a distribution the mainly is concentrated around the center of the day. During night time hardly any charging sessions are started.

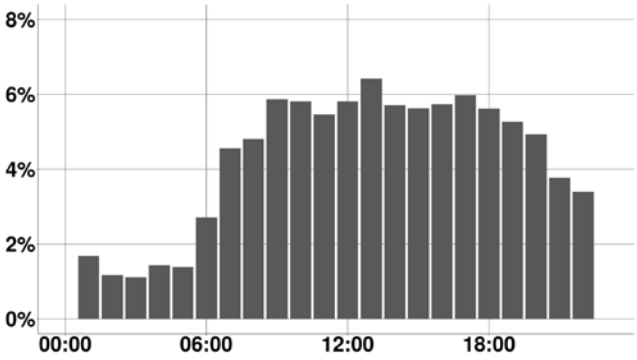

Fig. 3 Distribution of charging sessions for fast chargers over the day

Charging sessions at level 2 charging stations have a completely different pattern. They show a small peak in the morning and a larger peak in the afternoon. This pattern can be typically observed because many of these charging stations were placed on-demand (12). These charging stations are mostly used by those that rely on on-street parking for home or office charging.

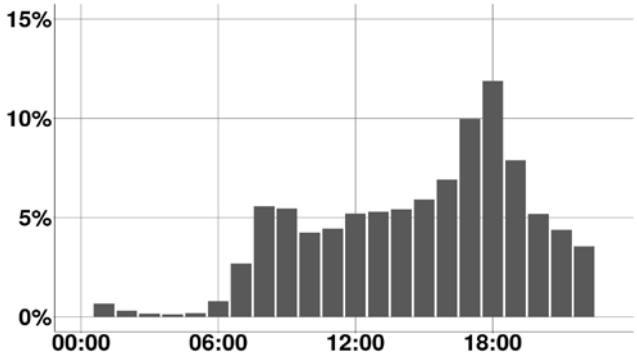

Fig. 4 Distribution of charging sessions for level 2 chargers over the day

Charging amount

Figure 5 and 6 show the distribution of the amounts (kWh) charging at sessions at fast and slow (level 2) charging station respectively. The distribution at the fast charging stations is very even and only drops off after 20 kWh. This is the need for drivers to continue their trip. We hardly see any charging sessions with more than 30 kWh charged. Most likely because trips do not last much longer than another 100 km.

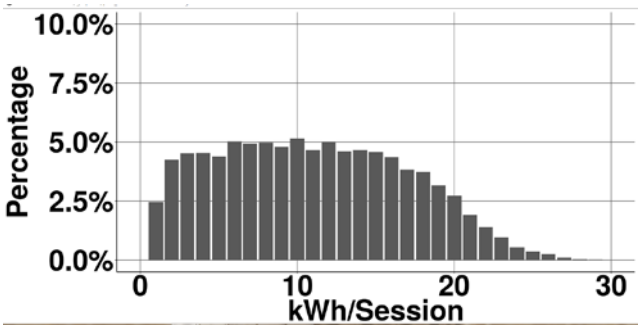

Fig. 5 Distribution of kWh charged at fast charging stations

The average kWh charged at fast charging stations (10.2 kWh) and level 2 charging station (8.3kWh) differ significantly from each other (t (58844) = 62.813, p=0.00).

The distribution of charging amounts at level 2 charging station shows that even smaller amounts are charged at these stations. The number of charging sessions with more than 10 kWh charged is very limited. The distribution is different as many Plug-in Hybrid electric cars are charging at these stations, which are not likely to charge at fast charging stations.

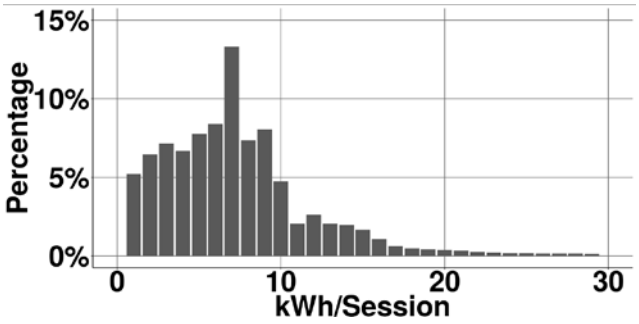

Fig. 6 Distribution of kWh charged at level 2 charging stations

Connection Time

As expected, the charging times at fast charging station are relatively short. Most charging sessions stop after half an hour and there are hardly any charging sessions longer than 1 hour. The need for longer charging sessions is not present.

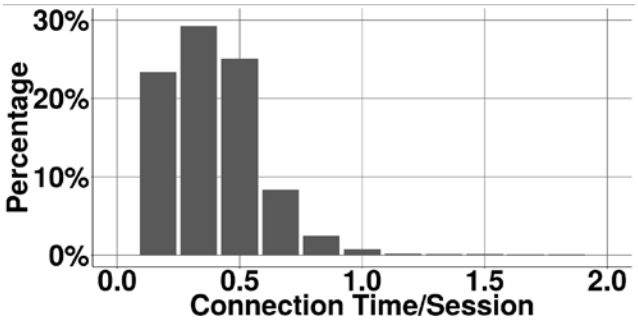

Fig. 7 Distribution of connection times at fast charging stations per 10 minutes

The average connection time at fast charging stations (0.59 hours) and level 2 charging station (11.09 hours) differ significantly from each other (t (62837) = -151.14, p=0.00).

This difference is also not surprising as the charging speed at these stations is much lower (3.7-11kW). However charging sessions often last much longer than necessary to fully charge the battery. Due to the earlier mentioned demand-driven roll-out many of these charging stations are used as a parking spot. They are therefore also used overnight or even for entire weekends (13).

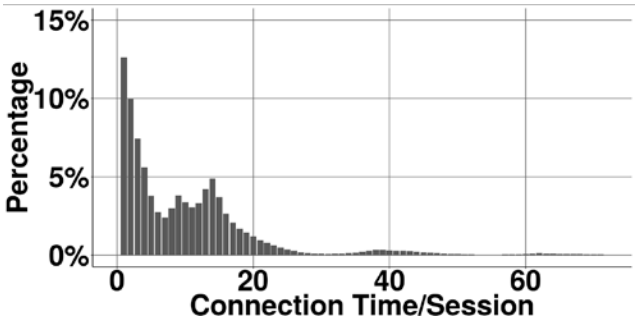

Fig. 8 Distribution of connection times at level 2 charging stations binned per hour

Conclusion

From the charging data we see that fast charging stations and level 2 charging stations are used in a completely different manner. Fast charging stations are used to fill up the electric vehicle when necessary while level 2 stations are used to charge at the office or at home while parking. This was in line with our expectations.

3.2 Survey

General information

Table 1 provides a general overview of the data collected at the charging stations. The average charging time during the survey was found to be 23 minutes, significantly lower than the 39 minutes found in the data collection in section 3.1. The average acquired range was 87km, corresponding to approximately 16 kWh (assuming 0.2 kWh/km). This is much lower than the average 10 kWh in section 3.1 Such differences are suprising as charging speed was equal at all of the locations (50kW). The average time at the next destination was nearly 6 hours, although the respons to this question varied a lot.

Table 1 General information on fast charging sessions

	Average	Minimum	Maximum
Charging time	23:34	10:00	1:06:00
Range at start	91km	28km	180km
Range acquired	87km	16 km	148 km
KM till next destination	29km	1km	170km
Time at next destination	5,9 hours	0 hours	115 hours

Type of trip

The survey was performed at four different fast charging stations of which three were inner-city charging and one location was highway charging. Table 1 provides an overview of the type of trip the drivers were undertaking at the moment of fast charging.

Table 2 Distribution of type of trip

Type of trip	Percentage of answers
Private	11%
Business	27%
Commute	13%
Taxi	47%
Different	2%

What stands out is high amount of taxi drivers that participated in the survey. This can nearly be completely (85%) contributed to the surveys at one of the inner-city chargers. Many of the taxi drivers at this location operated their taxis at the Schiphol airport in Amsterdam. They however did not have a fast charging station at this location, making them to drive to the nearest inner-city charger after driving a person downtown.

Main reason to charge

The main reason to use a fast charging station that was answered in this survey is by far *Time left and possibility to charge.* This is

suprising as many models assume fast charging will only be used in case a vehicle has insufficient range. Only 17% of the drivers indicated that this was the reason to use this station. More surprisingly was that of those 17%, only 17% responded this at the location next to the highway. Also at this location most people answered they had time left anyway.

Table 3 Main reason to charge

Main reason to charge	Percentage of answers
Insufficient range	17%
No charging station at home	4%
Cheap	8%
Charging speed	15%
Time left and possibility to charge	52%
Different	4%

Possibility to charge at next destination

Drivers were also asked if they would be able to charge at their next destination, which could provide more insight into the reasons to use a fast charging station. Despite the rather dense charging infrastructure in the Netherlands only 29% percent could charge at their next destination. Even if we look at the subset of those that stay at 2 hours at the location, the distribution of answers hardly changes (The answer *Yes* actually drops to 28 %).

Table 4 Possibility to charge at next location

Possbility	Percentage of answers
Yes	29%
No	44%
Unknown	27%

A large portion of the people als responded that they do not know if they can charge. The large share of taxi drivers is a part of the explanation. Of the taxi drivers only 3% responded yes to being able to charge at the next destination.

4. Conclusion

This paper has analysed two different sources about fast chargers. The first analyses on actual charging data from the fast chargers showed that they are used completely different than level 2 chargers on all aspects that were analysed. These included the timing of the session, the amount charged and the length of the connection. This analysis has therefore provided additional analysis that level 2 and fast charging stations cannot be used interchangeably in the planning of charging infrastructure. Especially in dense urban areas, such as the Netherlands, level 2 charging stations are better in serving so-called ‘park-and-charge’ behaviour. This includes overnight and office charging for those that rely on on-street charging. Fast charging serves the needs for those that require a quick fill-up.

The survey performed among those that were fast charging at both inner-city as corridor fast chargers provided insight into what the reason for such a quick fill-up is. Suprisingly this survey has found that the majority of charging sessions is not due to insufficient range to complete the trip but the main reason was time left and the possibility to charge. Even at the corridor location this was mentioned often.

The high number of taxis at the fast charging stations also gives an indication that fast charging infrastructure for different modes of transport could be required. Fast charging for taxis could be placed at typical lunch stops or when they have longer waiting times for clients. A comparison could be made for different modes such as car sharing or city logistics. Different modes of charging could be required for these locations.

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