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# Stakeholders' perspectives on future electric vehicle charging infrastructure developments

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ABSTRACT

Charging infrastructure development is vital for the adoption of electric vehicles (EVs). Yet, on the surface, there seems to be significant disagreement about when, how and which kind of charging infrastructure should be developed and most importantly, for what reasons. These reasons are concealed in the stakeholders' perspective on the future. Differences in stakeholders' perspectives regarding expectations on the future EV charging infrastructure may be expected, but should they prove irreconcilable they may stall the roll-out. However, to date, it remains unknown what these stakeholders' perspectives are, how they are aligned across stakeholders, which topics are heavily debated and which are agreed upon. This study uses Q-methodology to identify different perspectives on the future of roll-out of EV charging infrastructure. The analysis shows that stakeholders mainly differ in the extent fast charging should play an important role, the degree smart charging should be the standard in charging and how much government should intervene with infrastructure roll-out. There is a consensus on the importance of interoperability of charging stations. The four different perspectives were supported across different stakeholders, which supports the idea that perspectives are not strongly linked to the stakeholders' interests.

## 1. Introduction

With an increase in the number of electric vehicles (EVs) (International Energy Agency, 2017), charging infrastructure to facilitate these vehicles is becoming critical. The number of charging stations trails compared to the number of vehicles. Exponential growth of the number of EVs is predicted if battery prices continue to fall as in recent years (Nykvist & Nilsson, 2015; Nykvist, Sprei, & Nilsson, 2019; Shafiei et al., 2012). A slower roll-out of charging infrastructure compared to the uptake of EVs is becoming the major bottleneck in EV adoption (Maia, Teicher, & Meyboom, 2015; Wolbertus, Kroesen, van den Hoed, & Chorus, 2018). Scholars point to the chicken-and-egg dilemma that stems from the problematic business case for public electric vehicle chargers (Madina, Zamora, & Zabala, 2016; Schroeder & Traber, 2012) as the main cause for the low number of public chargers. Other causes receive less attention in the debate. It has been suggested that different perspectives from a large range of stakeholders on the roll-out strategy of charging infrastructure may slow down the adoption pace (Bakker, Maat, & van Wee, 2014). Not only the perspectives on current roll-out strategy differ, but stakeholders also view the impact of technological developments and policy changes on the charging infrastructure of the future differently (Wirges, 2016). Yet, this topic has remained unexplored from an empirical perspective.

Policy makers have to make mid- and long-term strategic decisions about roll-out strategies for charging infrastructure. Payback

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periods for infrastructure investments for emerging technologies are relatively long (Burnham et al., 2017). Given the limited amount of funds and time, policy makers have to make decisions on a which option they want to invest. Different charging technologies, old ones and new alike, are competing for the policy makers' interest. These include destination charging, (ultra-)fast charging, static and dynamic wireless charging and the re-emerging of battery swapping as an option to replace charging. The fast development of these technologies makes it hard to choose a single direction for the future. The large number of, and variety in stakeholders that want to have a stake, complicates the issue. Utilities, grid operators, automakers, new entrants (such as charging point manufacturers or operators), governments and oil companies all invest into charging infrastructure (Wirges, 2016). These stakeholders have different ideas about how the market should look like and how it should (or should not) be regulated. Policy makers are looking to see which topics should be addressed most urgently according to the stakeholders in the field. Although the interests of the stakeholders in charging infrastructure have been described before (Bakker et al., 2014; Wirges, 2016), a systematic overview of how these interests translate into perspectives on the future of electric vehicle infrastructure development is missing. Even more so previous studies have looked at the current status quo, as this paper aims to look at mid- and long-term developments. Moreover, these studies do not stipulate how these interests are aligned or are in disagreement.

To reveal the shared perspectives on the future of EV charging across the stakeholders we use Q-methodology, a method which is particularly suitable to reveal subjective viewpoints on a topic (Brown, 1980). In this paper, we argue that Q-methodology is useful and adds to current stakeholder analysis especially in the field of future studies. In contrast to stakeholder analysis, Q-methodology proceeds from the idea that perspectives are shared across stakeholders. In our case this allows us to gain an understanding of the long-term perspectives regarding the future of charging and identify the largest areas of dispute that need policy makers' attention. Using Q-methodology in future studies has been suggested before in the technological (Ligtvoet et al., 2016) and business model domain (Athanasopoulou, Reuver, Nikou, & Bouwman, 2019) but its application is still novel. Findings have also been used for modelling exercises (Eker, Daalen, & Thissen, 2017). This paper further explores the use of Q-methodology in future studies and compares it to results from other approaches that aim to find stakeholders' perspectives on the future. From the Q-experiment with 39 stakeholders from 9 different industries the results show that there are four different perspectives on charging infrastructure developments. The four different perspectives are further analysed to see which issues are the most prominent and how the stakeholders from different industries are divided across these perspectives. The results show that new areas which have previously had not been found in other stakeholder analyses are seen as most important.

The remainder of this paper is organised as follows. Section 2 is literature review on stakeholder analysis in charging infrastructure and addresses the Q-methodology approach. Section 3 provides an introduction to the charging infrastructure market and topics at hand. Section 4 of this paper presents the methodology used. In section 5 we present the results, which include the different perspectives and how they are distributed across the stakeholders. The section also highlights the main areas of consensus and conflict. In the final section we provide conclusions and policy implications.

## 2. Literature review and approach

### *2.1. Charging infrastructure*

EVs and the development of charging infrastructure are much discussed topics in the scientific literature. A review by Pagany, Camargo, and Dorner, (2018)) shows that the number of articles in 2016 had increased with than 200% compared to 2010. Regarding charging infrastructure most papers have focussed on optimal roll-out strategies given certain demand and supply (Shahraki, Cai, Turkay, & Xu, 2015; Zhang, Shaffer, Brown, & Samuelsen, 2015) Many modelling techniques take a multi-actor approach to optimise supply of charging infrastructure (Collantes, 2007; Gnann, Plötz, Kühn, & Wietschel, 2015; Harrison & Thiel, 2017). Interests of stakeholders are captured in formulas in which they will try to optimise their own utility (Hajer, 2006; Sweda & Klabjan, 2015; Torres, Bader, Romeral, Lux, & Ortega, 2013). Yet, such models offer a simplified version of reality in which stakeholder interests are much more complex and multi-dimensional. Stakeholder analysis techniques offer the opportunity to better understand the decision making process in certain contexts (Brugha & Varvasovszky, 2000).

Only a limited number of studies have focussed on stakeholder interest in the electric vehicles business and charging infrastructure in particular. Bakker et al. (2014) and Wirges (2016) described the interests of the main stakeholders in the field and tried to identify the major hurdles to overcome. Steinhilber, Wells, & Thankappan (2013) found similar issues as the previous studies but also took a broader perspective on the market looking at R&D subsidies and technological developments. They find that the technological developments are not yet heading in one single clear direction.

Besides using (semi-)structured interviews as a way to unveil the stakeholders' interests a few studies use different techniques. Warth, Gracht, & Darkow (2013) used a delphi approach to identify the most likely scenario for the future of electrification in the auto industry. Furthermore, using latent class analysis they found three clusters of stakeholders that have similar perspective on the future. These clusters mainly differed on the significance they see for car manufacturers in general and less specific for EVs. Although identifying different clusters, they did not show how the different stakholders were distributed along these perspectives. Zimmermann, Darkow, & Gracht (2012) integrated delphi with participatory backcasting methodology to investigate the electric mobility market in Germany. Their analysis focussed on the factors that are relevant in developping a preferred future for electric mobility. Three main issues that were found were the consumer preferences, market structure and government intervention. These issues were used to create possible futures after which delphi method was applied to reach a favourable future for all stakeholders.

### 2.2. Q-Methodology

These previous studies on electric vehicle stakeholder perspectives (Bakker et al., 2014; Steinhilber, Wells, & Thankappan, 2013; Warth, Gracht, & Darkow, 2013; Wirges, 2016; Zimmermann, Darkow, & Gracht, 2012) made use of different types of stakeholder analysis. Stakeholder analysis is a method used to gain a better understanding of "- *and possibly identify opportunities for influencing- how decisions are made in a particular context*" (Brugha & Varvasovszky, 2000, p239). The idea behind stakeholder analysis is that each stakeholder pursues his own interests and develops an accompanying discourse. Discourse is defined as "*an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices*" (Hajer, 2006, p67). A technology discourse is therefore how stakeholders think and talk about a specific technology at hand. Stakeholder analysis, especially in the case of new technologies, draws on the idea that "*organizations seek to develop discourses that suit their particular interests and advance their preferred technologies*" (Munir & Phillips, 2005, p1667).

Policy makers should look towards the issues in which the largest conflict arises and in which the largest diversity of opinions exist. This can be best be done through the process of *constructive conflict* (Cuppen, 2012). Q-methodology is especially suited to stimulate this conflict as it forces respondents to choose to prioritize between the opinions, they (dis-)agree the most (see section 4.2 on how). In contrast to traditional stakeholders analysis, in Q-methodology it is argued that these discourses or perspectives can be shared across different stakeholders and are not necessarily directly in line with their interests (Cuppen, 2012). Q-methodology does not aim to represent the different stakeholders, but rather be representative of the different perspectives (Risdon, Eccleston, Crombez, & Mccracken, 2003). There is a large diversity in opinions across and within stakeholders as they learn from each other through interactions. Other methods assume that stakeholders have their opinions and only later engage with one other to reach a consensus, Q-methodology assumes that such practices already take place and therefore ideas spread. Therefore, it could be that stakeholders already reach consensus on certain parts.

### 2.3. Literature gap and research question

So far, only a limited amount of studies have been done on stakeholders' perspectives on EV charging infrastructure. The studies that have been performed have often focussed on the entire eco-system of the electric vehicle and not solely on charging infrastructure. Additionally, these papers have proceeded from the idea the stakeholders have conflicting ideas on how the EV domain or charging infrastructure in specific should be developed in the future. No research has been found on shared perspectives across stakeholders. The research question in this paper therefore is:

> RQ: Which shared perspectives across stakeholders on future electric vehicle charging infrastructure developments can be found and how are these perspectives distributed across these stakeholders?

This paper proceeds from the idea that despite the different interests of the stakeholders, this does not lead to an equal number of different perspectives on how charging infrastructure should be developed. The expectation is that there a few major topics that stakeholder's debate about and there is consensus on various topics. Revealing these points of disagreement and agreement is crucial for the effective roll-out of future charging infrastructure as it allows policy makers to more specifically address the topics of debate instead of trying to meet all interests of stakeholders.

As such, the paper has two contributions, namely a methodological one (showing how Q-methodology may be employed to reveal future perspectives among stakeholders) and a substantive one (showing which particular points of consensus and dissensus exist among stakeholders regarding the future of electric charging). Although the first contribution might seem to be a contribution of the methodology as such, the idea of applying Q-methodology in future studies is still novel and has only been applied in a limited number of cases especially in the technological domain. This paper aims to further improve on its understanding and especially shed light on how perspectives can be shared across stakeholders which at first sight have opposing interests. While the second contribution may seem specific to the Netherlands, it should be noted that Dutch situation resembles one of the front-runners on public charging infrastructure. As such, it is likely that the substantive topics of conflict identified in this study (regarding the role of smart charging, fast charging and the level of government intervention) also arise in many other countries across Europe and outside. Indeed, the Dutch situation can be regarded as an exemplary case for the conflicts that will likely arise in dense urban areas that exist across the world.

To this end the discourses on charging infrastructure development in the Netherlands are characterized. The Netherlands is chosen as a case study because it is a frontrunner in public charging station deployment with over 36.000 public charging stations available by the end of 2018, as such having one of the highest density of publicly available charging infrastructure in the world (European Alternative Fuel Observatory, 2018). So, we expect that points of disagreement and agreement have crystallised to a greater extent than in other countries. The Dutch case is specific, however, in the sense that it is characterised by a high number of level 2 charging stations on the street, which are mainly used for home charging (70% of the Dutch rely on on-street parking).

## 3. Charging infrastructure discourse

### 3.1. The EV charging ecosystem

The EV charging ecosystem has four major components in which the stakeholders operate (Fig. 1). These are the policy side, research and consultancy, the energy market and the charging infrastructure market itself. Within the charging infrastructure market,

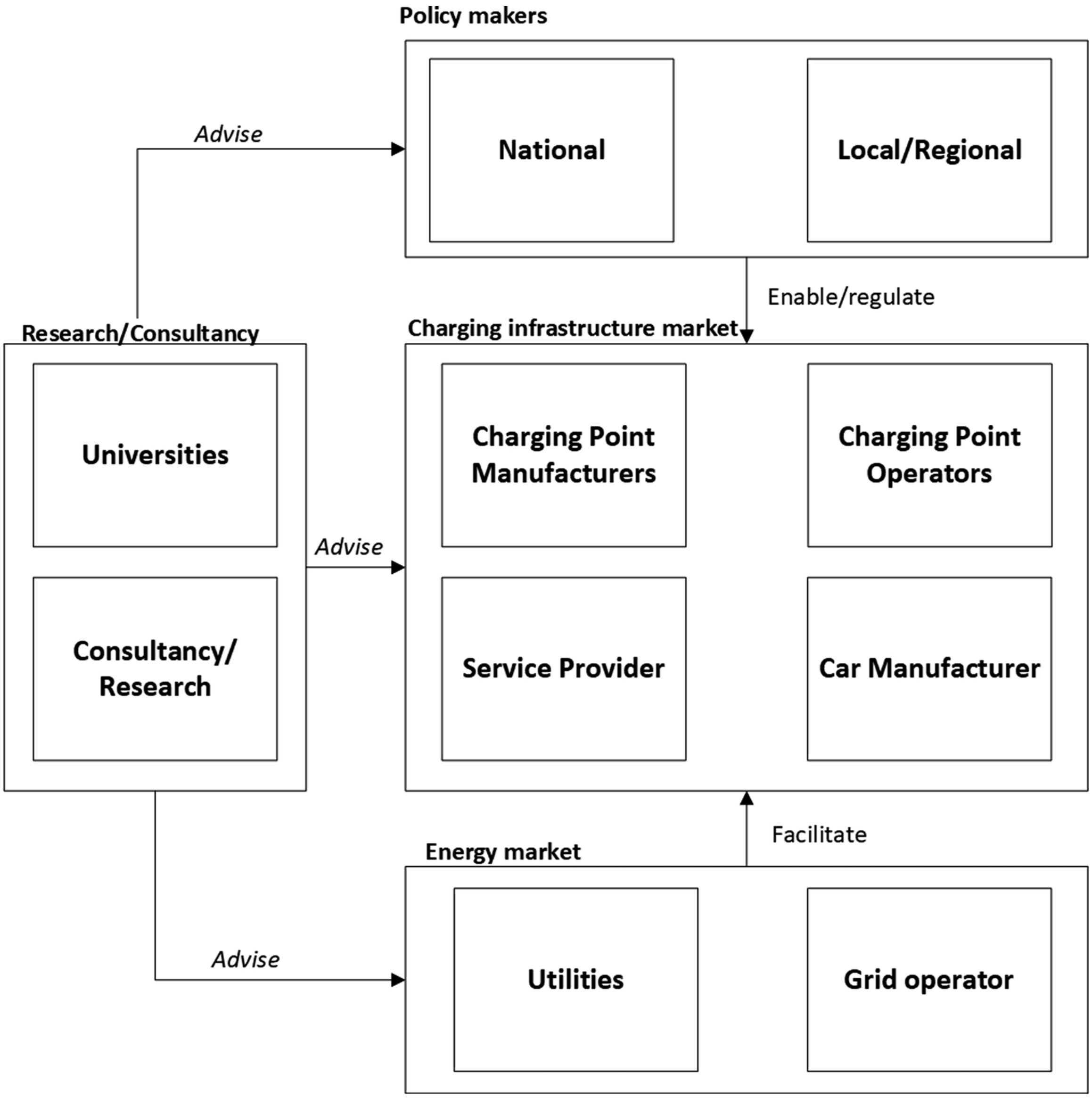


**Fig. 1.** The electric vehicle charging infrastructure market.

four major players are active. Charging point operators are those that sell the actual energy to the EV driver and are responsible for the day-to-day operation of charging stations. These charging stations are provided by the manufacturers of these stations. EV drivers can use these charging stations with the use of service providers, which provide access to the large number of different charging point operator and they provide billing services to the drivers. Car manufacturers develop their charging network of cooperate with charging point operators to ensure that the charging infrastructure is sufficient for the driver.

The electricity needed to charge the vehicle are supplied by the utilities and grid operators active in the energy market. Utilities are also active as charging point operators and service providers and therefore can assume multiple roles in the discourse. Grid operators facilitate by providing a sufficient network but also try to provide overload of the grid as this would lead to costly reinforcements. Policy makers enable the market players to act by both providing funds either through direct subsidies or procurement processes. On the other side policy makers are also expected to regulate the market to ensure a fair playing field for all actors and to protect the EV driver from possible abuse from the market players. All actors in the field are advised by research from universities, research institutes and consultancy agencies.

### 3.2. Discourse

In Q-methodology the concourse, all statements of opinion on a certain topic, is used to determine the statements for sorting exercise. These statements are part of the discourse on the topic. To create an understanding on the topic at hand this section describes the relevant discourse. The charging infrastructure discourse is described in this section and is divided into five main topics. These five topics were derived from analysing sources such as policy documents and white papers on the matter. The topics and the corresponding discourse is described. A glossary of charging infrastructure terms can be found in Appendix A.

#### 3.2.1. Charging technologies

The charging of an EV can be done in various ways. Most commonly the car is parked and connected through a cable to a charging station which can supply various types of power. Usually, in the public domain, this is either level 2 or fast charging. The car can also be charged while driving (so-called dynamic charging), for example, through overhead lines providing the charging power. Both the static and dynamic power can also be supplied wirelessly through a magnetic field that transfers the power to the vehicle. The other option is to completely switch the battery for a full one at a special designed station. The battery can then be charged at another time.

Due to the roll-out strategies of local and national governments, the focus for many policy makers has been on level 2 charging technologies at places were cars park with a back-up of fast charging stations alongside highways. These charging technologies are the mature technologies that are readily available. The charging speeds of fast charging have an increased from 50 kW in the early 2010’s to up to 350 kW in the more recent years. Such speeds enable refilling in up to 10 minutes. Level 2 wireless charging is still in an experimental phase. Dynamic (wireless) charging is hardly considered in the Netherlands and certainly not to the extent as in Sweden or Japan (Connolly, 2017). In earlier years battery swapping was considered as interesting but after the demise of the technology in the early 2010’s (Noel & Sovacool, 2016) it has not been considered. Recent re-emergence of the technology is China (Xu, Yao, & Zeng, 2015) has sparked interest but has not resulted in specific plans elsewhere. There have been only a few hydrogen electric cars on the road (Netherlands Enterprise Agency, 2018) mainly due to the lack of models on the market but also due to the low number of refuelling stations. The technology which showed great promise in the early 2000’s never took off. Interest however remains, especially among current producers of hydrogen. The debate in the Netherlands has mainly revolved around the question on whether to go on with a high number of level 2 chargers or a lower number of fast chargers (Lubbers, 2015).

#### 3.2.2. Local and national policy

Local and national government in the Netherlands have been pro-active in facilitating the roll-out of charging infrastructure. After an initial roll-out by joined distribution system operators (Elaad) which started in 2009, larger municipalities and regions continued a demand-driven roll-out. This roll-out strategy implies that charging infrastructure was mainly placed to facilitate those drivers that rely on on-street parking and charging (Helmus, Spoelstra, Refa, Lees, & Van den Hoed, 2018). These on-street level 2 charging stations were co-funded by national and local governments through so-called Greendeals (Formula E-Team, 2016). Local governments have invested in charging infrastructure in the past years mainly by tendering the deployment of charging infrastructure providing a concession for a single party to exploit the charging stations. Some municipalities however opted for an open market model in which several charging point operators are allowed to compete on placing charging stations. The exploitation of fast charging stations alongside the highways was not subsidized and taken on by several market players. The different policy approaches to the market have sparked debate on to which extent local and national policy makers should intervene and subsidize the market for both level 2 and fast charging.

#### 3.2.3. Integration with energy systems

As EVs draw a lot of power from the electricity grid, questions have arisen about the robustness of the electricity grid. As the adoption of EVs is likely to coincide with more renewable and intermittent energy, attempts are made to match supply and demand of electricity. The integration of electric vehicles in the grid has received a lot attention in the Netherlands. Early roll-out of charging stations was therefore facilitated by the foundation ELaad, formed by the Dutch grid operators. This allows them to monitor and experiment with concepts such as smart charging (García-villalobos, Zamora, Martín, Asensio, & Aperribay, 2014; Tamis, van den Hoed, & Thorsdottir, 2017) and vehicle-2-grid (Kempton, Perez, & Petit, 2014). These technologies could reduce peak load on the electricity grid. The pro-active role of ELaad has resulted in strong discourse that emphasizes smart charging technologies as a potential way to reduce grid investments and to use renewable energy more efficiently. However, not all actors agree with the pro-active role of grid operators in facilitating charging infrastructure. They would like to see a less prominent role for grid operators resulting in a (legally bound) strict division of the utilities and grid operators. Furthermore the debate concentrates on to which extent smart charging should be implemented and how users should be involved. Should the user be allowed to override a lower charging power when necessary or should the user have to agree to lower the power beforehand? Meanwhile, other technologies such as centralised storage are also competing to solve the same issue of intermittency. Yet, there is no consensus on how such technologies should be designed. Stakeholders in these industries find that charging infrastructure for electric vehicles should fit within the transition to sustainable energy.

#### 3.2.4. Market formations

The market for EV charging is still developing and as such standards for the charging plug and payment have not crystallised. As the potential market is very large, many technologies are still competing to become dominant in the market. There are therefore many ideas around of how the market should be organised and which parties should play which role. The access to public charging station and the fast charging cable standard are the two most prominent examples.

Access to charging stations in the Netherlands has from the early start been regulated by mobility service providers. They grant the driver access to the charging station with an RFID-tag or card. Stakeholder in the Netherlands has always been keen on the fact that charging stations can be accessed with any RFID-tag. Through the development of the Open Charge Point Interface Protocol (OCPI), the Netherlands has been trying to promote this throughout Europe. Service providers however, at the moment do not provide ad-hoc access to charging stations, something prescribed by the European commission (European Commission, 2013). Other network operators are therefore developing a more expensive credit and debit card access.

Another issue with interoperability among charging stations has been through fast-charging cable standards. Four major charging standards have been developed with the European dominated Combined Charging standard (CCS), the Japanese ChaDeMo standard, the Chinese GB-T standard and a separate standard for Tesla. Many of the fast charging stations provide all the major standards for cars that are on the market. However, some automakers push for separate charging networks such as the Tesla supercharger network, the European IONITY network which only provides CCS and recent announcements by for example Jaguar to provide a dedicated network for their cars (Hawkins, 2018).

#### *3.2.5. Integration of charging stations in public space and parking*

The final important issue discussed is the integration of charging stations in public space and parking policies. On-street charging also requires the reservation of parking spots alongside charging stations. The reservation of a parking spot can be a sensitive issue in the early phase of adoption especially when parking pressure in an area is high. The idea of a private parking spot for the EV driver can cause serious complaints and lawsuits by non-EV drivers (Wolbertus & van den Hoed, 2017). Meanwhile, cities try to reduce the number of parking spots on street or move them underground. Current roll-out practices are very often not aligned with these parking policies. Public space planners also fear a growing number of charging stations in the street reducing the accessibility of sidewalks. These discussions are often linked the choice of charging technology. Wireless charging reduces the need of additional street furniture. Others propose more fast charging stations in the city which can handle more vehicles per charging station, especially if charging speeds increase.

## 4. Methodology

To reveal stakeholders' perspective on the future of EV charging in the Netherlands, this paper makes use of the Q-methodology (Brown, 1980; Stephenson, 1935). Q-methodology is small-sample method which is quantitative in nature (i.e. based on factor analysis), but, at the same time, based on qualitative research principles, most notably, the principle of contextuality (Brown, 1980). As mentioned above, it is ideally suited to reveal shared viewpoints on a particular subject. To elicit these viewpoints respondents are asked to rank-order a set of statements of opinion regarding the subject under investigation. By rank-ordering (in Q-method parlance: Q-sorting) these statements, as opposed to rating them individually as is done in a typical survey, subjects are required to evaluate each statement vis-à-vis the others. Hence, respondents do not only need to consider whether they agree or disagree with a particular statement, but also the extent to which the statement is actually important to their way of thinking. In this process, a person's holistic viewpoint on the subject matter is revealed. By subjecting the resulting Q-sorts (viewpoints) to a (by-person) factor analysis clusters of similar Q-sort may be identified, which then reflect *shared* viewpoints on the subject matter.

Q-methodology proceeds in five steps (Brown, 1980; Exel & Graaf, 2005). The first step is to determine the concourse, which can be thought of as all statements of opinion regarding a particular subject (Brown; 1980). Hence, it reflects all the ideas, arguments, beliefs, etc. that are communicated (in text or verbally) about a particular subject. Since the concourse often contains too many statements to handle in the Q-sorting task, the next step is to make a representative selection, called the Q-sample. Then, participants are selected for the Q-sorting task, the so-called P-sample. This selection is not random (as in a typical survey) but strategic, ideally the P-sample (as a whole) should represent all existing perspectives in the field. In the fourth step the Q-sample is included in a rank-ordering task, which is administrated to the set of strategically selected participants. The statements do not have to be completely ordered, but a partial ordering, using a forced distribution (e.g. ranging from -5 to +5), suffices (Brown, 1980). With respect to the condition of instruction, participants are usually asked to indicate their level of (dis)agreement with each statement. The resulting rank-orderings are referred to as Q-sorts and reflect the various viewpoints regarding the subject under study. In the fifth step, common perspectives are revealed by subjecting the Q-sorts to a (by-person) factor analysis (Brown, 1980). By applying the factor analysis participants with similar Q-sorts (perspectives) are clustered together (i.e. they will load on the same factor). Next, a rotation method can be applied to achieve simple structure. Based on the resulting factor loading matrix, common viewpoints can be revealed by computing the (standardized) factor scores, which can then be translated to the original forced distribution that was used in the Q-sorting task.

### *4.1. Defining the concourse and Q-sample (Step 1 and 2)*

To determine the concourse relevant statements are sampled from different sources to capture all relevant ideas, arguments and beliefs regarding (the future of) electric vehicle charging in the Netherlands. These sources include scientific papers, policy documents, white papers, reports and magazines on charging infrastructure. The list used for this research can be found in Appendix B. A longlist of over 200 statements was gathered from these sources. From this longlist a subset of 44 statements is selected which is representative of the entire concourse to be used in the Q-sorting task (the Q-sample). This is line with the common size of such a set between 40 to 50 statements (Exel & Graaf, 2005). To select a representative Q-sample from the concourse we use a structure to sort the statements. The statements are first inductively categorized into five themes along the lines that we found in the discourse, namely (1) Local and national policy, (2) Charging technologies, (3) Integration with energy systems, (4) Market formations and (5) Integration of charging stations in public space and parking. Next, within each theme, statements were selected that adequately captured the variety of opinions present within that particular theme. In line with common practice in Q-methodology, the selection of statements is not driven by the number of times certain statements are voiced but is focused on ensuring that the variety of statements in the Q-sample is representative of the entire concourse. The statements should as much differ from one another as possible (Brown, 1980). The selection to drop statements was thus mainly focussed on preventing similarity across statements. This was done in iterative process among researchers. An initial test set was distributed among three scholars working in the field to see if important issues were missing.

### *4.2. Respondents and data gathering (Step 3 & 4)*

The aim of this study is to identify different perspectives across the stakeholders in the field (Risdon et al., 2003). Therefore, a large number of different stakeholders as identified by Bakker, Maat & Van Wee (2014) and Wirges (2016) are approached. On top of that, several scholars and consultancy firms are contacted. In practice they often inform and advice policy makers on policies making their opinions relevant in the debate, despite having no specific stake in the direction taken. Their opinions based on research and experience are however relevant as they consult policy makers. Consumers are represented by special consumer interest groups in the field of (electric) mobility (specified as stakeholder category "other"). In total 108 different stakeholders across 9 different industries are asked to participate in the Q-sorting task. The contacted participants were not randomly selected but were known to the researchers to have varying opinions on charging infrastructure developments. This variety was known due to previous voiced opinions in the studied sources or through personal contacts. This is important in Q-methodology as it is important to have a "*balanced inclusion of the variety of perspectives that exists within the stakeholder population*" (Cuppen, 2012).

Participants contact details were acquired through the personal contacts of the authors of this paper and approached via email with a request to fill out an online version of the Q-sorting task using the FlashQ software (Hackert & Braehler, 2007). Participants were first asked in June 2018 with a one-time reminder two weeks after the initial contact. In total 39 respondents completed the questionnaire. Table 1 presents an overview of the number of stakeholders that replied per stakeholder category.

In the survey participants were first asked to sort the statements into three categories, namely agree, neutral or disagree to get familiar with the statements and to get a sense of where they want to place the statements in the distribution After this initial task the respondents had to place the same statements in a forced distribution (see Fig. 2) but were free to deviate from their previous choice. The strength of using Q-methodology is that this makes the respondents evaluate the statements in relation to each other. In this way respondents are making, at least implicitly, (½ * 44 * (44-1) 946 judgements (in the case of 44 statements as in this study), instead of making 44 single judgements as in a standard questionnaire. Participants took on average 11 minutes and 9 seconds to complete the sorting exercise.

After the sorting task participants had the opportunity to comment on their highest and lowest ranked statements to provide further explanation and a general remark field to express any other concerns. Responses were treated anonymously but respondents did have the opportunity to declare their field of work. No additional personal information was asked as it was not deemed necessary for the goal of this research. Only one person did not declare their field of work but was included in the results under the category other/not declared

### *4.3. Analysis (Step 5)*

To reveal shared perspectives among the experts, we use a principal component analysis (PCA) on the transposed data matrix. This means that respondents' Q-sorts are treated as 'variables' and the 44 statements as 'cases'. Hence, applied in this fashion, the PCA reveals clusters of similarly ordered Q-sorts, which reflect the *shared* viewpoints on the topic. Solutions with different numbers of factors extracted (1-7) were tested. The different solutions (see Table 2) were compared on three criteria, namely the variance explained, the Eigenvalue and the number of factors that did not reach the minimum number of 3 respondents loading on it, a criterion identified by Brown (1980). The 4 and 5-factor solution were identified as candidates as they explained the most variance while still having 3 respondents loading on each factor. The 4-factor solution was considered optimal for two reasons. Firstly, after the 4-factor solution, the decrease in Eigenvalue (and increase in variance explained) was relatively small, indicating that the 4-factor

**Table 1**
Response rate per stakeholder category

| Stakeholder | Stakeholders contacted | Participants | Response rate |
|---|---|---|---|
| **Government (National)** | 5 | 2 | 40% |
| **Government (Local/regional)** | 18 | 7 | 39% |
| **Service Provider** | 12 | 3 | 25% |
| **Grid operator** | 9 | 6 | 67% |
| **Charging point operator** | 16 | 5 | 31% |
| **Car manufacturer** | 7 | 2 | 29% |
| **Research/Education** | 10 | 5 | 50% |
| **Consultancy** | 12 | 7 | 58% |
| **Charging point manufacturer** | 5 | 1 | 20% |
| **Not specified/Other** | 13 | 1 | 8% |
| **Total** | **108** | **39** | **36%** |

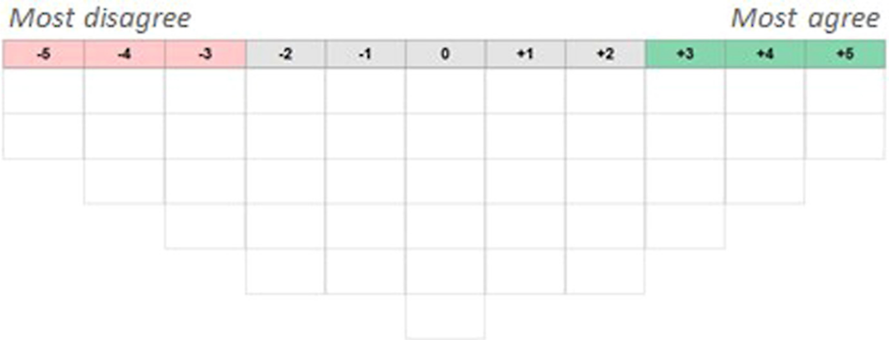


**Fig. 2.** Distribution along which Q-statements have to be sorted.

**Table 2**
Characteristics of results of VARIMAX rotation.

| Number of factors | Variance explained | Eigenvalue | Number of factors without minimum of 3 respondents |
|---|---|---|---|
| 1 | 36% | 14.15 | 0 |
| 2 | 45% | 3.55 | 0 |
| 3 | 52% | 2.72 | 0 |
| 4 | 58% | 2.08 | 0 |
| 5 | 62% | 1.80 | 0 |
| 6 | 66% | 1.59 | 1 |
| 7 | 70% | 1.41 | 3 |

solution was able to parsimoniously capture most of the shared variance. And secondly, adding a fifth factor provided little new information as in this solution the first and fourth factor had a high correlation between the factor scores (r = 0.69). In the 4-factor solution all correlations between factor scores were below 0.5.

To identify factor exemplars (i.e. respondents loading only on a single factor) the rotated factor matrix was further examined (varimax rotation was used to this end). Only respondents that loaded on a single factor were identified as factor exemplars. Using a significance level of 1% level the threshold for a significant factor loading is 0.37 ($2.48*1/\sqrt{N} = 0.37$, with N = 44). With this threshold 16 respondents loaded on two factors. Using Watts & Stenners' (2005) approach, this threshold was raised to have a minimum number of respondents loading either on none or two or more factors. Using 0.45 as a cut-off point provides a minimum of two respondents loading on two factors and four respondents on zero factors. An overview of the different cut-off points and the number of respondents loading on none or two factors is given in Appendix C. Using only the Q-sorts of the factor exemplars, an idealized factor array is produced (for each factor) which is shown in Table 3.

## 5. Results

The factor analysis reveals four different perspectives. These are labelled as (A) EV Drivers first by policy, (B) an open, smart and fast charging network, (C) smart charging priority and (D) wired electric only and open markets. Below, the four perspectives are interpreted in detail. The distinguishing statements (those with statistically significant different factor loadings compared to other factor) per perspective are used to this end. After the perspectives are examined, the statements on which there is a consensus are discussed. Finally, it is explored how the perspectives can be related to the different stakeholder groups. Statements are referred to by their number and the score in the given in the specific viewpoint (e.g. statement 24: score 4 is shown as 24:4). Statements in green are the most in agreement with and red in disagreement.

## 6. Perspectives

### 6.1. Perspective A: EV drivers first by policy

This perspective is shared by 15 respondents and explains 23% of the variance. This perspective puts the EV driver at the centre point of development of charging infrastructure. Integration of charging points into the electricity network should be sub-ordinate to this goal (23:4). Moreover in this perspective it is considered important that EV drivers should be well aware of what they are paying for charging (32:4). This perspective sees a mix of private, semi-public and public charging points as the way forward (13:5). Fast charging is important to tackle range anxiety (12:3) but is not expected to become the dominant charging mode (18:-5 & 40:-4).

Respondents sharing this perspective see a significant role for (local) policy makers in designing the charging infrastructure for the future. The respondents believe local policy makers should have a pro-active role in the roll-out of charging infrastructure (4:5 & 5:3). Local policy measures such as integration in the parking policy are not considered an issue (44: -5). Moreover, respondents feel

**Table 3**
Statements and factor array for each perspective

| No. | Statement | A | B | C | D |
|---|---|---|---|---|---|
| | ***Local and national Policy*** | | | | |
| 1 | The Netherlands is a worldwide leader in charging infrastructure due to the policy of the department of economic affairs | 0 | −1 | −2 | 0 |
| 2 | The government should only play a role in setting a framework for public charging infrastructure | −2 | 0 | −2 | −1 |
| 3 | The government should keep supporting public charging infrastructure financially | −1 | −4 | 2 | 1 |
| 4 | Municipalities should implement a pro-active instead of reactive policy to cope with the growth of public charging infrastructure | 5 | 1 | −1 | 4 |
| 5 | Local government should play a role in charging infrastructure rollout, because (public space) issues are mainly local | 3 | 1 | −1 | 4 |
| 6 | Politicians should promote electric mobility because Dutch industry can profit from this | 1 | −1 | 0 | 1 |
| 7 | Politicians should promote electric mobility to achieve sustainability goals | 3 | 2 | 0 | 3 |
| 8 | The current government is doing too little to realise enough charging stations by 2030 | −1 | −3 | 2 | 1 |
| 9 | Subsidizing public charging stations disrupts the market | −2 | −2 | −3 | −2 |
| 10 | The difference in available charging infrastructure between rural and urban areas is too big. Investments in rural areas are needed. | 1 | −2 | 2 | 0 |
| 11 | The zero-regret policy of the department of economic affairs, which keeps all options regarding charging technologies, has proven to be effective. | 0 | −2 | 0 | −1 |
| | ***Charging Technologies*** | | | | |
| 12 | Public fast charging stations are crucial to promote the sales of electric vehicles | 3 | −3 | 1 | 2 |
| 13 | The combination of a base network of charging stations at destinations (home/work) and a base network of fast charging stations is crucial | 5 | 3 | 0 | 5 |
| 14 | Fast charging will be become similar to refuelling | 0 | 2 | −3 | −2 |
| 15 | The demand for charging stations at semi-public and business parking locations shall increase faster than the demand for public charging stations | 0 | −3 | 3 | 2 |
| 16 | In 2030 a part of the fleet will be electric, but other (clean) technologies shall also play a role | 1 | 1 | 1 | −3 |
| 17 | Charging electric cars with a plug is an intermediate step to wireless charging | −2 | −1 | 1 | −3 |
| 18 | It is desirable that we only use fast charging stations in 10 years' time | −5 | 0 | −3 | −4 |
| 19 | Battery swapping is good alternative for fast charging | −4 | 1 | 1 | −4 |
| | ***Integration with Energy systems*** | | | | |
| 20 | Smart charging shall become an essential factor in a stable electricity grid | 2 | 5 | 5 | 5 |
| 21 | The electricity grid is not capable of handling the current increase of charging stations | 1 | 4 | 3 | 0 |
| 22 | With a growing number of EVs, investments in grid reinforcements can be prevented by using EV batteries for energy storage | 0 | 3 | 4 | 3 |
| 23 | The primary goal of a charging network should be to accommodate the EV driver. Integration into the grid is subordinate | 4 | −5 | −2 | −4 |
| 24 | Dynamic pricing should be allowed to incentivize users to charge at more – for the electricity grid- favourable times | 2 | 0 | 1 | 3 |
| 25 | Smart charging won't work as users find it too much of a hassle | −3 | −4 | −4 | −5 |
| 26 | Vehicle-2-grid is increasingly important for balancing the grid given the increase in renewable energy | −2 | 2 | 4 | −2 |
| 27 | Using only fast charging, we are not able to optimally make use of renewable energy | 2 | −2 | 5 | 1 |
| 28 | Smart charging is only relevant within the context of capacity management of a grid connection for a single location | −2 | −2 | −5 | −5 |
| | ***Market formations*** | | | | |
| 29 | It is essential that interoperability of charging cards is guaranteed at European level | 4 | 5 | 4 | 4 |
| 30 | It is up to the market to create an appropriate mix (private, semi-public, public and fast) of charging opportunities | −1 | 0 | −2 | 2 |
| 31 | Grid operators should focus on their primary task and should be not be actively involved in the rollout of charging infrastructure | 0 | −1 | −4 | −2 |
| 32 | At all times It should be clear what the EV driver is paying for the electricity charged | 4 | 3 | −1 | 3 |
| 33 | Charging stations shall be soon profitable | 1 | 2 | 2 | 1 |
| 34 | Charging infrastructure for smaller municipalities should be tendered at a regional level, as economies of scale will result in a positive business case | 2 | −1 | 3 | 0 |
| 35 | Government should ensure that all charging stations are accessible independent of type of car or brand | 2 | 4 | 3 | −3 |
| 36 | For a successful transition to electric mobility it is necessary that car manufacturers are actively involved with deploying charging infrastructure | −3 | −5 | −1 | 1 |
| 37 | The deployment of a dedicated charging infrastructure for only one brand delays the adoption of electric vehicles | −1 | 3 | 0 | −1 |
| 38 | Municipalities should not give long term concessions for charging stations on the street but leave it to the market | −4 | 0 | −3 | 2 |
| 39 | Fast charging stations should be provided a level playing field with gasoline stations along the highway | 3 | 1 | −2 | 2 |
| | ***Integration in public space and parking*** | | | | |
| 40 | If you can charge your car within 15 minutes, it is not necessary to furnish entire inner cities and residential areas with charging stations | −4 | 4 | −5 | 0 |
| 41 | Instead of spreading individual charging stations across a neighbourhood, charging stations should be clustered at special parking areas | −3 | −4 | 2 | 0 |
| 42 | Public charging stations should be integrated in current street furniture such as lamp posts or the side walk | −1 | 0 | 0 | −1 |
| 43 | Charging stations are obstructive objects in the public space | −3 | 2 | −4 | −3 |
| 44 | Charging stations are impossible to integrate into current parking policies | −5 | −3 | −1 | −2 |

that municipalities should keep in control by regulating the market with long term concessions (38:-4). It is therefore no surprise that the majority of local policy makers were found to load on this factor. This perspective resembles current practices especially among the larger municipalities in the Netherlands. Local governments are in control and try to balance the interests of different partners involved. However, their main focus is on facilitating the EV driver. A larger number of electric vehicles on the road will improve air quality within the cities.

### 6.2. Perspective B: An open, smart and fast charging network

Perspective B is shared by 6 respondents and explains 13% of the variance. This perspective differs from the other perspectives by a positive attitude towards fast charging. It sees a fast charging network within the city as a replacement for a large number of level 2 charging stations (40:4 & 14:2). In contrast to possibility of fast charging as a replacement for level 2, respondents belief that fast charging stations are not crucial to the uptake of EVs (12:-3). It is possible that respondents see a large number of workplace charging stations (13:3) and electric vehicles with a larger range as the main solution. Respondents in this perspective do not pose that fast charging cannot be smart charging. For them integration with the electricity network is most vital (23:-5, 25:-4 & 20:5). A possible solution is to include battery storage alongside fast charging stations (22:3).

The respondents are also very keen on an open charging infrastructure network. They do not like the idea of automakers investing in their own dedicated networks (36:-5) as they think this will hamper the transition to electric mobility (37:3). They see a role for the government to make sure that all vehicles can charge at each of the charging stations (35:4). However, this is as far as government should go. Further financial investment should not be necessary (3:-4).

This perspective draws support in various fields (local government, service providers and grid operators) but is mainly supported by consultants. The idea behind this perspective mainly draws on more future technologies such as ultra-fast charging and foresees a more mature charging infrastructure market.

### 6.3. Perspective C: Smart charging priority

This perspective is shared by 5 respondents and explains 12% of the total variance. Respondents that share this perspective consider smart charging as an essential part of the EV charging system (20:5). Respondents feel that smart charging is a concept that can be applied in a broader sense and can not only be applied to capacity management at a certain location (28: -5). Respondents do not believe that the EV drivers will experience smart charging as a hassle (25:-4). Similar technologies such as Vehicle-2-grid (26:4) and battery storage (22:4) are seen as solutions to make optimal use of renewable energy whilst charging.

In contrast to perspective B, respondents in perspective C do not see fast charging as a solution for the future. Respondents do not believe that fast charging is a substitute for overnight charging (40: -5), which can also be attributed to the idea that they do not consider charging stations as obstacles in the public space (43: -4). One of the objections to fast charging is that it cannot optimally make use of renewable energy (27:5).

This perspective is mainly supported by charging point operators. None of the grid operators loaded on this factor. This may be explained by the observation that respondents with this perspective object to the idea that grid operators should have a passive role in creating a future charging infrastructure (31: -4).

### 6.4. Perspective D: Wired electric only and open markets

This perspective is shared by 7 respondents and explains 9% of the variance. This perspective emphasises that the current wired charging technology will remain dominant and contain a mix of home, destination and fast charging (13:5). Respondents dislike the idea of wireless charging (16: -3) or battery swapping (19: -4). They also do not consider the idea of other alternative fuels in the mix in the future (17: -3). This focus on battery electric cars with wired charging is in line with their idea about the importance of smart charging (20:5, 25: -5, 28: -5) which is more suitable for a wired charging solution.

Respondents in this perspective have a very specific view of the role of government. They expect a pro-active role (4:4) of local governments (5:4). However they do not want governments to take full control. It should be up to the market to provide the necessary mix of charging infrastructure (30:2). This open market idea is also supported by the fact that they are the only group of respondents that does not see a role for the government in ensuring a single charging standard (35:-3).

The perspective is supported by a large variety of stakeholders. The perspective is specific as it is the only one that has a strong opinion about the technological developments, other perspectives did not consider these as the most important points. The role of government is the market is also very specific. It should be pro-active but not intervene with the ideas of market parties.

### 6.5. Consensus

The idea all perspectives highly agreed upon was that charging stations across Europe should be accessible with all charging cards (statement 29). This is not strange as many stakeholders in the Netherlands have been active with promoting this idea. Also, in practice this has already been implemented. The perspectives are in agreement that they are neutral about the success of the charging infrastructure market in the Netherlands as a result of national government policy (statement 1). They are also all slightly optimistic about the business case of public charging stations (statement 33). The early incentives to make this business case possible also did not create imbalances in the market. Such interventions were thus allowed (statement 9). In general, most of the topics the respondents agreed upon were did not have a high score (with the exception of statement 1).

Also, across several, but not all perspectives, there is consensus on distinct topics. A visual overview of how the different perspectives and their most relevant, in terms of factor scores, (rephrased) statements are aligned is shown in Fig. 3. Most perspectives are aligned in that smart charging is essential for a stable electricity grid (statement 20). As well, respondents that share perspectives A and D agree that a combination of different charging modes (statement 13) is the way forward and this roll-out should be developed with pro-active local policy (statement 40). Although participants that share perspective B see on a dominant role for fast charging

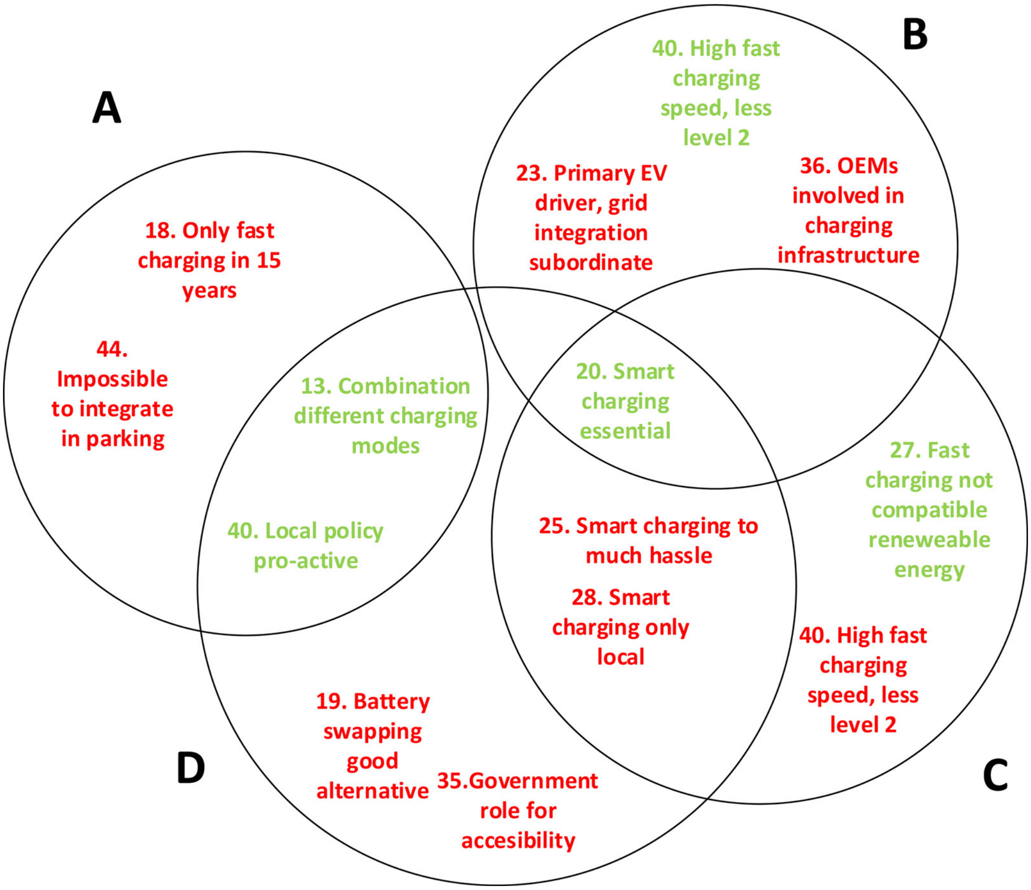


**Fig. 3.** Visual overview of alignment of perspectives. Green represents statements in agreement with, red in disagreement.

they agree with participants in perspective C that fast charging is not so much compatible with renewable energy.

### 6.6. *Conflict*

The factor analysis also revealed which statements and topics caused the most conflict among the four different perspectives. The factor scores with the highest contrast were selected and analysed. Three major topics showed the largest disagreement among the respondents which are the role of fast charging in the future infrastructure, the extent in which smart charging is a priority and how active governments should intervene in rolling out charging infrastructure. An overview of how the different visions see these topics is given in Table 4 in which '+' indicates agreement, '- 'disagreement and '0' a neutral standpoint. These scores are based on the factor array.

The first main conflict is between those that see a major role for fast charging and those that do not. There are many different perspectives on the role of fast charging in the future infrastructure. While respondents in perspective B see a major role for fast charging, respondents in perspective C rather have as little as fast charging as possible. As respondent 31 (CPO-statement 18) puts it: "*The fast charging network is necessary for the transition to electric mobility, but it should be abolished on the long term.*" Those that disagree mention consumer comfort and grid integration as major hurdles in switching to fast charging as dominant charging mode. Those in favour mainly mention the business case and public space issues as motivation to switch to fast charging. "*The costs per kWh (for AC charging) are too high. Faster charging = cheaper charging*" (11-CPO-Statement 33). The statements provide evidence that those in

**Table 4**
Overview of points of conflict

| Issue | A: EV drivers first by policy | B: An open, smart and fast charging network | C: Smart charging priority | D: Wired electric only and open markets |
|---|---|---|---|---|
| **Large role for fast charging** | 0 | + | - | 0 |
| **Smart charging as priority** | 0 | + | + | + |
| **High engagement from governments** | + | - | 0 | 0 |

favour and those not, argue about different aspects of the technology. Respondents in perspective A and D see the importance of fast charging but see it as a part of an integral network of charging infrastructure which also includes home and destination charging. Respondent 37 (Grid operator – Statement 13) states: "*As EV-driver you need both: Cheap home or workplace charging and premium ultra-fast charging along the way for long drives*".

The second main area of conflict is the priority that should be given to smart charging when rolling-out charging infrastructure. All the four perspectives agree that smart charging technology is essential for managing future grid overloads due to increased electricity demand by EVs (statement 20). All the perspectives agree that smart charging should not create too much hassle for the EV driver (statement 25). Yet there is significant disagreement regarding the extent smart charging should be prominent in the roll-out of charging infrastructure. Respondents in perspective A agree that the EV driver should be put first, especially during the early phase of EV adoption. Respondent 13 (Local government- statement 23) states: *"It depends to a great extent on the phase of the roll-out, but the EV-driver should always be put first. Right now, everyone should be able to rely 100% on the charging station it uses. This is of the utmost importance, all other things are subordinate. Even in the future, the wishes of the EV driver are more important than the wishes of the grid operator."* The debate specifies on the idea that charging stations should be limited in their charging speed (during specific times) or that the EV-driver should always be allowed to charge at maximum speed to facilitate an optimal experience. The underlying generic choice is between a system with smart charging by design or a user-controlled version.

The last area that came out as a prevalent issue of dispute is the role of governments in facilitating charging infrastructure. Especially those in perspective A and B are in in disagreement. Respondents in perspective A see a large role for local government. They do not see that the market can solve the social issues at hand. "*(…) The market aims for the largest profit on the short term. (….) We should steer towards the bigger picture – market parties cannot do so, the government will have to*. (Respondent 35 – unknown – statement 30). Respondents in other perspectives are more careful about government intervention. Especially at the national level and for fast charging stations they do not see the value of government intervention other than in standard setting. Respondent 1 (unknown) comments on statement 30: "*The market is mature enough. There is no need for government involvement other than rule setting and public space planning.*" There is serious disagreement between the perspectives on how active governments should be in facilitating or operating charging infrastructure. Perspective A (active involvement) and perspective B (only standard setting) provide the complete opposites, while perspectives C and D see a more engagement in a transition period. According to respondents in these perspectives the role of the government should slowly be phased out. In general, local governments are considered needed for the considerable future in pro-active planning of spatial and parking issues regarding charging infrastructure.

### *6.7. Line of profession*

Stakeholder analysis would link the conflicts that have risen to the interests of the respondents' line of profession a person is affiliated to. To analyse how these perspectives and the conflicts are linked to the various lines of profession, the number of respondents per line of profession that loaded on each factor are compared. Table 5 shows the number of respondents that loaded each of the perspectives. Those in the 'none' column loaded either on none (below the 0.45 threshold) of the perspectives or on multiple perspectives.

The results show that most perspectives receive support from a large variety in stakeholder. In general there is no clear relationship between the line of profession the respondents worked in and on which perspective they loaded. Only the relatively high number of local government employees loading on perspective A is an exception to this. The high number of participants from local governments loading on perspective A can be explained by the large role of local governments are expected to take within the perspective. This perspective is also a representation of the current practice in which local policy makers are actively engaged.

The fact that there is not clear relationship between the line of profession the respondents worked in and on which perspective they loaded, supports the idea that perspectives are shared across different stakeholders and their ideas are mutually exclusive to the interests of the parties these persons work for. These findings support the idea from Cuppen (2012) that visions are shared across stakeholders. For policy makers this implies that a straightforward stakeholder analysis in which all interests are noted and compared

**Table 5**
Number of respondents per line of profession that loaded on a perspective

| | Perspective | | | | |
|---|---|---|---|---|---|
| Line of profession | A: EV drivers first by policy | B: An open, smart and fast charging network | C: Smart charging priority | D: Wired electric only and open markets | None |
| **Government (National)** | 1 | | | 1 | |
| **Government (Local/regional)** | 4 | 1 | | 2 | |
| **Service Provider** | | 1 | 1 | | 1 |
| **Grid operator** | 2 | 1 | | 1 | 2 |
| **Charging point operator** | 2 | | 3 | | |
| **Car manufacturer** | 2 | | | | |
| **Research/Education** | 2 | | | 1 | 2 |
| **Consultancy** | 2 | 3 | 1 | | 1 |
| **Charging point manufacturer** | | | | 1 | |
| **Not specified/Other** | | | | 1 | |

does not necessarily imply that all visions are correctly represented.

## 7. Conclusions

This study has presented a systematic overview of stakeholders' perspectives on future electric vehicle infrastructure development and has stipulated how these perspectives are aligned or are in disagreement. Q-methodology was used to identify different perspectives on the development of electric vehicle charging infrastructure. 39 respondents from nine different industries related to electric vehicle charging infrastructure participated in the Q-experiment. Factor analysis revealed four different perspectives on how charging infrastructure should be developed in the future. These perspectives are (A) EV drivers first by policy, (B) An open, smart and fast charging network, (C) Smart charging priority and (D) Wired electric only and open markets. These perspectives are shared across the different stakeholders with no clear relationship between the perspectives and respondents' affiliation to various stakeholder groups, with the exception of local policy makers.

The analysis of these perspectives showed that three dominant issues divide the four perspectives. These are (i) the role of fast charging, (ii) the degree smart charging should be the standard option and (iii) the role of government. Fast charging is either seen as a dominant option in the future or found to be in conflict with 'smart charging' strategies. The analysis also showed that those in favour and those that oppose fast charging as main charging mode, use very different arguments in the debate. Those that oppose refer to consumer comfort and grid integration as major hurdles for fast charging while those in favour find that the business case and public space are positive aspects of fast charging. The perspectives agreed that smart charging plays a vital role in the future to incorporate charging stations in the electricity grid but disagreed on the degree smart charging should be the standard in charging. The dilemma at hand is the choice between a system with smart charging by design (perspective B-C-D) or an user-controlled version (perspective A). On the role of the government multiple ideas existed, which varied in extent from nearly full government control to only standard setting practices. Perspectives took C & D contained a viewpoint with a government that should aid the transition but should slowly retreat as the market takes over.

The main policy implication from a methodological perspective is that Q-methodology aids policy makers to better able to steer on the most important issues of debate instead of trying to make policy for all aspects that are relevant for the stakeholders. Q-methodology has been proven as an approach to include stakeholders' perspectives into future studies. The analysis showed very specific differences in opinion that were not identified by other stakeholder studies such as the debate on whether smart charging should be standard or user controlled. The combination between the quantitative features of Q-methodology, which allowed to specify the most important areas of conflict, and using the comments from the respondents allows policy makers to focus on the important issues at hand both now and in the future. The finding that perspectives are not mutually exclusive with the stakeholders' interests, implies for policy makers that only looking at the stakeholders' interests is not the most effective way to manage stakeholders. Moreover, these results show that multiple perspectives can exist within and across stakeholders in the same line of profession. This implies for policy makers that working together with a few stakeholders from each line of profession will not cover all the perspectives that are available with the stakeholders in a specific line of profession. Research into shared perspectives and the most important sources of conflict can be far more effective. The Q-methodology approach entails that participants have to choose which topics they prioritize, revealing more common ideas about the future than a classical stakeholders analysis might provide. Inviting all stakeholders for participation sessions to express their interests, could leave points of conflict and consensus unexplored. This analysis shows that stakeholders could be interested to look beyond their current interests and have similar visions as other industries despite differences in the stakes they pursue, Q-methodology provides an effective way to do so.

For charging infrastructure as a case this study has provided several starting points to rethink their policies for the mid- and long-term. A major issue is the fast versus slow charging conflict, which needs more alignment across stakeholders as they focus on different arguments in the debate. For smart charging it was generally recognised that it has a prominent future, but the focus should go towards the extent the user should be involved. The role of policy makers themselves and the extent to which they should intervene needs more discussion in the future as the market is becoming more mature. These results show that policy should not only be aimed at technical and social processes, but that critical reflection of the policy makers' own role in transitions should remain at the forefront. In this way the Q-methodology approach has identified three major issues that should receive more attention as they are the most prominent across the different stakeholders.

In comparison to previous studies in this field this study has revealed new areas of conflict and confirmed others. This study confirmed the importance of smart charging technologies to able to facilitate with the current electricity network as also found by Bakker et al. (2014) and Wirges (2016). In addition to their analysis this research has found that the type of smart charging implementation, by design or user controlled, is the most relevant in this debate. Although the initial review of sources revealed integration into parking services as an important topic, in line with Bakker et al. (2014) it did not show as a top priority in one of the four perspectives. In addition to previous research, this study has found that the conflict between fast or level 2 charging as dominant charging mode is considered very important for policy makers in the coming years. Furthermore, the role of policy makers themselves is considered relevant. In stakeholder analysis the role of policy makers themselves is often overlooked and also how other stakeholders look at them. There are substantial differences in the degree that policy makers should be pro-active or only facilitating in this field.

A limitation of this study is the focus on the Dutch situation. It should be noted, however, that the Dutch situation resembles one of the front-runners on public charging infrastructure. As such, it is likely that the topics of conflict identified in this study will also arise in many other countries across Europe and outside. The Dutch situation can be regarded as an exemplary case for the conflicts that will likely arise in dense urban areas that exist across the world. Nevertheless, the Dutch case also has several peculiarities, such as the high number of on-street parking at home and the high involvement of local municipalities. A recommendation would be to repeat a similar experiment in comparable cities in Europe such as Oslo and Stockholm, but also to compare it other frontrunner areas such as California or several Chinese cities such as Shenzhen. Diverging ideas could exist depending on the local context. Another limitation is that this study provides a view on how these stakeholders view the future on this moment. The rapidly changing technology might change their opinions despite their expertise. A repetition of this study in a few years could provide more insights on how technology developments influence the perspectives. Despite these limitations this paper provides better insights on the perspectives shared among stakeholders on how to develop future charging infrastructure.

## Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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## Appendix A. Glossary

| Concept | Description |
|---|---|
| Level 2 charging | Charging by cable with powers from 3-11 kW mainly used for charging at home or the office while car is parked |
| Fast charging | Charging by cable with powers greater than 50 kW. |
| Dynamic charging | Charging while the car is driving |
| Wireless charging | Charging without cable, but static as dynamic |
| Battery swapping | Replacing the car battery with a fully charged new one |
| Tender | Formal offer to operate charging stations for a stated price |
| Open market model | Allow multiple operators to place charging stations and determine their own prices |
| Open Charge Point Interface protocol | Open protocol that supports connections between any Mobility service Provider and Charge Point operator |
| Charging Standard | - Fast charging standard mainly used by European OEMs |
| - Combined Charging standard | - Fast charging standard mainly used by Japanese OEMs |
| - ChaDeMo | - Fast charging standard mainly used by Chinese OEMs |
| - GB/T | - Fast charging standard used by Tesla Motors |
| - Tesla connector | |
| Private charging | Parking and charging at home on own driveway or garage |
| On-street/Curbside | Parking and charging on the street or parking ground that is public |
| Semi-public | Parking and charging that are available to those with access but are shared, e.g. parking garages, company specific parking |
| Smart Charging | Alternate charging speed in order to prevent electricity grid overload or optimise use of renewable energy |
| Vehicle-2-Grid | Alternate charging speed and option to provide power back into the grid from EV battery |
| Storage solutions | Energy storage not in vehicles to temporarily store excess electricity |

## Appendix B. List of sources used for statements

| ABB- White Paper: Towards Winning Business Models for the EV-Charging Industry. Who plays this game, what are the rules and why IT is one of the most important competences in this industry |
|---|
| ABB – White Paper: Electric Vehicle Charging Infrastructure An evaluator's guide to DC fast charging stations |
| AgentschapNL (2012) De stekker in elektrisch vervoer, maar hoe? |
| Allego – White Paper: Urban Mobility in de toekomst visie of realiteit? |
| Bakker, S., Maat, K., & van Wee, B. (2014). Stakeholders interests, expectations, and strategies regarding the development and implementation of electric vehicles: The case of the Netherlands. Transportation Research Part A: Policy and Practice, 66(1), 52–64. |
| CE Delft: Uitbreiding publieke laadinfrastructuur tot 2020 |
| Connolly, D. (2017). Economic viability of electric roads compared to oil and batteries for all forms of road transport. Energy Strategy Reviews, 18, 235–249. http://doi.org/10.1016/j.esr.2017.09.005 |
| Dutch Incert - Werkdocument: Verkenning Elektrisch rijden |
| Ecofys – Eindrapport Toekomstverkenning elektrisch vervoer |
| Fastned- The Fastned story |
| Hardman et al. (2017) Considerations for the development of plug-in electric |
| IAE – Global EV Outlook 2017 |
| IAE – Global EV Outlook 2018 |
| AIP E-mobility- Roadmap Elektrische Mobiliteit in Nederland, November 2017 |
| ICCT- White Paper: EMERGING BEST PRACTICES FORELECTRIC VEHICLE CHARGING INFRASTRUCTURE |

ABB- White Paper: Towards Winning Business Models for the EV-Charging Industry. Who plays this game, what are the rules and why IT is one of the most important competences in this industry

Master's thesis
Ministry of Economic affairs: Vision on the charging infrastructure for electric transport
Municipality of Rotterdam (2015): Kader voor de plaatsing van laadinfrastructuur voor elektrische auto's
Municipality of The Hague (2014) Plan van aanpak laadinfrastructuur elektrische auto's
Municipality of Utrecht: Elektrisch rijden in de G4
Municipality of Utrecht (2017): Plaatsingsleidraad en inrichtingskader publieke laadinfrastructuur
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## Appendix C. Number of respondents loading on two or no factors for different cut-off points in the 4-factor solution

| Cut-off point | Respondents loading on two factors | Respondents loading on zero factors |
|---|---|---|
| 0.36 | 16 | 0 |
| 0.37 | 14 | 0 |
| 0.38 | 14 | 0 |
| 0.39 | 13 | 0 |
| 0.40 | 11 | 1 |
| 0.41 | 11 | 1 |
| 0.42 | 11 | 1 |
| 0.43 | 9 | 1 |
| 0.44 | 6 | 2 |
| 0.45 | 2 | 4 |
| 0.46 | 2 | 5 |

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