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a data-driven analysis

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Charging station hogging: A data-driven analysis

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Abstract

With a growing number of electric vehicles (EVs) on the road and charging infrastructure investments lagging, occupation of installed charging stations is growing and available charging points for EV drivers are becoming scarce. Installing more charging infrastructure is problematic from both a public (tax payers money, parking availability) and private (business case) perspective. Increasing the utilization of available charging stations is one of the solutions to satisfy the growing charging need of EV drivers and managing other stakeholders interests. Currently, in the Netherlands only 15-25% of the time connected to a public charging station is actually used for charging. The longest 4% of all sessions account for over 20% of all time connected while barely using this time for actually charging. The behaviour in which EV users stay connected to a charging station longer than necessary to charge their car is called "charging station hogging". Using a large dataset (1.3 million sessions) on public charging infrastructure usage, this paper analyses the inefficient use of charging stations along three axes: where the hogging takes place (*spatial)*, by whom (the characteristics of the *user)* and during which *time* frames *(*day, week and year). Using the results potential solutions are evaluated and assessed including their potential and pitfalls.

1 Introduction

Despite the growing number of EVs on the road [1] public charging infrastructure investments are trailing. Occupation of charging stations is growing which can result in longer waiting times and failure to charge at peak times. Instalments of new charging stations are lagging due to a number of reasons. First, the business case for public charging stations is lacking [2][3]. Second, attributing public funds to such investments is unpopular and third, assigning designated parking areas for charging stations in high parking pressure areas can lead to public protests or abuse of such spots by gasoline driven vehicles [4].

Increasing the utilization of current charging stations could provide a solution that benefits all stakeholders. Earlier research [3] has shown that approximately 20% of the time that an EV is connected to a charging station is actually used for charging. The phenomenon has been described as "charging station hogging", the tendency of EV users to keep the charging station occupied without actually charging. Possible use by other EV users during this idle time could result in better charging station availability resulting in an improved business case. Such an increase in efficiency is apparent for fast charging stations [5][6], however for level 2 public charging solutions are less evident. Especially in areas in which home chargers rely on street-charging parking and charging conflicts of interest arise. Charging behaviour is more opportunity based and therefore coincides with regular parking behaviour. Defining charging station hogging is therefore not a straightforward as the time that is not used for charging. This paper proposes four definitions and evaluates them in the light of a level 2 public charging infrastructure with a large proportion of overnight charging, as in currently the case in the Netherlands. Such a situation is relevant for many dense urban areas in which users mainly rely on on-street parking facilities.

With these definitions this paper analyses charging station hogging in the Netherlands by using data from over 1.3 million charging sessions at public level 2 charging stations in the four major cities in the Netherlands (Amsterdam, Rotterdam, The Hague and Utrecht) gathered in 2016. An analysis is provided among the three axes that define charging station hogging, *spatial*, *user* and *time*. First, the spatial analysis compares cities and identifies hotspots for potential increased utilization. Secondly, the user perspective is analyzed to see if the problem is widespread or can be boiled down to a smaller set of users. Lastly, an analysis of the time component is provided to signal patterns throughout the day, week and year. Using this analysis we quantify the effect of the inefficient use on the availability of charging stations. After providing a detailed analysis of the problem solutions to the charging station hogging are proposed and pros and cons for such a solution are being discussed.

2 Methodology

2.1 Data analysis

Data on charging sessions from the public level 2 charging stations in the Netherlands are used. The data has been collected throughout 2016 and stored in the CHIEF database. *Table 1* describes the relevant variables for this analysis. For the different dimensions of the analysis the shown variables are relevant for the analysis. General (besides charging times, see [3] for calculations), Spatial and Time data are readily available, variables for the user axis need to be derived from available variables. Data received is anonymous and no specific data from the vehicle is collected. A specific untraceable user key is used. From recurrent charging behaviour other variables are derived. In some unique cases (taxi, car sharing service) the user type is predefined.

Table 1 Relevant variables for each axis of analysis

Axis	Relevant variables
General	- Length of Connection time - Length of Charging time
User	- Battery capacity - PHEV/FEV - Use type
Spatial	- Street address - City
Time	- Time of day - Day of the week - Date

In total 1.39 million charging sessions were recorded in 2016 in one the four participating municipalities. Data with session that have 0 kWh energy transfer were considered as erroneous data. After removing these sessions (3.5%) 1.340.665 charging session remained for analysis. For the analysis the data is clustered per axis that is relevant for the analysis.

2.1.1. Descriptive statistics

Table 2 gives an overview of mean values of the charging sessions that are part of the database. Averages are also shown per city to give an indication of the differences between the cities. In total nearly 3000 level 2 charging stations are part of the database. On average 8.1 kWh was transferred per session but variance was high with a recorded minimum of 0.1 and maximum of 100 kWh. Average connection times are high compared to international studies on public charging behaviour [7][8][9] due to a high number of overnight charging sessions and different policy conditions on connection time for EV drivers (e.g. fees for connecting whilst not charging). A high number of unique users were registered on the network, approximately half of the EVs in the Netherlands [10], but many of the registered charging cards were only used once.

Table 2 Descriptive statistics of charging data 2016

	No. of charging stations	**Sessions/day**	**Mean kWh/session**	**Mean hours connected/ session**	**#unique users/year**
General	2836	3673	8.1	10.39	47883
City					
Amsterdam	1069	1680	8.7	10.8	28333
Rotterdam	691	843	7.3	9.8	16030
The Hague	635	671	7.8	10.3	13904
Utrecht	441	478	7.8	10.2	10851

2.2 Solutions

To understand the effectiveness of possible solutions a workshop with four policy makers from different municipalities and three market players (charging point operators and consultants) was organised. An analysis of charging station hogging, similar as shown in this paper was presented. Solutions were presented either by the authors of this paper which has based their findings on a literature review and solutions that are currently in the market or by stakeholders that had developed the solution.

Participants in the workshop were invited to comment on the proposed solutions and give feedback on the presenters. Feedback could be given in an open discussion in which other participants could also comment. During the workshop three main themes surfaced; effectiveness, user friendliness and business case opportunities. The solutions were scored by the authors of this paper based on the feedback during the workshop.

3. Results

3.1 Defining charging station hogging

Figure 1 shows the distribution of the charging session length, grouped per category of connection time. It shows that although there are a larger number sessions with small connection times, these do not contribute a lot to the total connection time. Vice versa, a very small number of sessions with a large connection do contribute a respectively large portion to the total occupation in connection time. Sessions longer than 24 hours (5,8%) cause 28,8% of all occupation measured in hours. In *figure 2* we see this distribution more specified per hour of connection time to show more specific charging behaviour. The blue bars indicate the number of charging sessions with this particular length, showing a large number of sessions with the length of 0-4 hours. A second peak is concentrated around 10-16 hours, a common length for those EV drivers that charge overnight. The red bars indicate the cumulative number of hours of occupation that charging sessions with a particular length generate, e.g. the number of charging sessions of 10 hours longs is approximately 100.000 while the number of hours connected exceeds 1 million. The majority of occupation is caused by these overnight sessions. The sessions that last longer than 72 hours are grouped together. Although the number of sessions is low, they still contribute a large amount of occupation.

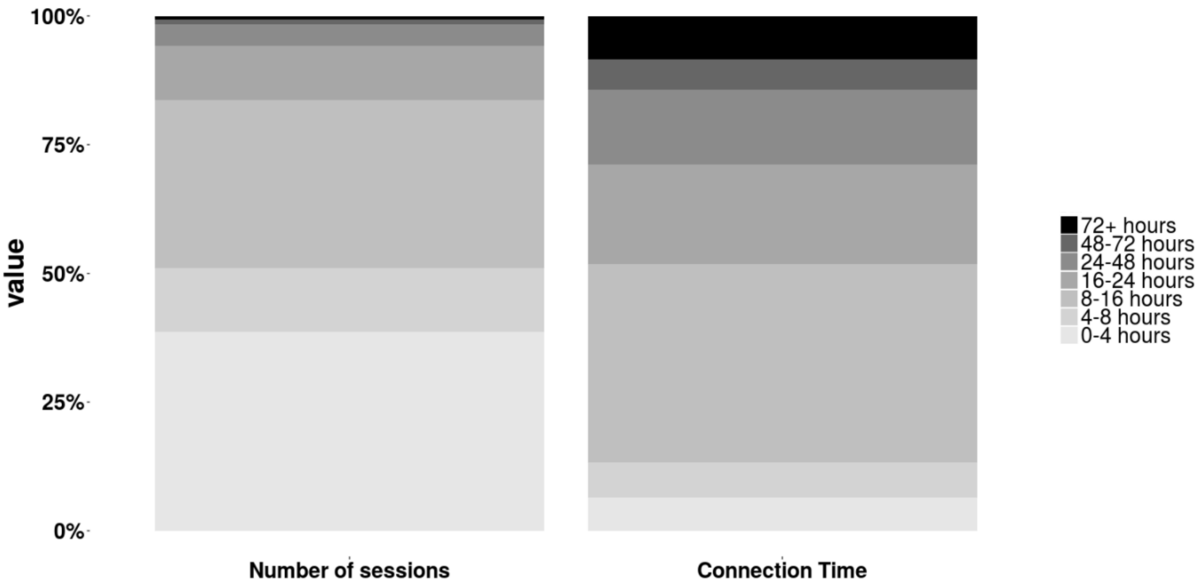

Figure 1 Comparing distribution of number of sessions and connection time per charging sessions length

On average the time used for charging in a session is about 2 hours. Given the results in *figure 1 and 2* (showing that connection times extend this two hour charging average to a large extent) *there* is a great deal of idle time in charging sessions. This does not necessarily mean that such behaviour is out of the ordinary as it mainly evolves around regular daily parking patterns.

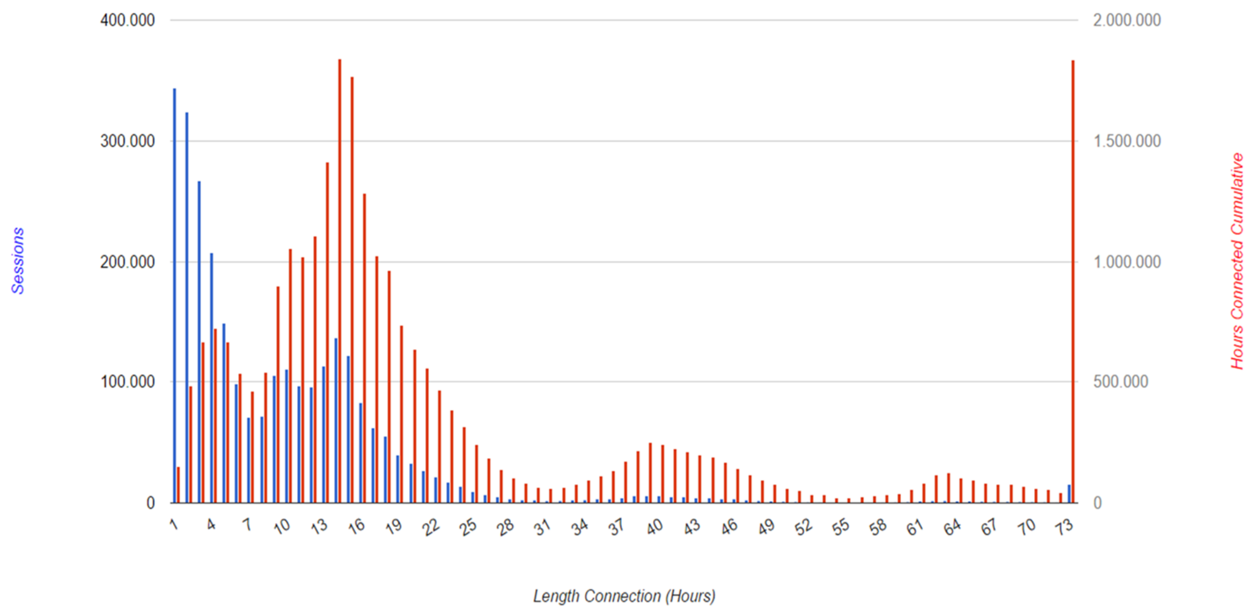

Figure 2 Number of charging sessions (blue) and cumulative hours of connection (red) per connection time (in hours)

Due to the specific nature of the data as described below there are various options to define charging station hogging. Defining charging station hogging is relevant for policy makers is under what circumstances hogging takes undesirable forms. Based on discussions with policy makers and review of literature we come to 4 possible definitions under which hogging becomes undesirable.Each of the definitions are discussed below:

- **Connection time > charging time**

Definition in which the user is considered to hog if he/she continues charge after the vehicle has been fully charged. The definition is mostly applicable for fast charging stations. For level 2 public stations this definition is not useful as these stations are often built to facilitate opportunity charging and for those that rely on on-street parking at home or at the office. Using this definition office and overnight charging would then be considered as charging station hogging.

- **Connection time > 16 hours**
  As shown in *figure 1* and 2 most charging sessions (84%) do not last longer than 16 hours, the typical time for overnight charging. Charging sessions lasting longer than 16 hours could be considered outside normal parking behaviour, with exceptions of the weekend. In implementing solutions for charging station hogging the 16 hour barrier might however seem like a random pick to the user.
- **Connection time > 24 hours**
  Similar to the 16 hour definition the 24 hour definition incorporates all overnight sessions and also a number of overnight sessions between 16 and 24 hours. It can be considered as a natural definition of charging station hogging as it represents a single day. It could however be problematic with over-weekend charging sessions.
- **Connection time > 72 hours**
  The last definition considered is longer than 72 hours, which also takes into account weekend sessions. As shown in figure 1 the number of 24-72 hour sessions is not big, they still represent a substantial part (28,8%) of the connection time. Over-weekend charging could still be considered as normal parking behaviour, making the 72 hour definition of charging station hogging relevant.

In this research, which focusses on public level 2 charging stations, the latter two definitions are used. The first definition is not applicable to level 2 charging because charging station use is centred around office and overnight charging. The second definition is relevant but there are still a large number of sessions (10%) lasting between 16 and 24 hours and moreover the 24 hour definition is relevant for policy makers. The 24 and 72 hour definitions of charging stations are used both in the analysis and compared when relevant to the axis in which charging station hogging is defined.

3.2 Time

The starting time is an important predictor for the length of a charging session and is therefore the first axis along which charging station hogging is analysed. Predictability of the length of a charging session can be explained by looking at normal parking behaviour. Examples are charging sessions that start in the morning around 8 o'clock that last about 8 to 10 hours, the equivalent of a working day. Charging sessions starting between 17:00 and 20:00 usually end in the morning and therefore last between 11-16 hours, see the peak in *figure 2*.

Such trends can also be identified for charging sessions that last longer than 24 or 72 hours. Looking at a yearly distribution of sessions lasting longer than 24 hours in *figure 3* weekly trends are visible with more longer charging sessions each weekend. The outlier at the end of April 2016 can attributed to a national holiday in which EV drivers had their car connected for over a day. Similarly the 72+ hours sessions, although in much lower numbers, have weekly patterns with spikes in the weekend. Spikes in May occur because of national holidays such as Ascension day, resulting in a four day weekend for many workers. The same can be seen at Christmas in December. The two spikes in October coincide with the start of autumn holidays. Such behaviour can thus be attributed to normal parking behaviour and is not EV specific.

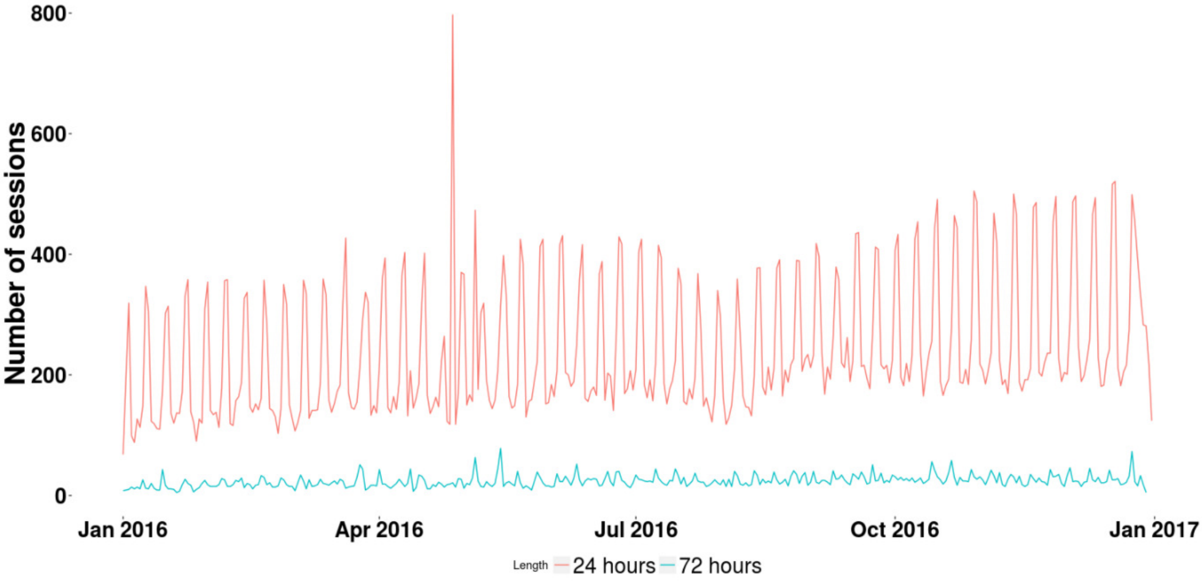

Figure 3 Distribution of charging hogging (24+ and 72+ sessions) over the year

There is however a general baseline on a number of sessions that last longer than 24 or 72 hours. About 150 to 200 sessions, out of 3800 on average per day last at least 24 hours of longer. This baseline is also visible in *figure 4* where the average occupation of charging station across the week for all cities combined is shown. The figure shows how occupancy rates tend to be comparable for all weekdays, that occupancy tends to be 15-20% higher during night time than during daytime, and that weekend-days shows a similar trend, but with slightly less difference between day- and night time.

The colours indicate which part of the occupation can be attributed to part of charging sessions below 24 hours (blue), more than 24 hours (green) and more than 72 hours (red). Weekly trends are visible as especially in the weekends the part of the 'long charging'-occupation is much higher than during the week. In the weekends 10% occupation rate is due to part of sessions lasting longer than 14 hours, which is 25-35% of the total occupation. Throughout the week a minimum of 5% of occupation rate (about 10-15% of the total occupation) is caused by charging station hogging. Weekend occupation due to charging station hogging is nearly double of that during weekdays, this is a reverse of the demand, in number of sessions, for charging stations which is higher during the weekdays.

The hours beyond 72 hours of connection of a charging session have a minimum impact on occupation levels compared to the 24+ hours. This is mainly due to the much lower number of charging sessions which last this long as was shown in *figure 3*. For policy makers this is relevant as only tackling 72+ hours charging sessions does not provide a relief for other EV drivers. A focus on 24+ hour charging sessions would be more beneficial.

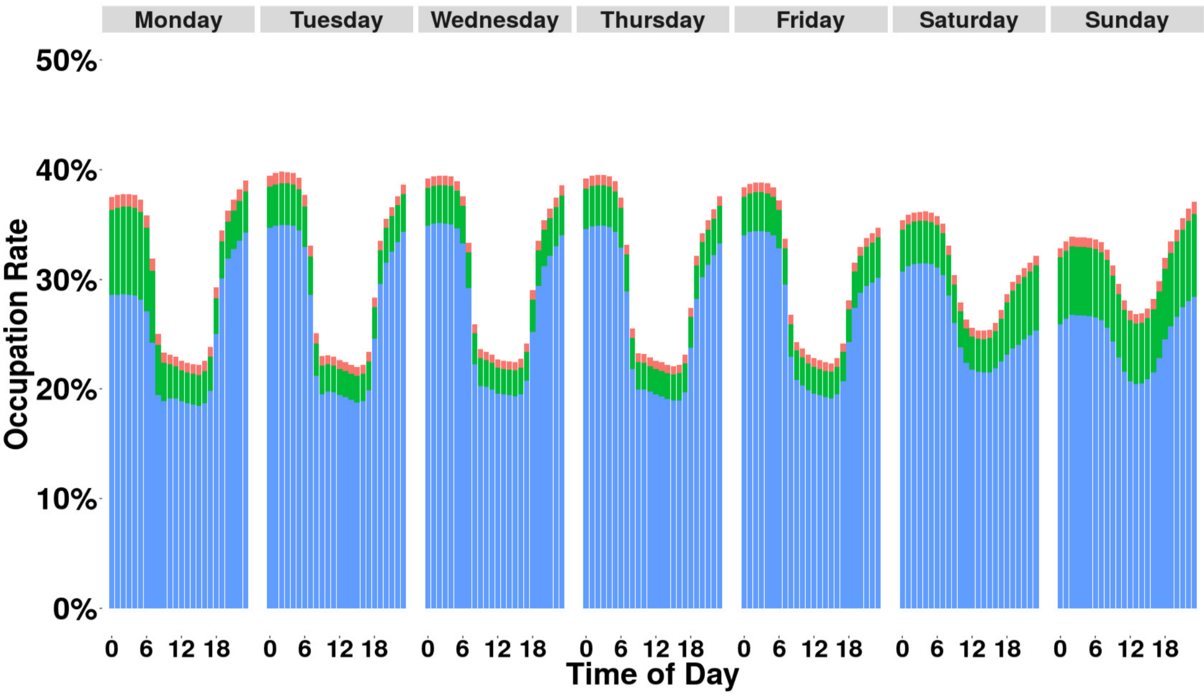

Figure 4 Impact of the part of charging sessions lasting shorts than 24 (blue), longer than 24 (green) or 72 (red) hours on occupation rate of charging stations

3.3 User

The second axis alongside charging station hogging is analysed is the EV drivers itself, the *user*. Using this analysis it is possible to identify if a small group of users is responsible for most charging station hogging or that the phenomenon is more widespread. Different user groups are compared to see if specific type of users are to be addressed in policies using a chi-square analysis. In the available dataset 47.833 unique users were identified based upon the charge card (RFID) they used to activate the charging station. Within this total set, 8.438 users (17%) registered at least one charging session longer than 24 hours while 2678 (5%) left their EV connected to the charging station for longer than 72 hours.

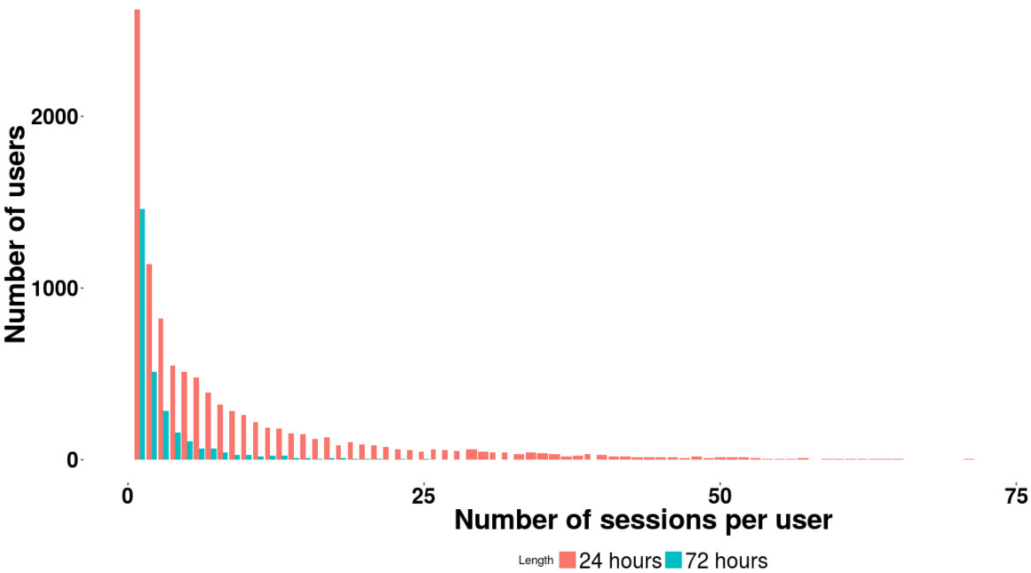

Figure 5 Distribution of users on the number of long charging sessions per user

From *figure 5* it can be concluded that most of these users only had one charging session longer than 24 or 72 hours. The number of users quickly declines as the number of occurrences increases. The contribution to the total number of charging hogging sessions however lies with the more frequent charging station hoggers. Of those users that registered a maximum of 5 charging sessions lasting longer than 24 hours only contributed 14% to the total number of 24+ hour charging sessions. 86% of charging hogging sessions are by only half of the users (48%) that show this behaviour more often. A similar distribution holds for the 72+ hour charging sessions. Although at first glance a high number of users shows charging hogging behaviour, the more frequent hoggers contribute are responsible for the majority of the problem.

In *table 3* different user types and their representation among charging station hoggers are shown. User types were either given or derived from the definition of Van den Hoed & Helmus [11], those with <20 charging sessions were classified as visitors, leaving a small group of undefined users. PHEV and FEV distribution was determined on the maximum amount of kWh charged per users, with a cut-off at 16 kWh based on the current availability of electric vehicles in the Dutch market[1].

Table 3 Distribution of users and sessions by user type

Type of user	**Total no. of users**	**No. of users with 24+ hour charging sessions**	**No. of users with 72+ hour charging sessions**		**Total No. of charging sessions**	**No. of 24+ hour charging sessions**	**No. of 72+ hour charging sessions**
PHEV	41701 (87%)	6776 (80%)	2210 (82%)		1029316 (77%)	62462 (78%)	6285 (76%)
FEV	6182 (13%)	1662 (20%)	468 (18%)		311349 (23%)	16947 (22%)	1933 (24%)
Overnight	6702 (15%)	915 (11%)	16 (0,5%)		748908 (56%)	31408 (39%)	410 (5%)
Office	2953 (7%)	49 (1%)	0 (0%)		246211 (18%)	1586 (2%)	0 (0%)
Visitor	36006 (72%)	6760 (80%)	2409 (90%)		154248 (12%)	35373 (45%)	6891 (84%)
Taxi	288 (1%)	82 (1%)	21 (1%)		28137 (2%)	853 (1%)	58 (1%)
Car sharing	411 (1%)	394 (4%)	220 (8%)		69096 (5%)	3220 (4%)	582 (7%)
Not classified	1519 (4%)	235 (3%)	12 (0.5%)		94065 (7%)	6969 (9%)	277 (3%)

Chi-square test (χ^2 (2) = 824.28, p= 0.00) shows that the overrepresentation of fully electric vehicles among charging station hoggers is statistically significant. Fully electric vehicles are generally more likely to display charging station hogging. There are no differences comparing the 24 hour or 72 hour definition of charging station hogging. This can partly be explained by the high number of car sharing services among the fully electric vehicles. Although the number of users varies the number of charging sessions hardly shows any difference.

Among the different use types there are significantly different distributions among regular charging behaviour and charging station hogging (χ^2 (10) = 14812, p= 0.00). Most noticeable is that the most frequent users, overnight and office chargers are not common charging station hoggers. Especially for overnight chargers this is surprising as these are users that were most expected to leave their car during the weekend. A potential explanation is that these users have a high frequency and know how annoying it can be to find an occupied charging station and therefore engage in more social charging behaviour. The number of visitors

[1] EV Database, www.ev-database.nl

and shared vehicles is higher among charging stations hoggers than in the normal distribution. However for the number of sessions we see this only holds for visitors. Car sharing services we see that charging hogging is more incidental, the mean connection time is low, however they do sometimes have longer charging sessions because of low demand during e.g. holidays.

3.4 Spatial

Charging station hogging does not occur at the each city, neighbourhood or charging station in the same extent. Table 4 and chi-square tests shows that there are large differences between cities in the magnitude of percentage of sessions test (χ^2 (6)= 126360, p= 0.01) and occupancy due to charging station hogging (χ^2 (6)=, 1543300, p= 0.01). Especially Amsterdam stands out with a higher number of 24+ hour and 72+ hour sessions and higher contribution of these sessions to the total occupation of charging stations. A first explanation for this could be that Amsterdam has a higher parking pressure compared to the other cities making it nearly impossible for EV drivers to move their car once it is fully charged. Secondly the city of Amsterdam is the only city with an extensive car sharing service. As shown from the analysis in section 3.3 these vehicles are more likely to show charging station hogging behaviour due to the unpredictability when they will be used again.

The cities of Rotterdam, The Hague and Utrecht are at a similar level when looking at the 24+ hour sessions. In Rotterdam the number of sessions that are longer than 72 hours is not higher however the contribution to the occupation is nearly double of The Hague and Utrecht. This is an indication that there a few very long sessions in Rotterdam. Rotterdam has a relative high number of overnight chargers compared to other cities. It is possible that these users also leave their car connected during holidays resulting in very long charging sessions.

Table 4 Comparison of charging hogging behaviour across cities

	No. of sessions	**% of 24+ hour sessions**	**% Occupation by 24+ hour sessions**	**% of 72+ hour session**	**% Occupation by 72+ hour sessions**
General	1.340.665	5.9%	28.5%	0.6%	7.8%
City					
Amsterdam	612.895	7.1%	35.2%	0.9%	11.3%
Rotterdam	307.789	4.5%	22.9%	0.3%	6.6%
The Hague	245.196	5.1%	21.7%	0.5%	3.2%
Utrecht	174.785	5.2%	22.4%	0.3%	3.7%

The data shows that intercity differences are not only variable to take into account when analysing the spatial component but there are also large differences between charging stations within the same city. As an example the % occupation due to charging station hogging (24+ hours) per charging station in the city of The Hague is shown in *figure 6*. Other cities show a similar pattern. The percentage of occupation due to hogging varies from 0% to 80% between the charging stations. Charging station hogging seems to be clustered with a few exceptions of charging stations without close by alternatives. The clusters seem to dispersed all over the city with a slight stronger clustering the centre. Possible explanations for these clusters are high parking pressure in these areas or strong competition between different users. In case of solely placed charging stations this last explanation should be reversed as users there might not have the feeling that they need to move their car if deciding to park for a long time as there is no demand for the charging station by other users.

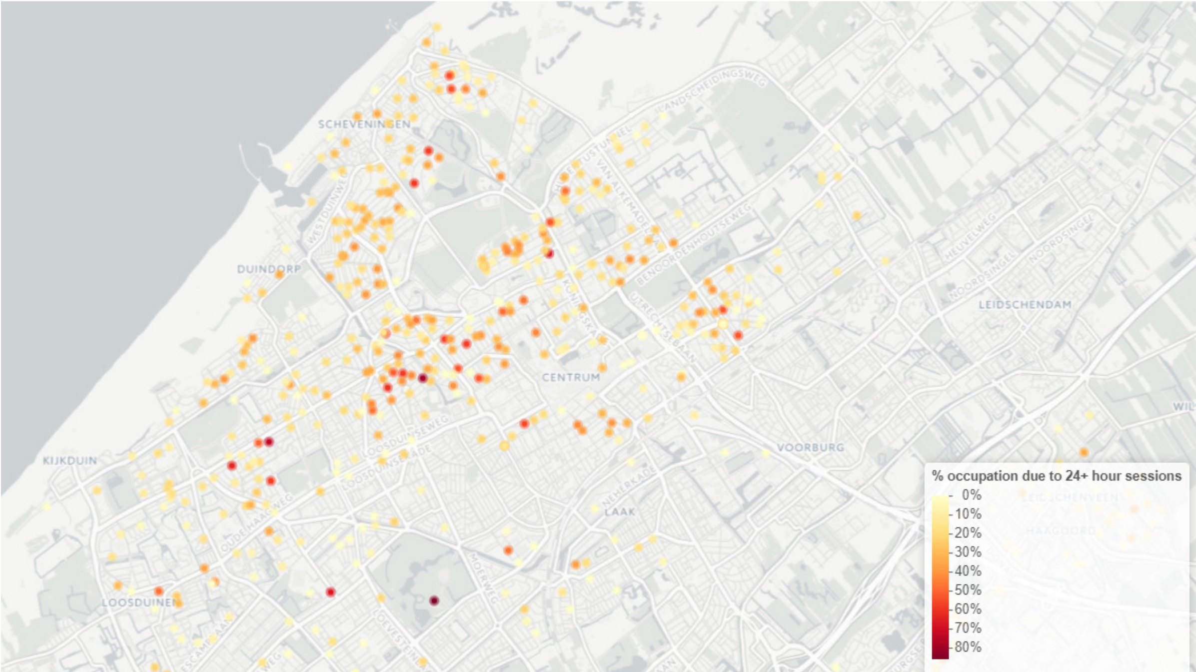

Figure 6 Spatial distribution of charging hogging behaviour across charging stations in The Hague, the Netherlands

Spatial comparison of charging station hogging is relevant as there are large differences between cities and single charging stations. Such an analysis could give an indication of underlying reasons for charging station hogging (e.g. high parking pressure) and could therefore result in different policies to tackle the issue.

3.5 Conclusion

Data analysis of charging session of public charging sessions along the *time, user* and *spatial* axis has shown that charging station hogging is not a general trend that can be observed to the same extent across the day, week or year, different type of users or across cities and individual charging stations. Charging station hogging can to some extent be explained by regular patterns in time (i.e. weekends, holidays) and users (i.e. car sharing services) or across cities (i.e. due to parking pressure). These variables provide an explanation for peaks in charging hogging behaviour, while a general line across all axes remains unexplained.

Due to the high variability in charging hogging behaviour across the analysed axes it could be difficult for policy makers to come up with a one stop solution that does not intervene with regular behaviour of certain users or at certain locations. The broad pallet of solutions available is discussed in the following section and are the effectiveness is held in the light of the presented findings.

4 Solutions

The solutions for charging station hogging analysed in this section are an idle fee, a monetary reward for positive behaviour, connecting users through the internet, valet charging and allowing unplugging by other users. The pros and cons of each of these solutions are presented on the basis of a literature review, interviews with public and private stakeholders and a workshop involving a variety of these stakeholders. *Table 5* gives an overview of the assessment of the solutions across three measurements that were named most important by the stakeholders during the workshop.

4.2 Idle fee

An idle fee could be asked for when the user has finished charging but is still connected to the charging station. The user is charged for each period of time that the car stays connected. This should motivate to the user to move the car to a different parking spot or start his journey. The height of the fee could be set depending on how fast the charging point operator wants the charging stations to become available again.

Such a fee could work well for fast charging installations for which charging station hogging could be detrimental. Currently fast charging station operators are already using such a fee [5]. For public level 2 charging the need for this is less clear. Connection times, as shown in this paper, are much longer because charging coincides with the parking behaviour. Especially if level 2 charging stations are placed to serve overnight charging for those that rely on on-street parking, a well-designed version of an idle fee is needed. Based upon the results in paragraph 3.4 and discussions with policy makers an idle fee would need exceptions for overnight, weekend and holiday charging as this is 'normal' parking behaviour. Holidays would include e.g. Easter, Christmas or national holidays but not include e.g. summer holidays. Such exceptions would not hamper the effectiveness of the idle fee as demand for charging services is low during this time. Other concerns that were raised were related to parking pressure. In case of high parking pressure the EV driver would not have the option to park his car elsewhere close with long cruising times as unwanted side-effect.

From a charging point operator an idle fee could provide a better business case as charging stations increase their availability so more sessions could take place during the day or they get compensated by the idle fee. Expectations among stakeholders is that an idle fee could generate more income, charging point operators are talking about lowering charging prices to lure in more costumers as a reward for efficient charging behaviour.

4.3 Reward

The opposite of the idle fee would be to give a reward for those with efficient charging behaviour. Such a fee could be a discount or any other (non-) monetary reward for those that remove their EV within a certain timeframe after the vehicle has been fully charged. Stakeholders considered a reward as interesting because it is very user friendly. Concerns were raised about the effectiveness, which was not ranked as high as the idle fee. Other concerns were differences in charging speed, for level 2 chargers the charging speed between 1-phase and 3-phase chargers is considerable. We would then require different behaviour from users based upon technology (e.g. charging speed). This could be confusing for the EV driver and not match with regular parking patterns.

Charging point operators also indicated that they did not see a business case for such a reward at the moment. It is unclear what the potential is for when the car is removed once it is fully charged. Due to the relative low number of electric vehicles on the road it could just result in an empty charging station. Costs for such a reward which would need to be high enough to really be an incentive were estimated to be higher than potential revenue from new charging sessions.

4.4 Connecting users

The problem with an idle fee or reward is that there is uncertainty about whether or not another EV driver will make use of the then available charging spot. Such a fee would rather only be implemented if there is an actual demand for a charging station. This would be very user friendly for those in need of a charging station and would not require unnecessarily moving the vehicle, possibly creating additional parking pressure.

Services that connect EV drivers that are looking for a charging station and those that have finished charging are currently being developed[2]. The EV driver can (anonymously) request the EV driver that is currently at the charging station to move the car if it is fully charged. The effectiveness of the measure was not considered as high as fees due to the anonymous nature but workshop participants mentioned that such "social charging" often happens within neighbourhoods or in a business setting in which users are acquainted with each other.

The solution was considered user friendly as it only involved moving your car when there is an actual demand for charging. Business case opportunities were considered but mainly focussed on B2B type of contracts and not so much in the public domain. The solution could result in more turnover for charging point operators.

[2] Social charging, www.social-charging.com

4.5 Valet charging

Valet charging would work just as valet parking in which the driver hands over the car to an employee which then parks the car and connects it to an available charger. The employee notes the time when the driver wants to leave with a full battery. Managing the battery levels of the car and the times when the driver wants to leave in a smart way could result in needing less charging stations. The employee could disconnect the cars when fully charged and give priority to those that have to leave at an earlier time.

Valet charging can be very efficient as the user is not involved is managing the efficient use of charging stations. With the experience of the valet charging employee or efficient computer planning optimal use of charging stations can be ensured. It is user friendly as the driver does not have to move the car themselves but is does give some restrictions as departure time has to be known beforehand.

Valet charging is most likely to be used in a closed compound such as a hotel or office building. The business case is built upon reduced infrastructure investments and a reduction in grid connection costs. Yearly grid connection costs can be reduced if peak demand stays lower. Valet charging can more evenly distribute the demand over the day without smart charging techniques. Early experiments show that a reduction in grid connections costs can be higher than personnel fees [12].

A potential solution in public space could be employees that move shared vehicles if they are parked too long at a charging station. Employees could move the vehicles to areas with a higher demand and make the charging station accessible for other users. Analysis in section 3.3 has shown that this is relevant for large number of shared cars.

4.6 Unplugging

Some charging stations allow unplugging of the charging cables. This allows for the user to take control if they want to charge if the vehicle and the charging station is occupied by another EV. Not all charging stations allow this behaviour as some lock the charging cable if the user is expected to bring their own charging cable and locking is used to prevent theft.

Unplugging could results in less charging station hogging but the solutions has some downsides. First, unplugging does not mean the charging station becomes immediately available as the parking spot alongside the station is still occupied. The charging cable has to be long enough to reach other parking spots. Second, the charging cable might be unplugged during the charging session resulting in hinder for other users, this could especially happen if the charging station has no indication on whether the charging is still in process. Last, using smart charging services it might seem if the charging has finished but the charging session could resume at a later stage, unplugging could then also result in not fully charged batteries.

Generally the effectiveness of unplugging could be rather low and it can be considered very user unfriendly if the charging session has not finished. Although it could result in more energy transferred per charging station the effect on the business case is estimated to be minimal. In general stakeholders are not keen on unplugging as it is not in line with ‘charging etiquettes’.

Table 5 Overview of assessment of solutions

Solution	**Effectiveness**	**User friendly**	**Business case**
Idle fee	++	--	++
Reward	+	++	-
Connecting users	+	+	0
Valet charging	++	+	+
Unplugging	0	-	0

5 Conclusion

Analysis of a large dataset on public charging infrastructure has shown that charging station hogging is a serious problem for efficient use of public charging stations. Although the low charge time/connection time ratio can partly be explained by many overnight charging sessions on the public charging infrastructure in the Netherlands, large amounts of idle time are a result of sessions longer than 24 hours. Various definitions of charging station hogging were proposed of which two were selected because other definitions included too much regular parking behaviour. Even using these definitions the analysis along the time axis has shown that spikes in the charging station hogging could be explained by ‘normal’ parking behaviour such as over weekend parking or even longer due to holidays. Still a baseline of charging station hogging behaviour remained which could be addressed by the right solutions or policies.

The user component of charging station hogging showed that a relatively large part of charging hogging is caused by a relative small number of users, less than half of the users cause more 85% of all charging station hogging. Many users (52%) only show charging hogging behaviour only a few times, but those that misused the charging infrastructure multiple times accounted for most of the inefficient use of the infrastructure. More regular users such as overnight and office chargers contributed very little (<5%) to charging hogging but a large number of visitors does result in longer connection times than necessary. Shared vehicles also show this behaviour

Spatial analysis has shown that there are large differences between cities, neighbourhoods and individual charging stations. The analysis has given some indication of relevant factors that play a role in hogging behaviour such parking pressure or remoteness but further investigation is needed to confirm these findings. These findings do give an indication that policies to target this behaviour could perhaps differ between neighbourhoods to reach maximum efficiency.

Different solutions were discussed and values after discussions with municipal policies makers and stakeholders such as charging point operators. Monetary stimuli can be very effective but especially in case of a fee be user unfriendly as such a fee would almost certainly also influence ‘regular’ parking behaviour negatively. More socially oriented solutions, seem more user friendly and are more aimed at the actual demand, but effectiveness is considered low and social norms around these solutions should first be established. Valet charging could be very effective in a closed environment but is not applicable to public chargers.

Policy makers concerned are dealing with a complex issue on the intersection of multiple fields during a transition phase. Most likely charge time/connection time ratios will improve in the future due to larger EV battery packs, which result in fewer but larger charging sessions. This makes availability even more stringent and charging station hogging even more problematic. Experimenting with solutions could be key to see how effective they are and which problems should be dealt with.

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