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Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands

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ABSTRACT

The objective of this study is to identify factors that influence actual electric vehicle (EV) drivers' acceptance of Vehicle-to-Grid (V2G) charging. The study takes a qualitative approach in order to provide insight into actual EV users' perceptions of V2G technology and their underlying motivation to accept or not accept V2G. The Theory of Planned Behaviour is adopted to create a basic conceptual model of the potential factors influencing users' acceptance of V2G. Twenty semi-structured interviews are conducted among Dutch EV drivers, including both regular EV drivers, as well as participants who had previously taken part in V2G projects. The factors that are found to be most important for fostering acceptance are financial compensation, transparent communication and reliable control of the system by the user. On the other hand, the factors that are found to have a negative effect on acceptance are range anxiety, discomfort experienced while participating and battery degradation. Our study shows that the majority of our interview participants accept V2G albeit with some reservations and caution. As EVs and V2G are new technologies, our sample of twenty actual EV users consists of early adopters. As such, their attitudes may not reflect those of the majority of future users. However, our study suggests that there are EV users who are willing to use V2G charge points and will continue to do so. The reasons behind such user acceptance are further described in the study together with additional insights and ideas for future research.

1. Introduction

The vehicle-to-grid (V2G) concept, as suggested by Kempton and Letendre (1997), proposed the use of electric vehicles (EVs) to deliver electricity back to the grid when needed. The objective is to utilise the large storage capacity of aggregated electric vehicle fleets to provide services to the grid in exchange for which EV drivers are financially compensated. The potential benefits of such a system are envisioned to include the ease of integration of greater shares of variable renewable electricity production, reduction in investment in peaker plants and financial remuneration for EV drivers to incentivize the adoption of EVs (Kempton and Tomić, 2005).

The use of V2G is entering the phase of commercialization with off-the-shelf charging points becoming available in the European market (EVTEC, 2020; OVO Energy, 2020). A few EVs which are sold commercially are already compatible with existing V2G charging standards (MacLeod and Cox, 2018). Grid operators in Europe are making arrangements to enable the integration of EVs in the electricity system through market-based mechanisms (TenneT SwissGrid, 2020). Legal barriers to the widespread V2G application, such as the double taxation[1] of storage, are being addressed by new legislature at the European level (Ghotge et al., 2019). Before further adoption and commercialization of V2G can proceed, consumer acceptance is essential (Sovacool et al., 2017).

Despite its importance, consumer acceptance has been relatively understudied in comparison with the more technical aspects related to V2G. Renewable energy integration and storage, services for the electricity grid at the global and distribution levels and the impact on EV batteries, causing accelerated degradation, are the areas that the vast majority of V2G studies focus on. Sovacool et al. (2018) found that social aspects of V2G related to consumer acceptance were mentioned in less than 3% of available peer-reviewed literature on V2G. Similarly, Park

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[1] Double taxation, particularly in case of grid-connected energy storage assets, refers to taxation on both charged as well as discharged energy units.

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Lee (2019) found socio-technical obstacles to V2G to be highly understudied in V2G related literature. In particular, there are gaps related to the perceptions of V2G prevalent among current EV drivers, the underlying motivations behind their attitudes and the factors influencing their acceptance of the technology. Earlier studies in this area have primarily focused on choice experiments (Geske and Schumann, 2018; Kubli et al., 2018; Zonneveld, 2019; Meijssen, 2019; Noel et al., 2019a) and to a lesser extent, on interviews with experts in the field (Kester et al., 2018; Noel et al., 2019b; Sovacool et al., 2019a,b). The in-depth analysis of the end-user's acceptance of the V2G system remains under-addressed. Since the widespread adoption of V2G requires considerable engagement and the acceptance of the EV driver, a better understanding of EV drivers is of vital importance.

This paper aims to understand the prevalent perceptions of current EV drivers about V2G and their reasons for these perceptions. Based on this, we aim to identify the factors that influence their acceptance of V2G. Since there is limited work done in the field, this study is exploratory in nature and we have adopted a qualitative approach. An additional reason for using a qualitative approach is that we are especially interested in the underlying motivations of end users to accept V2G, or not. Qualitative research is especially strong in identifying such underlying motivations.

The research was initially approached through a survey of academic literature on what constitutes acceptance in general and acceptance of V2G in particular. We extended the Theory of Planned Behaviour (TPB) to enable it to be used by building a conceptual model of factors influencing the acceptance of V2G. The model was then used to identify key topics for the interviews. Finally, semi-structured interviews with 20 EV drivers in the Netherlands were conducted, and the content of these interviews were subsequently analysed and discussed.

The paper is structured as follows: Section 2 describes the theoretical foundations which were used to structure the interview protocol. In Section 3, we describe the interview methodology used. Section 4 provides an overview of the interview results, which are discussed in detail. Finally, Section 5 presents the conclusions of this work together with recommendations and directions for future research.

2. Literature review and conceptual model

Previous literature related to V2G acceptance was used to inform and structure the direction of research. Within the scope of the literature review were papers and reports that covered V2G and social acceptance. Various scientific literature databases were searched using the following keywords interchangeably: "vehicle-to-grid", "consumer acceptance", "social acceptance", "adoption factors", "perceptions", "attitudes". Subsequently, 30 papers and reports were selected, based on their titles and scanning of the abstract. In parallel, various studies from the field of behavioural psychology were reviewed. We initially review the outcomes of earlier work and the methods they used to determine the research gap. We then explicitly define what we mean by 'acceptance of V2G'. Finally, we choose and motivate a suitable conceptual model with which we study V2G acceptance.

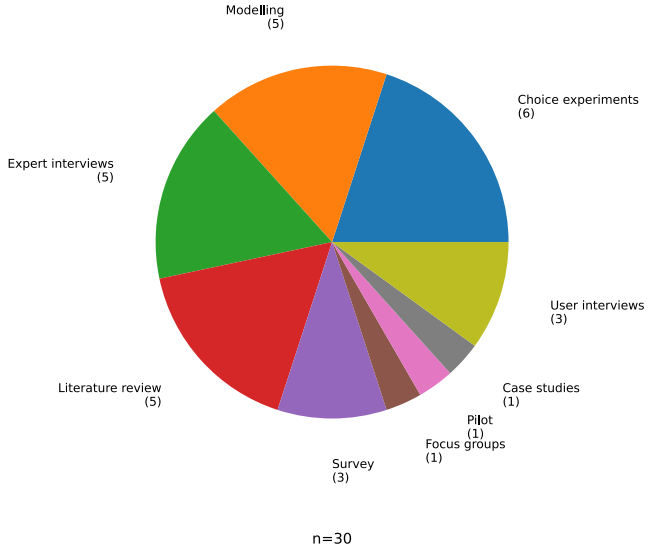

Fig. 1. Methods used by 30 reviewed studies that covered V2G and social acceptance. None of the studies included interviews with EV users about V2G acceptance, though some have covered unidirectional smart charging.

2.1. Previous studies: Overview of results and methods used

Several previous works investigated the acceptance of V2G by potential customers, focusing on various aspects, such as willingness to pay for EVs with V2G, willingness to participate in V2G contracts, preferences with respect to these contracts and so on. Additionally, although not strictly involving V2G, we briefly review literature on the acceptance of unidirectional smart charging, since there are significant overlaps.

Parsons et al. (2014) collected data through online surveys from internal combustion (IC) engine vehicle drivers (prospective EV users) in the USA. Based on preferences stated by respondents to the survey questions, they proposed that customers be provided with either upfront incentives or be charged on a pay-as-you-go basis rather than with contracts imposing specific charging behaviour. Geske and Schumann (2018) investigated the willingness to participate in V2G through discrete choice experiments, concluding that 'range anxiety' and 'minimum range' were especially important parameters. As in the earlier case, owing to the low EV penetration in Germany at the time of the collection of data, the work largely relied on surveys filled in by conventional vehicle users interested in the future purchase of an EV.

Kester et al. (2018) interviewed over 200 experts on electric mobility, based on which they drew attention to double taxation on energy storage, dynamic pricing of electricity, market structure and the role of aggregators, as well as the necessity for better frameworks guiding technology, regulatory and policy development. Noel et al. (2019a) used a choice experiment, gathering data through online surveys in the five Nordic European countries. Diverging attitudes on the willingness to pay for V2G compatibility in EVs were found: customers were willing to pay more for vehicles with V2G compatibility in two countries, while they were not in the others.

Zonneveld (2019) built upon work on V2G contracts conducted by Park Lee (2019). A choice experiment was conducted via an online survey and found that remuneration, guaranteed energy, contract duration, discharging cycles and plug-in duration were the most important elements (in decreasing order of importance) in V2G contracts among Dutch EV drivers. Also, taking advantage of the relatively high EV penetration rate in the Netherlands, Meijssen (2019) used online and offline surveys to contact Dutch EV drivers. The availability of fast charging facilities was found to reduce EV users' concern for minimum battery state of charge, and consequently made them more willing to participate in V2G contracts.

Several studies also investigated consumer acceptance of unidirectional smart charging. As unidirectional smart charging technology is further developed, interviews with consumers in demonstration projects have more commonly been used as a methodology. Among these earlier studies, the ELVIIS (Electric Vehicle Intelligent InfraStructure) project, conducted in Göteborg, Sweden, interviewed 16 EV drivers who used the smart charging system developed over the course of the project. The results revealed that the interviewees were largely satisfied, but found the experience slightly stressful, though the experience seemed linked more to the specific interface used than the concept (Pettersson, 2013).

Similarly, Schmalfuß et al. (2015) interviewed 10 EV users after they

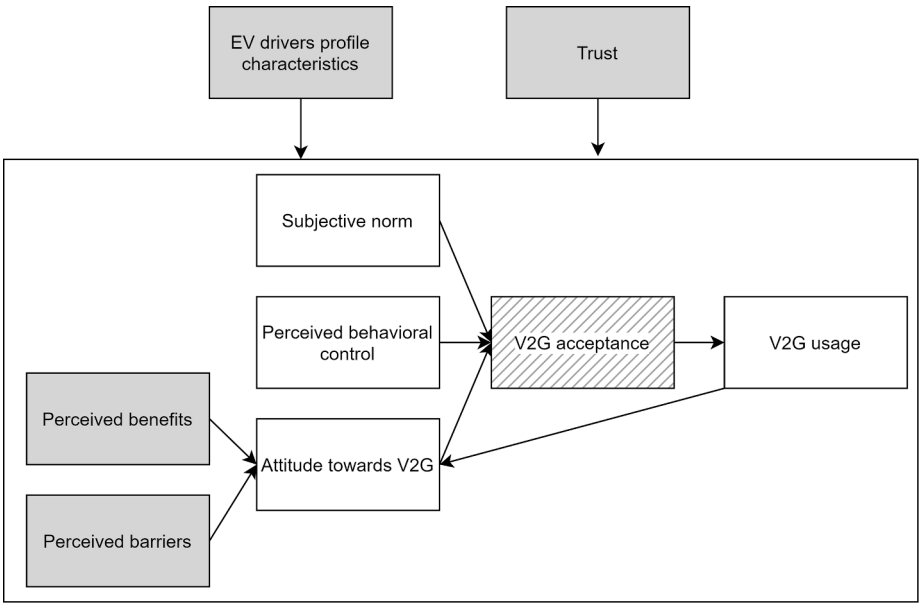

Fig. 2. Initial conceptual model based on the literature review describing the influence of factors on V2G acceptance. The white boxes represent the original TPB while the grey-coloured variables represent added variables having reviewed the literature. The arrows represent the direction of influence.

had used a smart charging system for EVs as part of a project in Germany. The control of charging was accepted by most interviewees, though a few had problems with the knowledge and skills required to use the interface. Also in Germany, Will and Schuller (2016) used surveys to collect data from EV users in order to understand the factors influencing users' acceptance of smart charging (unidirectional). Again, the results show high levels of acceptance of the concept, with the strongest motivations being contribution to grid stability and integration of renewable energy, rather than monetary compensation. Delmonte et al. (2020) conducted interviews with both EV users and IC engine users in the UK, and reported that twice as many users opted for management of charging themselves as the number that opted for automated charge scheduling.

Since smart charging is further developed as a technology than V2G, studies have been based on actual EV drivers who have been informed through gaining in-depth experience of the entire process, including the interface. On the other hand, discussions on battery degradation and uncertainty about compliance with standards, which are quite central to V2G, are noticeably absent.

A large number of the papers investigating the acceptance of V2G mainly consider only IC engine users. However, experience with EV usage and driving can play a major role in shifting preferences of drivers (Jensen et al., 2013). Further, of the 30 reviewed papers, a majority of original research was based on stated choice experiments and expert interviews. Fig. 1 provides an overview of the methodologies used in these studies.

Stated choice experiments provide useful insights into consumer preferences such as the amount of financial compensation or which contract attributes EV users prefer. These studies do not address the underlying reasons and motivations of the participants nor do they provide deeper insights into why study participants provided certain answers. Expert interviews, on the other hand, do provide deep insights. However, they do not always reflect the opinions and attitudes of consumers, particularly in cases where the number of customers are extremely low at present, as is the case with V2G charging points. In summary, there are few studies providing insights about consumers' underlying motivations for using V2G as part of their daily lives. Very few studies reveal what EV drivers think about the V2G concept, whether they are willing to use it and why.

2.2. Defining 'consumer acceptance of V2G'

There are different opinions and perspectives regarding acceptance and the most appropriate definition. Huijts et al. (2012) made a distinction between citizen acceptance and consumer acceptance. An example of citizen acceptance is the reaction of the general public to the construction of a nuclear power plant. Consumer acceptance, on the other hand, *"reflects the public's behavioural responses to the availability of technological innovations which leads to the purchase and use of such products"*. One example is the purchase and use of a heat pump. Since V2G is perceived as a new technological product or service which EV users can purchase and use, the focus of the present study was on consumer acceptance and we use the definition provided above.

2.3. Theory of planned behaviour and its extension

For our study, the Theory of Planned Behaviour (TPB) was adopted as a basic structure for a conceptual model. The TPB explains that the intention for behaviour determines the actual behaviour. The intention is influenced by the attitude towards behaviour, subjective norms and perceived behavioural control (Ajzen, 1991).

The TPB was chosen for two main reasons. Firstly, the model has often been used in studies for the social and end-user acceptance of technologies. For example, the Technology Acceptance Model, a well-known model in Information Systems research, was in essence based on the TPB (Venkatesh et al., 2003). Ojeda (2013) studied the acceptance of the "car as a power plant" (CaPP) concept and proposed the CaPP technology acceptance model, which was also based on the TPB. Will and Schuller (2016) investigated smart charging acceptance and partly based their model on the TPB. Secondly, based on previous studies, the TPB has been found to provide relatively high-quality results. For example, in information systems research, it seemed that perceived usefulness and ease of use are determinants of people's intentions to use computers (Davis et al., 1989). Additionally, the model is suitable to be extended further with new factors for a specific context: V2G acceptance in our case. Therefore, it was deemed suitable for the exploratory research performed here.

The TPB has various known limitations:

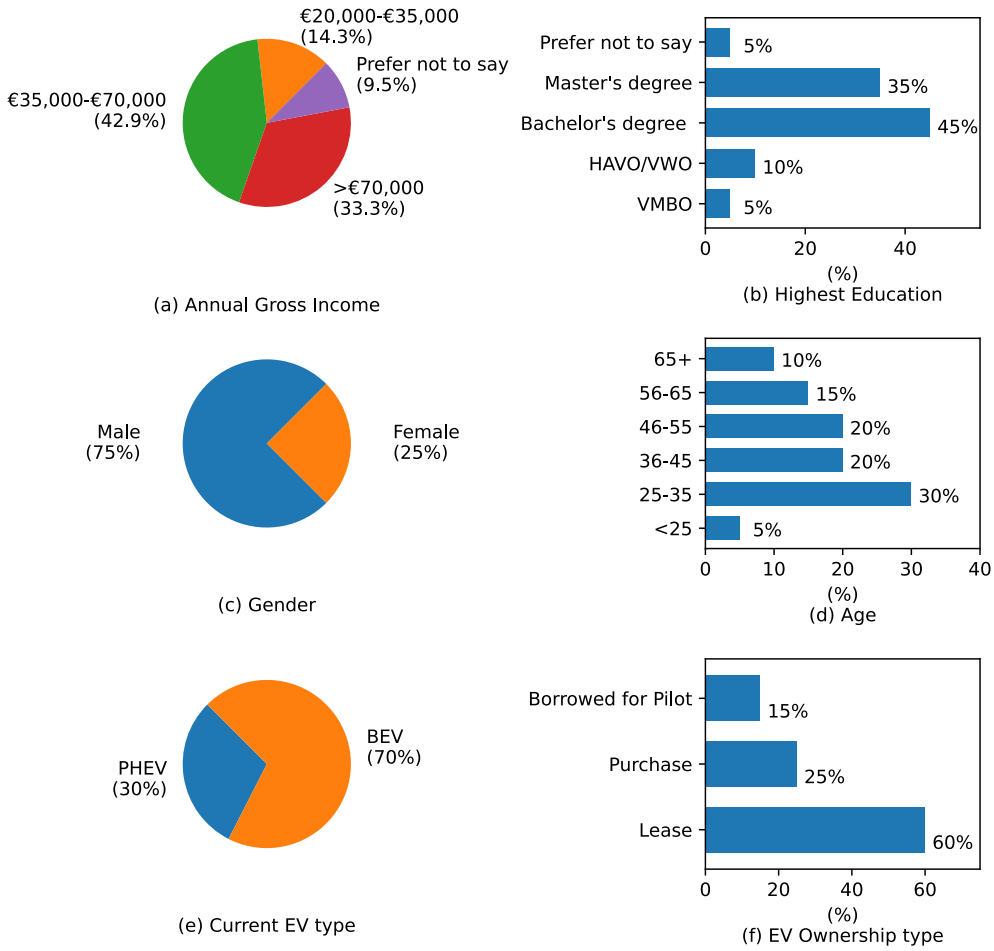

Fig. 3. Socio-demographic characteristics of interviewee: Distributions based on (a) income, (b) education level, (c) gender, (d) age, (e) current EV type and (f) EV ownership type.

1. Models may be incomplete due to the exclusion of habits and emotions moderating variables (Jokonya, 2017).
2. Individuals are assumed to be rational actors (Sniehotta et al., 2014).
3. Possible correlations between the variables may exist (e.g. actual usage of the technology also influences an individual's attitude) (Van Wee et al., 2019).
4. The model has limited predictive validity (it is difficult to predict a complex phenomenon such as V2G acceptance with high accuracy based on a relatively small number of variables or static preferences) (Sniehotta et al., 2014).

Other studies provided insights into how the model of the TPB could be further expanded in order to be more suitable in the context of V2G acceptance. In other words, new potential variables were identified to make the model more complete for V2G consumer acceptance. The process of expansion was iterative over the course of the literature review.

Huijts et al. (2012) used the TPB to study the social acceptance of environmental technologies (e.g. hydrogen storage) and argued that the perceived benefits, costs, and risks influence an individual's attitude. They included trust (e.g. trust in the actors responsible for the technology) in the model. By including perceived benefits, perceived barriers (i.e. costs and risks) and trust in the model, we aim to include more subjective elements within the scope of the model. Also, the TPB was further extended by including demographic and EV driver characteristics in order to make the model more complete. For instance, Will and Schuller (2016) hypothesized that various characteristics (e.g. EV-interest, EV-experience or technological innovativeness) would lead to a higher acceptance of smart charging.

Van Wee et al. (2019) argued that actual usage may influence attitudes towards behaviour, which was also included to identify possible internal correlations within the model. However, no adjustments could be made to circumvent the limited predictive validity, and this limitation remained in the final conceptual model. The outcomes of our research cannot lead to highly accurate predictions regarding the future consumer acceptance of V2G.

2.4. Conceptual model

The conceptual model that was drafted is shown in Fig. 2. The TPB was chosen as the basis and contextualized for V2G acceptance, represented by the boxes in white. Based on what we found in literature, the model was further expanded, represented by the boxes in grey. The goal of the study was to investigate V2G acceptance (the striped box). The TPB has been slightly modified. The final two factors of the TPB have been changed to *V2G Acceptance* and *V2G usage*.

We make a distinction between acceptance of the technology and usage of the technology. As seen in our model in Fig. 2, V2G acceptance, the indicator we assess (shown in stripes) is based on subjective norms, perceived behavioural control and prevailing attitudes towards V2G. On the other hand, usage is linked with action and adoption, for which prior acceptance is a prerequisite. The gap between acceptance and usage, variously described in literature as the value-action gap or the Knowledge-Attitudes-Practice (KAP) gap, describes the transition from acceptance to usage (Rogers, 2010). In the scope of this study, we were unable to assess the usage of V2G but we are interested in the reasons for

acceptance, shown in the left of the figure.

An individual's attitude towards V2G is influenced by the perceived benefits for them and perceived barriers to usage. Based on the literature, it was not clear how trust and drivers' characteristics directly influenced V2G acceptance. We used this conceptual model to construct the interviews (i.e. the interview topic areas and questions shown in Appendix A). The initial model was modified and improved based on input from the interviews, with the final model used to structure our results (shown in Section 4).

3. Methodology

The literature review revealed relatively few references to consumer acceptance of V2G, and there were also a lack of interview based studies. A qualitative and exploratory research approach was therefore adopted. The data collection through interviews and methods of data analysis are described together with an overview of the interviewees.

3.1. Semi-structured interviews

Interviews with Dutch EV drivers was deemed to be a suitable data collection method in order to gain more insight into the defined problem. Such interviews provide rich insight into the issues at hand and enable the interviewer to further clarify answers and search for underlying motivations and attitudes. Moreover, it is a suitable data collection method when the research is still in its early stages and rather exploratory in nature (Sekaran and Bougie, 2016; Emans, 2004). Potential interview candidates were approached by means of advertisements on a social media channel: 'Association of Electric Drivers', and by approaching individuals in the researcher's professional network.

When preparing the interviews, the literature-based conceptual model (Fig. 2) was used as input for the design of the interview protocol. The interview questions were constructed by using the different identified factors from the initial conceptual model, to formulate various topic areas. For example, participants were asked about the benefits of V2G that they perceived. During the interviews, the interviewees were shown an animated presentation based on which different applications of V2G were discussed. Questions were asked about their beliefs and motivations regarding driving EVs. They were also asked about their personal experiences and opinions regarding conventional charging and V2G. Each interview was held in Dutch and had a duration of approximately 60 minutes. The responses of the interviewees were recorded and transcribed. The transcripts were send to the interviewees for approval. In Appendix A, an overview of the interview protocol is provided, including more details about how the interviews were constructed, along with screenshots from the animated presentation that was shown to the interviewees.

3.2. Qualitative data analysis

The data analysis process consisted of data reduction, data display and drawing conclusions (Miles and Huberman, 1994). The interview reports were categorised into codes, each of which related to a factor that influences V2G acceptance. To do this, we used our conceptual model, as discussed in Section 2.4. The coding process was an iterative one, during which new themes emerged and were identified. A total of 81 codes related to V2G consumer acceptance were found in the interview transcripts.

3.3. Interview sample

The population was defined as all current Dutch EV drivers of both Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). Potential future EV users have not been included in the scope because they have no experience with EV driving and charging. Therefore, their answers to interview questions would be less reliable. In total,

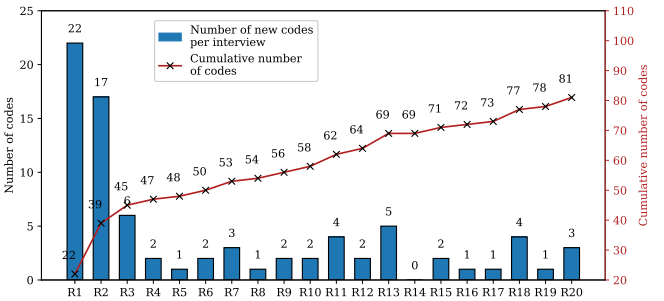

Fig. 4. Code saturation observed over interviews.

20 Dutch EV drivers were interviewed - further information on the sample can be seen in Fig. 3.

Three interviewees already had knowledge of V2G bi-directional charging points as they were participants in a V2G pilot project. However, they did not have experience of using the system beyond doing some mobility planning with a smartphone app. Of the total sample of participants, 75% were male. The majority of the sample had a University background and belonged to higher income groups. The ages of the participants ranged from 18 to over 65, with over half of them between the ages of 25 and 55. Most had leased their EVs, though a few owned them and a small section used the EVs as part of the pilot projects in which they participated. The vehicles were mainly BEVs, though some used PHEVS.

3.4. Representativeness of the interviewee sample

It was difficult to substantiate the representativeness of the sample because no socio-demographic statistics or EV driver characteristics of the population (all current EV drivers in the Netherlands) are publicly available. That is why we compared the profiles with other studies involving Dutch EV drivers. For instance, Meijssen (2019) conducted a survey among Dutch EV drivers in which 86% were male, 93% were highly educated, 63% were middle-aged and 61% belonged to higher income groups (>€50.000). Zonneveld (2019) conducted a survey among Dutch EV drivers where 91% were male, 79% had a high level of education, 69% were middle-aged and 39% had high incomes (>€70.000). National Dutch statistics about EV type show that as of December 2019, 53% of EVs in the Netherlands were BEVs while 47% were PHEVs (Netherlands Enterprise Agency, 2020). The distributions found in the sample of interviewees in this study have common features with those in the studies mentioned above. For example, most EV drivers interviewed were males, with higher incomes and education levels. It seems that there is a somewhat representative distribution of demographics (e.g. age) and EV driver characteristics, despite the low number of 20 interview participants.

On the other hand, low and middle income households form a higher share in total vehicle ownership in the Netherlands (Netherlands Enterprise Agency, 2020). This suggests that the subset of EV drivers is itself not representative of the larger population of private vehicle owners. Thus, we cannot explicitly state that the sample is representative, and therefore limited generalisations can be made to a wider population of private vehicle owners.

3.5. Code saturation

Twenty interview participants seems a modest sample. However, during the first two interviews, 48% of the total of 81 codes were already identified, as can be seen in Fig. 4. The figure shows that we approach code saturation after a relatively small number of interviews. Not much new information and relatively few factors were identified after the first seven interviews. The thirteen interviews thereafter helped to further validate the findings. Due to the code saturation observed, we expect our

Table 1
Codes mentioned by interviewee and final acceptance.

		Participants																				
	Number of interviewees mentioning the factor	Current EV Drivers																	V2G Driving Participants			
		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	
Factor		26	29	31	12	16	24	20	14	18	25	25	17	34	23	32	32	32	32	33	12	Groundedness
Compensation	17	2	0	2	1	0	2	2	0	1	1	2	2	2	1	3	3	3	1	2	3	33
Battery degradation	18	2	0	1	1	2	1	1	0	1	2	1	1	3	1	2	2	1	1	1	1	25
Range anxiety	16	1	1	3	1	1	0	0	1	1	1	2	1	3	1	0	2	1	1	0	2	23
User interface	12	2	0	1	0	0	1	0	0	0	1	1	0	0	2	5	2	3	3	1	1	23
Location	18	1	1	1	1	1	1	2	1	1	1	1	2	2	1	1	2	1	1	0	0	22
PR and communication	8	0	0	0	0	0	1	0	0	0	2	1	1	0	0	3	0	2	3	2	0	15
Societal contribution	9	0	1	3	0	1	0	1	0	1	2	0	0	0	2	0	1	0	0	0	1	13
Lack of standards/ protocols	6	1	0	1	0	0	0	0	0	0	0	0	0	2	0	3	0	2	0	2	0	11
Control important	13	1	0	1	1	1	1	0	0	1	1	1	0	2	0	1	0	1	1	1	0	14
User-friendliness	10	1	1	1	1	0	1	1	0	0	0	1	0	0	0	1	0	1	1	0	0	10

findings to provide an reasonably accurate overview of the current situation (last quarter of the year 2019) with regards to Dutch EV users' attitudes and opinions related to the V2G concept and V2G acceptance.

4. Interview results and discussions

The factors identified through the interviews and their analysis reveal consumers' perceptions of V2G.

4.1. Identification of the influencing factors for V2G acceptance

Based on the interviews, 81 factors that influence EV drivers' acceptance of V2G were identified. Table 1 shows the 10 factors which were mentioned most often by the interviewees. The number of interviewees who mentioned each factor are also noted. These factors and the context in which they were discussed during the interviews have been elaborated upon.

4.1.1. Compensation

As shown in Table 1, compensation was mentioned by most interviewees as an important reason to participate in V2G. Both the type of compensation and the amount of compensation play a role. However, the degree to which different EV drivers were triggered by compensation was found to vary. For instance, R17 with a leased BEV just wanted to be compensated for battery wear caused by V2G participation:

The concept of V2G is fantastic! Because you get compensated for battery degradation and my car serves a function even when I am not around.

R11, with a leased PHEV, indicated that compensation was important to him, but was also willing to receive another form of compensation:

I think that the financial compensation aspect (for instance discount on charging/parking tariff) is an important advantage of V2G. I will always consider: what is in it for me?.

R15 made the following clear during the interview:

A monetary compensation, for instance cheaper energy, free parking, etc., will stimulate and encourage me to use V2G

However, R13, who owned a BEV, believed that compensation was not enough to convince him to participate in V2G:

Financial compensation does not influence my willingness to participate. I do not believe that, with V2G, an amount of financial compensation could be realized which is enough to compensate for the degradation of the battery of my vehicle.

4.1.2. Battery degradation

As shown in Table 1, battery degradation was mentioned by most of the interviewees. They had different perspectives and beliefs regarding battery degradation and attributed varying levels of importance to it as a factor influencing their acceptance. R3, a female EV driver with a leased Battery Electric Vehicle (BEV), stated:

I find the possible negative effects of V2G on battery degradation acceptable as long as the effect is not larger than for instance battery degradation caused by regular driving.

However, R13, a male EV driver with a privately purchased BEV, stated that he would not participate in V2G because of possible battery degradation:

If discharging for V2G-mode is done only a couple of times per year, then I would find it acceptable to participate in V2G. But if you do V2G on a daily basis (hundreds of times per year), I believe that the battery pack will be damaged and then I would not participate.

Participants seemed to have different opinions about battery degradation. EV lessees were found to be less concerned about the effects of battery degradation than EV owners. They were more concerned about who received compensation for both the energy delivered as well as the battery degradation. For instance, R6 with a leased BEV mentioned:

The caused battery degradation may be noticed after 3–4 years, but then I can get a new car from the lease company.

R10, with a leased BEV, argued that:

Possible battery wear caused by (dis) charging is not a barrier for me so that I will not use the V2G services…it is acceptable as long as it is transparent and clear to me to what extent there is battery wear and that you are somehow compensated for it.

Some EV owners seemed more concerned about the influence on the

battery lifetime than the compensation, displaying detailed knowledge of battery management. In the words of R4, who owned an EV:

> *When (dis) charging between 20% and 80% state-of-charge, it has no negative influence on battery life…Fully charging the battery and a completely empty battery is bad for the battery pack.*

The effect of the ranges of depth of discharge on battery degradation is discussed in further detail by Wikner and Thiringer (2018), where avoidance of high states of charge and use of shallow cycling at low states of charge were found to prolong battery lifetime. The interviewees opinions on battery degradation were found to influence their acceptance of V2G.

4.1.3. Range anxiety

Users were worried about the availability of sufficient battery capacity in the EV, particularly for unexpected trips. R3, a female driver with a BEV, mentioned that:

> *How do I know that my car is sufficiently charged when I want to leave?*

Similarly, R5, a female driver with a leased BEV questioned:

> *What happens when I have to make an ad hoc trip? Does there exist a risk that the battery is low?*

4.1.4. User interface

Interviewees indicated that a user interface on the charging station would increase transparency and ease of use of the system and thus their acceptance. The user interface could, for instance, display charging and discharging information and allow the end-user to view certain settings of the V2G system. Most interviewees indicated that they would prefer such an interface. For instance, R1 proposed the idea of a software system with a user interface:

> *I want to be able to keep control of the system by using a smartphone application which provides notifications about when the car is going to discharge. Furthermore, I want to be able to set a limit for a minimum state-of-charge.*

4.1.5. V2G charging point location

As seen in Table 1, the location of the V2G charger was a topic which was extensively discussed by the interviewees. Location of the charging point was not found to have a large influence on users' acceptance: the most commonly used charging locations - home and at work were both seen as suitable locations. Most interviewees seemed to judge the suitability of V2G for a particular location based on convenience. Some interviewees mentioned that there were various locations which would be ideal for them to have a V2G charging point. R1, for instance, indicated:

> *I believe there is not just one specific location where V2G is more likely to be seen. I perceive V2G as the new future standard for charge points.*

4.1.6. Public relations and communication

Public relations (PR) and communication were found to be essential to interviewees for fostering long-term acceptance. This included the provision of accurate information about V2G projects and communication of both the benefits of V2G and the possible risks. For instance, R18 remarked that PR and communication are of importance when it comes to general acceptance:

> *I believe that PR is very important. So, spread the word and share success stories of V2G projects…PR is important to stimulate familiarity with the V2G concept*

4.1.7. Societal contribution

Societal contribution is related to the fact that individuals can contribute to solving grid balancing issues and contribute to a more reliable grid. It also included the possibility to reduce CO_2 emissions by using sustainable energy. As shown in Table 1, interview participants frequently indicated that it was an important benefit of V2G. R18, a male EV driver with actual V2G user experience, argued:

> *A better ecological footprint is important for me. We are dreaming about gas-free households and a transition towards solar energy and wind energy. I like the idea that my car can contribute to that.*

R3, with a leased EV, mentioned that:

> *If the grid becomes overloaded, we will all experience the disadvantages of it. The grid balancing problem is a societal issue which I, as an EV driver, contribute to…when I can do something back for society by participating in V2G and help to balance the grid, it is a good thing.*

4.1.8. Lack of standards/protocols

Multiple interviewees indicated that they were concerned about whether their current EV supported V2G functionality. R1 was willing to participate in V2G, but indicated:

> *I am not sure whether my current car has V2G capabilities*

During the discussion, R13 mentioned:

> *I believe that it is a first step to widespread acceptance of V2G to make sure that most EVs support V2G*

Interviewees also indicated that, in case of a software system or smartphone application, they would prefer one standard. R15 mentioned:

> *It is better to have one app than all separate smartphone apps.*

R19, a previous V2G pilot participant, explained that her current EV does not support V2G:

> *I cannot discharge with my current car [a Chevrolet Volt] …OEMs and traditional car manufacturers should enable V2G and use one protocol.*

4.1.9. Control over (dis) charging

Control over charging and discharging was mentioned by interviewees as a functionality that can contribute to acceptance. For instance R4, with a purchased BEV, mentioned that:

> *I want to keep control…I do not want [a case where] I am going to make a trip and a third party just drained the battery of my EV.*

However, there were also some interviewees who did not want to have this possibility and just wanted the system to arrange everything automatically. For instance, R10, stated that:

> *Preferably, I do not want real-time control. For instance, I don't want to get notifications throughout the whole day about V2G…I believe that a weekly or monthly report (on display in the car or on my smartphone) are enough for me.*

4.1.10. User-friendliness

Interviewees indicated that a user-friendly system was an important factor affecting their acceptance. This was mentioned by a number of interviewees as a precondition for the use of V2G chargers. A complex system with very little information or unclear information would block their acceptance. Therefore, this factor is closely related to user-interface. For instance, R10 mentioned:

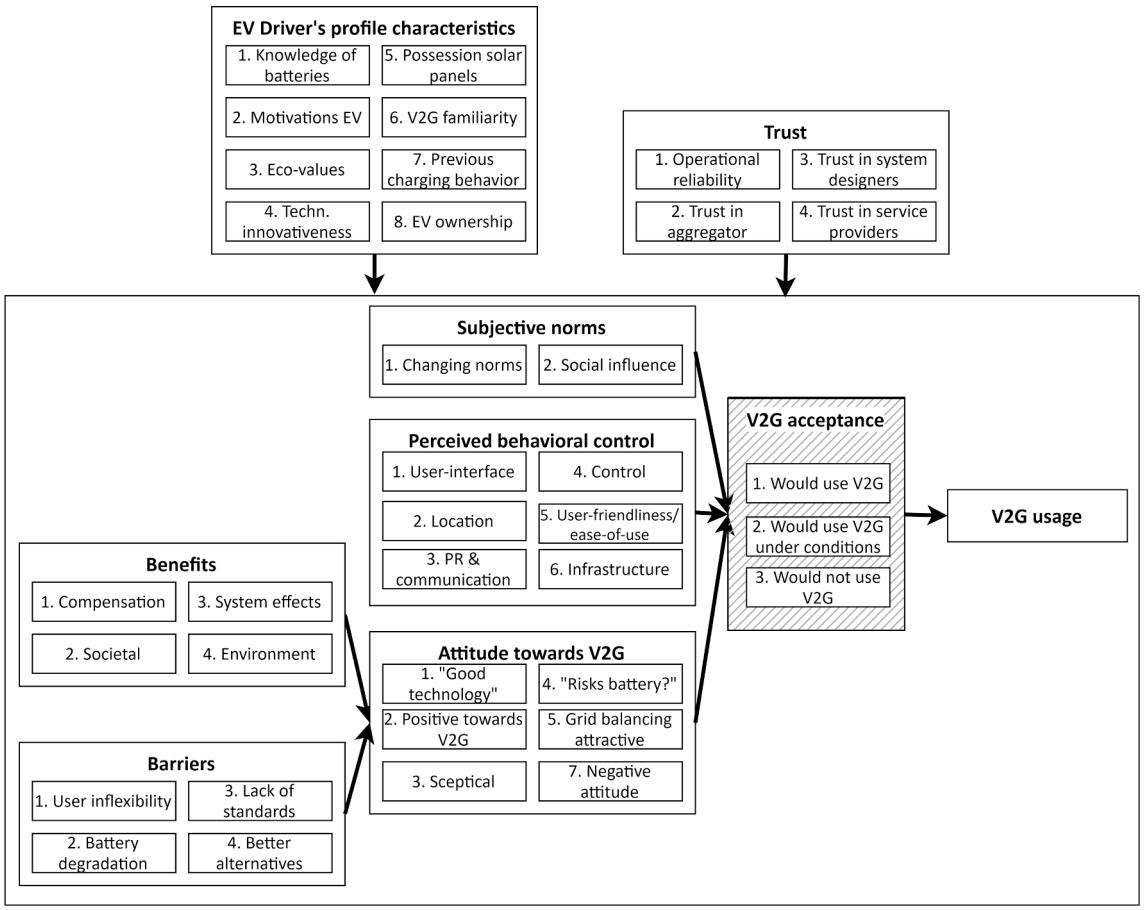

Fig. 5. Resulting conceptual model in which the insights of the interviews are included with regard to EV user acceptance of V2G.

V2G participation should not be a hassle …Generally, I do not want V2G to be very different from regular charge points.

R19, a previous V2G pilot participant, mentioned:

I think that V2G should be made as simple as possible for the end-user. [There should be] free software and the system should work without errors.

Many interviewees proposed the idea of using mobility planning software and suggested that a user-friendly experience could be achieved through proper software or a user-interface. R20, a previous V2G pilot participant, mentioned:

There should be an extensive and advanced planning system in place.

4.2. Resulting model

Fig. 5 shows the resulting model that includes the results from the interviews. The original structure from the literature study, based on the Theory of Planned Behaviour, remains unchanged. Various factors have been inserted within each category. For example, compensation, social contribution, system effects and the environment are listed under perceived benefits. Fig. 5 can be perceived as a summary of all the factors identified to contribute to consumer acceptance of V2G (the striped box). Factors were differentiated into perceived benefits and barriers, each of which was found to influence an individual's attitude towards V2G differently. For example, some interviewees considered V2G to be a positive concept because they could earn money with their cars and help balance the electricity grid, despite the disadvantages of possible battery degradation or user-inflexibility. As shown in Fig. 5, subjective norms, perceived behavioural control and attitude towards V2G influenced the V2G acceptance.

Most interviewees were found to accept V2G. In line with the Theory of Planned Behaviour, our model explicitly assumed that if an individual accept V2G, they would proceed to actually use it. However, in reality there could be a dropout rate between the "V2G acceptance" and "actual usage", this being the KAP gap mentioned earlier. This could not be further explored because most interviewees did not have the opportunity to use V2G compatible charging points. This is a limitation of our study which can be addressed in future research.

Based on the interviews, EV driver profile characteristics and Trust were found to be important factors influencing acceptance, but the direct influences of other variables was not clear. Therefore, in Fig. 5, EV driver profile characteristics and trust are visualized outside the general model structure of TPB. Since none of the interview participants had actual experience with V2G usage on a daily basis, we could not investigate how actual usage influences their attitude towards V2G. In summary, the general model structure from the initial conceptual model in Fig. 2 has been validated based on the interviews, except for the influence of actual usage on attitudes.

Table 2 shows an estimate of the degree of acceptance per interview participant. For each interviewee a qualitative estimate was made of whether acceptance was high, neutral (i.e. acceptance only under specific conditions), or low. This estimation was made based on the interview transcripts by the lead author, who also conducted the interviews. The results obtained here are expected to be indicative and based on interpretation of the authors rather than based on an explicit quantitative response from the interviewees based on a Likert (or similar) scale. Since the estimation is based on interpretation, we have not assessed the intercoder reliability. Instead, we directly present the excerpts from the

Table 2
Degree of acceptance among interviewees.

Participants		Quotations from transcripts	Degree of acceptance
Current EV drivers	R1	"good idea", "will be the future standard of charging"	High
	R2	"would use V2G at several locations"	High
	R3	"good concept, but various questions", "some questions/uncertainties", "would use it at long-term parking"	Neutral
	R4	"very nice concept", "but some questions/uncertainties", "could make EVs even more attractive"	High
	R5	"cool concept", "what happens when I have to make an ad hoc trip?"	High
	R6	"smart concept. Good concept for the energy companies "and grid operators", "not many perceived barriers", "Would find it great to participate!"	High
	R7	"idea of V2G is a good idea", "not many perceived barriers"	High
	R8	"positive as long as it costs no money", "no major barriers","would use V2G"	High
	R9	"would use it when it becomes available", "not many barriers because of PHEV (still able to drive when battery empty)	High
	R10	"interesting concept", "but is mobility suffering?","discontinuity?", "would be ideal at home because of PV"	High
	R11	"positive attitude, but…", "why not store locally?","but battery degradation", "would maybe use it"	Neutral
	R12	"OK on conceptual level, but…", "home application nice","how much money", "goal = charging"	Neutral
	R13	"hope it will not be realized in the next 10–15 years","too many barriers", "battery not ready","no incentive for user"	Low
	R14	"smart concept but not sure if it is the best solution for grid, congestion", "limits the end-user in certain aspects", "not sure he would use it"	Neutral
	R15	"OK concept", "not much end-user incentives" "better alternative solutions"	Neutral
	R16	"promising concept", "couple of barriers", "but think only small group of EV users actively want to use it"	Neutral
	R17	"fantastic concept", "better use of solar", "alternative","function EV", "I cannot think of good reasons why consumers would not be interested in V2G"	High
V2G users	R18	"good to solve imbalances", "would use it","trip planning not a big issue"	High
	R19	"very good concept as long as the system works properly"	High
	R20	"V2G is good in combination with car-sharing","compensation for battery degradation"	High

transcript, based on which the estimation was made.

The results show that a majority of the interviewees show enthusiasm for the concept and acceptance to use it, should it be made available. Many saw value in the idea, not only for themselves as financial beneficiaries of the V2G system, but also to other stakeholders, such as energy suppliers, grid operators and owners of solar PV home systems.

Many interviewees expressed scepticism regarding the operation of V2G, especially the incentives for end-users, the adequacy of compensation, battery degradation and its conflict with charging the vehicle for mobility. This did not always prevent them from accepting the system i.e. they were not perceived as strong barriers for acceptance. Some interviewees cited specific conditions, which if satisfied, would lead them to accept the system, typically related to the factors mentioned above. One single interviewee saw too many barriers in the use of the system to accept it, citing in particular the lack of incentives and the insufficient maturity of battery technology.

4.3. Comparison of results with literature

The results obtained in our study validate some of the results documented in earlier literature, though there are also some conflicting points. At the broad level, the high levels of consumer acceptance of V2G among relatively early adopters of electric vehicles is more similar to results obtained in Germany through survey methods (Geske and Schumann, 2018). While divergent attitudes were seen among the interviewees, the overall outlook seemed more positive than the one obtained in the Nordic countries by Noel et al. (2019a).

In our study, compensation proved to be one of the most significant factors, a theme repeatedly brought up by interviewees, along with battery degradation and range anxiety. These results appear to differ from the German case, where multiple studies have shown the low importance of monetary compensation (Will and Schuller, 2016; Geske and Schumann, 2018). This difference may be caused to some extent by the system differences between V2G and smart charging; only the latter was studied in Will and Schuller (2016). However, in contrast with Geske and Schumann (2018), who found range anxiety to be the most important determinant of willingness to participate and compensation to be far less relevant, we find compensation to be at least equally influential. This may also be linked to the advanced adoption of electric vehicles in the Netherlands at the time of this study as compared with that in Germany at the time of earlier publications.

We found diverging attitudes on the degree of control of the system that the interviewees wanted, ranging from a desire for continuous monitoring and control to a desire for complete automation. This differs from the case in the UK where the majority of interviewees were found to prefer retaining control over charging cycles because it was associated with higher perceived simplicity and lower perceived risk (Delmonte et al., 2020). We also found that interviewees expressed a desire for transparency about various parameters, such as battery state of charge, utilization of the discharged energy (for grid support, renewables integration, etc.), net compensation over weekly or monthly periods, and level of battery degradation, even when they did not want control over the process.

The location of the V2G charging point was not a factor found in the literature reviewed. However, the interviewees in this study brought up the location of the charging point quite often, suggesting its relevance to them, though it was not found to greatly influence acceptance. V2G was considered mainly at locations where the interviewees frequently charge, i.e. at their residence and workplace, though there was no real preference expressed for either option.

We also note the relatively high degree of knowledge among the interviewees, some of whom brought up sophisticated points of discussion, such as detailed and up-to-date knowledge of the influence of cycling depth and state of charge on battery degradation, and the current lack of universal standards on both vehicles and charging points in V2G. In V2G user studies in which mainly IC engine vehicle drivers were focused on, such as those conducted by Geske and Schumann (2018) and Noel et al. (2019a), these issues are notably absent, though they are frequently mentioned in interviews with experts (Noel et al., 2019b; Kester et al., 2018) and academic reviews (Sovacool et al., 2017; Sovacool et al., 2018).

It is also clear that consumer focus is slightly different from that of system experts and academics, as noted by Kühl et al. (2019). As an example, none of the interviewees paid much attention to the currently high costs of V2G charging points which is a frequently mentioned point in academic literature (Ghotge et al., 2019).

4.4. Generalisation of the model results

The respondents interviewed in this study represent a small sample size of a far larger population. Further, the interviews were conducted over a short period of time and represent a cross-sectional observation of the interviewee's responses. The results outlined here would offer insights into future acceptance of V2G technology only if they are generalisable over both the larger population as well as over time.

We may conclude that most of the interviewees accept the technology, albeit with some reservations and caution, while a minority does not primarily out of fear for their batteries, insufficient perceived compensation and perceived discomfort. Since EVs are still relatively new, our sample of EV drivers consists entirely of early adopters of the technology, as described by Rogers (2010). Based on several earlier studies, early adopters of EVs are known to be characterised by high income, high education levels and concern for the environment (Carley et al., 2013; Plötz et al., 2014; Hardman et al., 2016). This was also found to be true in our study. It remains uncertain if these attitudes are reflected across larger groups of EV drivers, particularly among drivers who are expected to transition to electric mobility in the near future. It seems likely that their attitudes may not reflect those of the larger population, for whom financial compensation could be more important and emission reduction less of a concern.

Analysis of the generalisability of the acceptance of the interviewees observed here over a larger timeframe appears more complex. The acceptance of V2G by EV drivers in the future is likely to be dynamically interlinked with the energy transition, the development of the mobility sector and competition with other technologies which provide similar services to the grid as V2G. Further, V2G technology itself is developing rapidly, alongside EV and charging point markets.

It seems clear from our research that there is potentially a large share of current EV users who, as early adopters, accept V2G charging points. It seems likely that this share of EV users will probably continue to accept V2G. The size of the share of the population that accepts V2G could change, relative to the population of overall EV users could change with the increased electrification of the passenger vehicle fleet. It is, however, uncertain whether it will increase or decrease over time.

Early adopters of EVs have been found to have similar characteristics in various countries (Hardman et al., 2016). Further, regardless of their location, they drive vehicles produced by a small, common set of original equipment manufacturers. In this study, though we focus on Dutch EV drivers, the results provide valuable insights for other countries as well. We do, however, expect differences of opinion related to some factors. The share of lease drivers, particularly company lease drivers, is large in the Netherlands at over 50% (Kampert and Ewalds, 2018). A correspondingly large share (60%) of our interview sample consisted of leasers. In other countries the ratio of leased to purchased EVs could differ, leading to different attitudes towards battery degradation and compensation among others. Differences in driving habits by country have been shown to be statistically significant (Pasaoglu et al., 2012). This could also lead to differences in attitudes to certain factors.

5. Conclusions

This study aims to explore the attitudes of Dutch EV drivers towards V2G and to provide insight into the factors influencing their acceptance of V2G. The insights from the literature review conducted were used as the basis for the design of an interview protocol. Semi-structured interviews were then conducted with 20 Dutch EV drivers.

Eighty-one codes were identified from the interview transcripts, describing the most relevant factors that influenced EV users' acceptance of V2G. The factors that were found to be the most important to foster acceptance among users were compensation, transparency in terms of the operation of the system and reliable control of the system by the user. Adequate compensation was a particularly important factor for interviewees, who often expected battery degradation costs to be covered. Other forms of compensation, such as discounts on charging or parking tariffs were also found to be acceptable. A high degree of transparency regarding both the use of the battery as well as associated benefits and risks for users was seen as essential by interviewees, and often conditional to acceptance. Although a few participants did not want any additional hassle, the majority wanted to be able to control battery discharge at least occasionally, preferably through a smartphone app.

The factors that were found to be the greatest barriers to V2G acceptance were range anxiety of the users, anticipated discomfort through participation, battery degradation, uncertainty about standards and the low availability of V2G infrastructure. The reduction of available battery capacity for trips due to participation in V2G and the consequent need for additional planning was of concern for many users. Battery degradation was repeatedly brought up, though opinions on it were divergent, ranging from deep concern to informed acceptance of degradation.

Participants had diverging opinions when asked whether they would use V2G charging points with their EVs when they become more publicly available in the future. The majority of users expressed acceptance of the system, including enthusiastic willingness to participate. A few users said that they would only use V2G compatible charging points subject to certain conditions. The conditions mentioned were:

1. Only if no additional costs were incurred
2. Only at long-term parking lots, where it did not conflict with mobility
3. Only if trip-planning was well integrated into the system.

For system planners and designers, these are important concerns that need to be addressed. Finally, one interviewee expressed unwillingness to participate unless battery technology developed further so as to minimise the effect of additional V2G cycles on battery life.

Our results validate earlier survey-based studies showing high acceptance of both V2G and smart charging. However, certain differences are noted – compensation appears to be a more important factor in our study than in other works. Transparency of the process was also considered to be important for the interviews rather than desire to control the system, as perceived in earlier studies. The factors that appeared to be important to consumers were found to be different from those focused on in academic literature and expert interviews.

The generalisability of our results over the larger population and over the coming years is limited. It seems likely that a large share of current EV users, who are early adopters, accept V2G. However, this is likely to change in the future as future EV drivers may have different priorities. Specific issues which are of concern to early adopters related to compensation, transparency, battery effects and range anxiety will also need to be addressed before there is increased acceptance of V2G among new users.

A particular shortcoming of this work was the inability to interview EV users with comprehensive experience of participation in V2G pilots, including trip planning, discharging at various locations and the associated range issues, if any, and compensation. This presents a clear opportunity for further research. The divergence of opinion seen among users also suggests that it may be possible to cluster users into representative archetypes and compare the results between the groups (e.g. using Latent Class Analysis). It would also be interesting to compare the results obtained here with those obtained in other locations around the world with different levels of vehicle electrification, access to charging infrastructure and attitudes towards vehicles and the environment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Koen Heuveln: Methodology, Formal analysis, Conceptualization, Writing - original draft. **Rishabh Ghotge:** Conceptualization, Writing - original draft, Project administration. **Jan Anne Annema:** Conceptualization, Writing - review & editing. **Esther Bergen:** Writing - review & editing, Supervision. **Bert Wee:** Writing - review & editing. **Udo Pesch:** Writing - review & editing.

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Appendix A. Interview protocol

The interview protocol provides an overview of the topics or questions that have been explored during the semi-structured interviews with Dutch EV drivers. The interviewees were asked for the underlying reasons and motivations behind their answers. The structure of the interviews is presented below along with a few interview questions. Screenshots from the animated presentation shown to the interviewees are shown in Figs. 6 and 7.

Fig. 6. Screenshot of the animated presentation shown: V2G at office buildings.

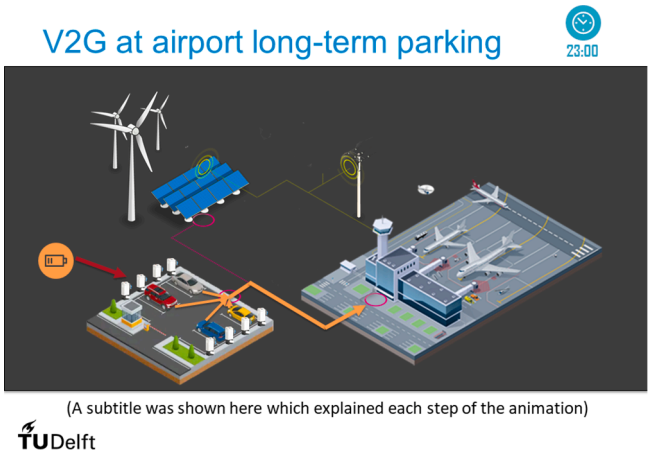

Fig. 7. Screenshot of the animated presentation shown: V2G at airport long-term parking.

1. Interview opening/welcome, brief explanation of request to record the interview.
2. Previous experiences regarding EV driving and charging (example questions below).
- Why do you drive electric?
- What do you think of driving electric in general? (pros/cons/risks).

3. Show animated presentation of the concept of V2G and the system effects and talk about V2G on a conceptual level (example questions below).
- Based on what you have seen, what do you think about V2G?
- What are important benefits of this system for you?

4. Show animation of V2G at the office, home and airport long-term parking, and V2G use cases and applications (example questions below).
- What is your opinion about V2G at [place] for [application] in terms of benefits, costs, risks?
- What would be the ideal V2G charger location for you?

5. Interview closure and provision of information regarding approval of transcripts.

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