The battery electric vehicle-experience

Understanding BEV perceptions, from early adopters towards mass acceptance

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15 March, 2018

Electric mobility is considered as the next step towards more sustainable mobility. Within the Netherlands, as one of the leading countries when it comes to electric mobility, the market share of battery electric vehicles is still limited to 0,2 percent. Many studies have been executed focusing on potential consumer adoption behaviour with respect to electric vehicles. However, little studies were found that are focused on the perceptions of battery electric vehicles users. A theoretical framework was developed to understand if and how actual user experience relates to perception, attitude and adoption behaviour. The following Q-study reveals four shared perspectives among experienced battery electric vehicle users, which are all overly positive. Differences were found comparing these perceptions with general perceptions from unexperienced consumers found in literature. Interestingly, the Q-study results suggest that general positively perceived attributes to battery electric vehicle usage is not only related to functional vehicle attributes such as drivetrain technology, driving range and charging technology. Additionally, brand image, self-identity and innovations in the field of user interface seem to be of importance to the respondents. Given that experience influences perception on BEV usage, it is interesting to understand how to utilize this understanding and bring experience towards non-experienced users.

Key words: battery electric vehicles; perceptions; adoption; mobility; the Netherlands

1. Battery electric vehicle adoption

Currently, the total share of battery electric vehicles (BEVs) within the total electric vehicle (EV) market is limited (Sierzchula, Bakker, Maat, & Van Wee, 2014). Nonetheless, BEVs are widely considered as the long-term replacement of internal combustion engine vehicles (ICEVs). For closing the well-known attitude-behaviour gap (Stern, 2000), this study provides further understanding of consumer BEV adoption by investigating perceptions of experienced BEV users. Consumer intentions and adoption behaviour of EVs are for the biggest part based on studies researching non-BEV users rather than actual BEV owners and users (Rezvani, Jansson, & Bodin, 2015). How respondents perceive these perspectives once they have owned and/or used an EV – let alone a BEV – is still largely unclear. It can be concluded that a potential future uptake of BEVs will depend heavily on how consumers perceive BEV usage. One recent literature review concludes on the matter: “one reason for the modest adoption figures is that the mass acceptance of EVs to a large extent is reliant on consumers’ perception of EVs” (Rezvani et al., 2015). As BEVs are a subset of EVs,

I assume this dependency on consumers' perception also applies to BEVs. Establishing and understanding this relationship between consumers' perception and BEV acceptance is the focus for the remainder of this study is. The research question here is: "Which perceptions on BEV-usage exist among BEV-users, and how can this knowledge contribute towards further BEV adoption?"

The development and presentation of the theoretical framework is described in the next section, followed by the details of the empirical research method and approach. Findings of the empirical part of the study are presented next. I then use the theoretical framework to interpret the empirical findings and put them into context. The article concludes with reflection on the main research findings and suggestions for further research.

2. Developing a framework for understanding adoption behaviour

For the purpose of this study, I assume purchase, ownership and usage to be all indicators for acceptance – also referred to as adoption. Several scholars stress the importance of subjectivity when interpreting the slow BEV acceptance. Generally speaking, psychological barriers to use a new product are based on existing norms and perceptions associated with the product (Hoeffler, 2003). This general construct was previously applied in studies that relate consumers' perception of vehicle attributes to their intention to adopt EVs (Schuitema, Anable, Skippon, & Kinnear, 2013). One study points out that "technology adoption is typically described by attributes of the technology or attributes of the adopter. (…) They often emphasize the adopter's perception of new technologies, related to performance expectancy (usefulness), effort expectancy (ease of use), social influence and facilitating conditions" (Bjerkan, Nørbech, & Nordtømme, 2016). This school of thought is based on the popular and widely applied technology acceptance model (TAM) (Davis, Bagozzi, & W., 1989).

As core basis for the theoretical framework for this study the TAM was adopted (see Figure 1). Subjectivity sits at its core, defined by perceived usefulness and perceived ease of use. Therefore, it serves as a plausible starting point for the further development of our conceptual model. Moreover, returning to our main research question, it is centered around our key concepts (perceptions and acceptance). Both perceived usefulness (U) and perceived ease of use (E) are assumed to have a positive impact on attitude and consequently actual system use (A) (Venkatesh & Davis, 2000). This rationale is visualized in the diagram below (see Figure 1).

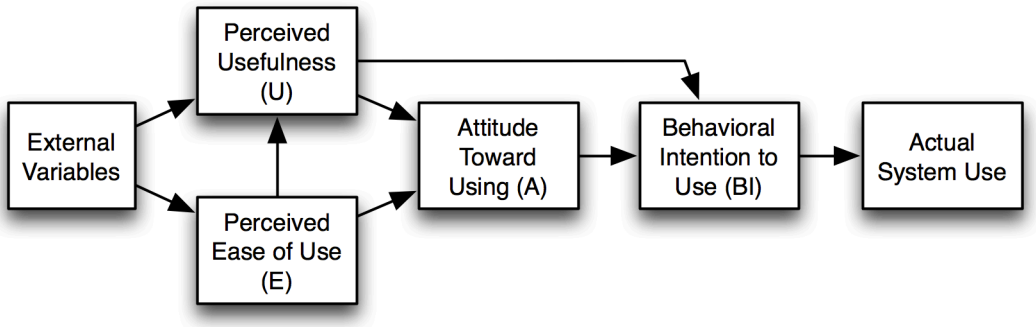

Figure 1 - Technology Acceptance Model by Davis, Bagozzi & Warshaw (1989)

It was repeatedly found by authors of user studies with BEVs that experience with BEVs generally changes the perceptions of the user on BEV usage in a positive manner (Axsen & Kurani, 2013; Schmalfuß, Mühl, & Krems, 2017). One study in particular shows several experience-based differences in evaluations of BEV attributes, attitude and purchase intention, with most BEV attributes being evaluated more positively when people had BEV experience (Schmalfuß et al., 2017). Research concludes that a significant number of experienced BEV users was willing to pay a premium for a BEV compared to an ICEV (Larson, Viáfara, Parsons, & Elias, 2014). All of this suggests a significant difference in perception between consumers with and without EV experience in perspectives on EV ownership and usage.

Adoption is an individual process detailing the series of stages one undergoes from first hearing about a product to finally adopting it. Diffusion signifies a group phenomenon, which suggests how an innovation spreads. The TAM is useful for explaining individual steps whereas the Diffusion of Innovations emphasizes a more holistic approach to exploring innovation adoption.

As found in this literature review, studies have been executed into adoption of electric personal mobility, especially on consumer preferences with stated choice experiments regarding further EV adoption. In paragraph 2.5, I elaborated on these studies into willingness of adoption where direct BEV experience is mostly limited. Scholars note a lack of published research on the effect of experience on the perception of an instrumental attribute such as range as a barrier in electric vehicle use (Franke, Cocron, & Bühler, 2012). A more recent study draws a similar conclusion with relation to experience: “Many studies take the form of surveys, with participants who have had no direct experience of EVs on which to base their responses. In this way, they are psychologically distant from EVs, and this limits the validity of inferences about adoption drawn from their responses” (Rezvani et al., 2015).

The figure below summarizes the theoretical framework which has the TAM at its core and is expanded with additional theory on innovation diffusion and specific applied research in the field of BEV adoption. The TAM helps to explain technology acceptance on an individual level. Schmalfuß et al. (2017) found a positive feedback loop from actual system use to the general perception on BEVs, which was added to the model (uninterrupted blue arrow). However, user experience and associated perceptions on BEV usage are still to be explored. This subjectivity of multiple individuals was studied using the Q-methodology. The main focus of this methodology is to reveal subjectivity and group participants with shared perspectives. Refer to the following chapter for details on this methodology.

Rogers’ (1995) approach to innovation is more holistic and focusses on groups instead of individuals and on communication channels. Experienced users could be influential to non-experienced consumers. This is depicted in the diagram below (dotted blue arrow).

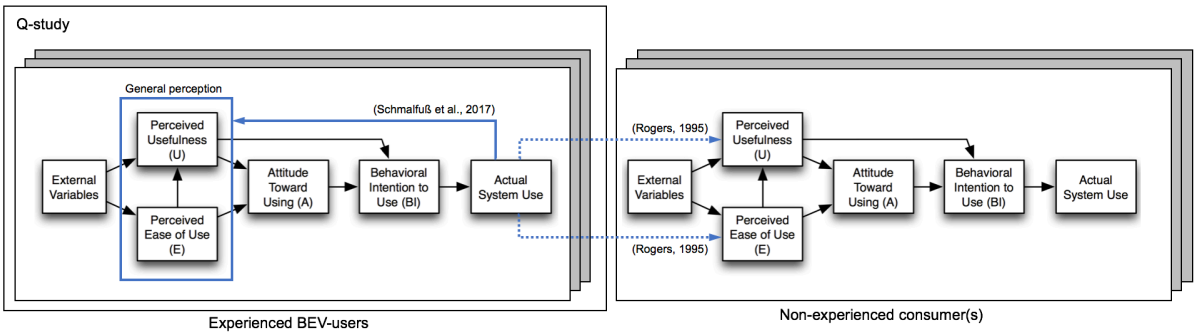

Figure 2 - Theoretical framework

3. Research method

The findings from the literature review make up the theoretical perspective of the thesis. All articles for this literature review were found through online databases Scopus, Google Scholar and ScienceDirect. When researching stat-of-the-art technological developments and market adoption figures of electric vehicles in general, it becomes clear that in recent years the focus of manufactures and policy makers has changed from HEVs and PHEVs to BEVs. The general research agenda has also progressed in a similar fashion. In the Netherlands, a similar development can be found when looking at recent registrations of electric vehicles (see Figure 3).Thus, this literature study is grounded in studies published in the 2010's, preferably from 2015 and onwards.

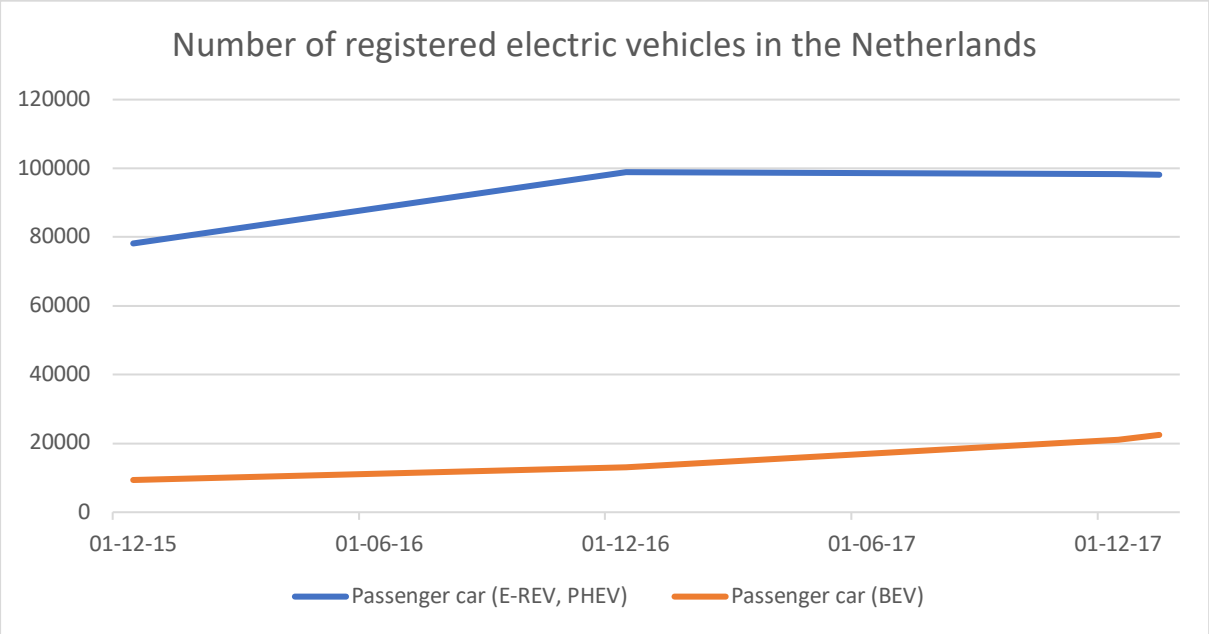

Figure 3 - PHEV stabilization and BEV growth based on Netherlands Enterprise Agency / RVO.nl (2018)

Q methodology was chosen as primary research methodology for this study. First and foremost because the methodology is perfectly aligned with the aim of this study: to reveal subjectivity and group participants with shared perspectives (Brown, 1993). Since the aim of this particular study is to surface perspectives that experienced BEV users might have on BEV usage and to group them accordingly, Q methodology is very useful. The aim of the empirical data gathering was to collect and consequently group perspectives on BEV usage by experienced BEV users. These perspectives are uncovered by applying the Q methodology. Simply put, this methodology requires

participants to sort statements according their personal preferences: A *Q sort*. The set of statements or *Q sample selection*, which is used for the Q sort is pre-determined and selected from a total set of statements, the so-called *concourse*. This concourse is largely based on literature study and is complemented by statements derived from semi-structured interviews with experts. Additional interviews with the participants in the Q sort were also used for interpretation of the sorts.

The case study took place within the Netherlands considering the relatively high number of BEV users and the possibility to interview them at supercharger stations during vehicle charging. Data collection was conducted in the Netherlands during June and July 2017 at the supercharger station and Tesla service center in Amsterdam, and at the supercharger station in Zwolle. As this study was executed in the Netherlands, respondents are selected on being a resident of the Netherlands. The final P-set consists of 40 Tesla users randomly selected at 'supercharger' stations. User experience is desired among participants; therefore, all respondents are the main driver of the vehicle, and have been using it for at least six months. Note that Q methodology is an exploratory technique and it cannot prove hypotheses (Watts & Stenner, 2005). Thus, expectations of different perspectives within the group are not formulated.

4. Descriptive analysis and interpretation

At first, descriptive data helps to understand the composition of the group of respondents, and also gives more insight in the background of the data collected. In Figure 5 the age of respondents, and in Figure 4 the job descriptions of respondents is presented. Considering the purchasing price, the deviation of age is not surprising. The purchasing price also relates to the job description, which exists mainly of relatively high paid jobs.

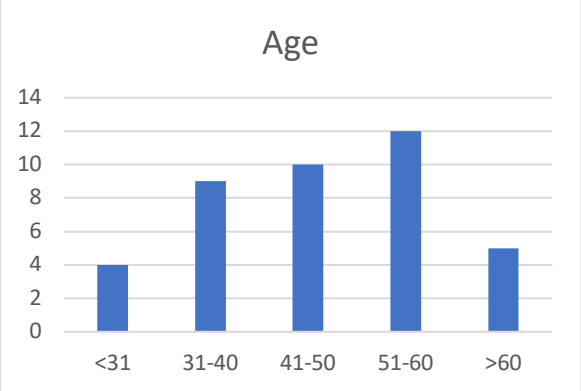

Figure 5: Respondents age graph

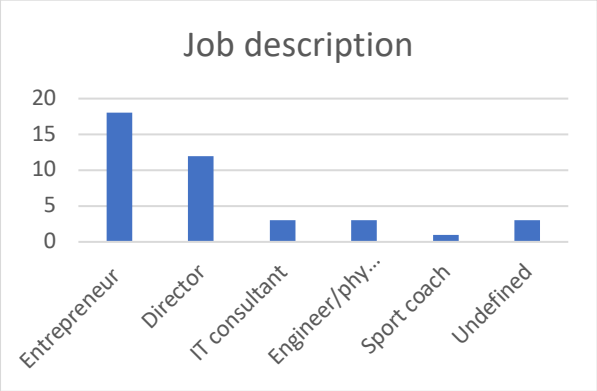

Figure 4: Job description

Furthermore, in Figure 7 the experience with BEVs is presented with the average score per experience group. Here we see a slight increase in average score from 8,7 in ''1 year or less'' towards 9,2 with 3 years of experience. In Figure 6 the education level shows that over half of the respondents have a graduate degree or higher. Notably, the number of high school graduates is surprisingly high, giving a closer look to the respondents within this category including the job description, we see mainly entrepreneurs, IT consultants and the respondents with an undefined job description.

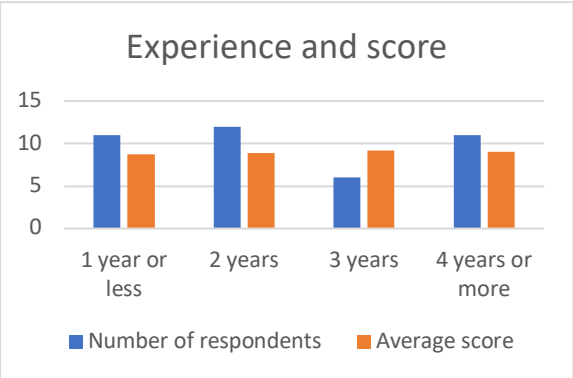

Figure 7: BEV experience and average score

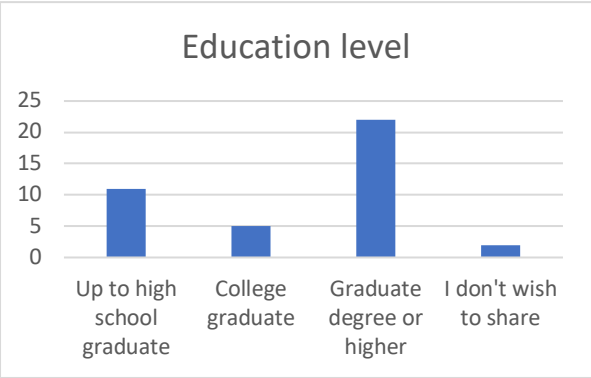

Figure 6: Education level

The analysis part of the study was the first step in translating the 40 individual Q sorts into an interpretable set of shared perspectives on BEV usage. These shared perspectives are based on factors which are extracted from the individual Q sorts through factor analysis performed using the application PQMethod. Factor analysis tells us how many different shared perspectives (factors) may be identified based on the set of Q sorts. Factor analysis typically starts with examining the correlation matrix between the different Q sorts. It shows which Q sorts were highly correlated with one another and therefore may be considered to have a resemblance. Q sorts belonging to the same shared perspective are expected to be highly correlated with one another, but uncorrelated with Q sorts of other perspectives. In short: Q sorts (participants) with similar views on the topic will share the same factor (Exel & Graaf, 2005). In conclusion, the number of identified factors is therefore purely empirical and wholly dependent on how the Q sorters (participants) actually performed (Brown, 1993).

Identification and subsequent selection of factors starts with considering the eigenvalues. The absolute value of the eigenvalues is a proxy for the explanatory power of a factor. When a factor has a value greater than one, it indicates that the factor explains more variance than a single statement within the Q-sort. Thus, a standard requirement is to select only those factors with an eigenvalue in excess of 1.00 (Watts & Stenner, 2005). Performing a Principal Component factor Analysis (PCA) resulted into 10 factors with an eigenvalue greater than one. An interpretable factor must ordinarily have multiple respondents that load significantly onto the same factor. This is not a mathematical consideration, but a practical. These Q-sorts are called ‘factor exemplars’ as they exemplify the shared pattern that is the characteristic for that factor. Researchers do not agree on an exact number. Considering the relative high number of factors with an eigenvalue in excess of 1.00 and the high number of respondents, I chose to look for at least three respondents that load significantly onto the same factor (Exel & Graaf, 2005). This results into selection of four interpretable factors (‘perspectives’). Executing the Q-varimax rotation with four factors, the software produced the variables as presented in **Fout! Verwijzingsbron niet gevonden.**. For each Q-sort the load for each of the four factors is determined after rotation. Using the automated pre-flagging function, the numbers are marked with a X that are significantly loading on one of the four factors over the other factors.

The four factors, interpreted as shared perceptions, have different loads on each of the 24 statements. Table 1 contains only the significant loads that exists on the statements for each of the factors, these fifteen statements have a defining role on the

four factors. The other nine statements don't have significant influence with the factors, in Table 1 these statements are left out to create a clear overview on the significant loads per factor on the determining statements.

Table 1: Significant loads per factor on statements

Statement	Factor 1	Factor 2	Factor 3	Factor 4
1 Pay more for environment	1.750			
3 Miss the engine sound		-1.510	-2.023	-2.026
4 More planning required			1.685	
7 Driving a BEV is cool				1.583
8 BEV stop during trip	-1.236	-1.669	-1.700	-1.786
9 Less dependency on fossil fuels	1.207			
10 Acceleration/power		1.297	1.950	2.046
13 Charging infrastructure not sufficient				-1.578
14 Contributes to less CO2	1.604			
15 Government subsidies		1.877		
16 Difficult to find charging point		-1.417		
18 Mileage is limited	-1.688			
19 Tax advantages on usage		1.263		
21 No overview on costs of BEV	-1.436	-1.532	-1.258	
24 Saving money compared to petrol				1.199

Interestingly, there are no disagreements among the four factors within a single statement. This means that differences between the four factors are mainly based on importance of statements rather than contrary opinions towards statements. The perception groups derived from these four factors are correspondingly labelled in four perception groups: (P1) Environmentalists, (P2) Financial drivers, (P3) Realists, (P4) BEV positivists. This will be further substantiated in the next paragraph.

5. Interpreting user perceptions

The first group of similar sorts is labelled *the environmentalists*, since their high loads are all related to environment and fossil fuels. Taking a closer look into the individual respondents within this group, it is noticeable that only two respondent makes a remark about environment: *"We all have to work together to reduce CO_2 emissions"* and *"I support the supervision to sustainable energy".* This shows that although respondents do explicitly mention the environment, their sorts reveal a strong preference. Other remarks made by the respondents mainly concern positive statements about the concept of electric driving in general.

The second group that was found is labelled *the financial driver*. Two out of three statements with a high load relate to governmental financial incentives, which motivates the chosen label. Considering the four perspectives, this is the group that is represented strongest, explaining 19% of the variance of the total dataset. Characteristic for this group is their strong opinion on the financial statements. They seem cautious about the financial incentives that comes with electric driving, and have a clear overview on the costs of driving their electric vehicle. During the sorting exercise respondents were confident about the financial benefits, saying: *"I never drove a car this cheap in usage"* and *"I thank the government every time I step into my car"*. This

observation confirms the presumption that the main incentive for this perception group are the financial benefits.

The realists can be seen as the perception group with the most critical opinion on their BEV experience, which its existence is according to my expectation. What I did not expect is that this group is still relatively positive, they seem to understand the disadvantages of driving a BEV as well they understand the advantages. This observation suggests that a significant factor for respondents with a strong negative perception on their BEV usage does not exists.

The fourth and final perspective that was found was labelled *BEV positivists*, because they seem solely positive about their BEV experience. A distinguishing factor is the statement *"Driving a BEV is cool"*, where most of the respondents of other factors don't seem to be interested in this statement, within this group it has a significant role. Another interesting observation is that six out of seven respondents mentioned the engine sound in the post Q-sort questions to endorse the advantage of no engine sound at all. The overall score given by this group to their BEV experience is 9,00, a second reason for the label of this perspective.

As four perception groups were identified it is interesting to focus on consensus and disagreement among the shared perspectives. The Q-study suggests that the differences in perceptions of the four groups is mainly based on importance of statements rather than contrary opinions. Besides, if agreement among multiple perspectives exists, it regards solely positive perceptions towards BEV usage.

6. Implications of perceptions

In this section, the theoretical framework is used to make sense of the perceptions. My research objective was to discuss the perception of experienced BEV-users on BEV-usage, and which factors can be of influence towards further adoption. Studying the perceptions of experienced users, might uncover differences between perceptions of non-users and experienced users. Factors as range anxiety, limited charging infrastructure, charging time and uncertainty of costs are considered as the main barriers for non-users in their attitude towards using this new technology. Interestingly, within the results of this study, only one of these main barriers (sufficient charging infrastructure) returns as a determining variable in one of the four shared perceptions. Here, ''The realists'' slightly agree on an insufficient charging infrastructure (statement 13), in which they also slightly agree to statement 4 (more planning required), which in my opinion is related to the fact that the infrastructure is not sufficient. The other barriers which exists in the perception of non-users, seem not to be considered as ''bad'' in the perception of experienced users.

Returning to the *Technology acceptance model,* the *perceived usefulness* and *perceived ease of use* is influenced by the mentioned barriers. But experienced users don't consider these main barriers as important as expected during *actual system use*. Besides the insufficiency of the charging infrastructure for *''the realists'',* none of the other barriers seem to have a significant impact in the composition of the four shared perspectives. Concluding that no negative association exists towards these barriers, there seem to be a difference in perceptions between users and non-users. This suggests a change of perception when BEV-adoption takes place, which endorse the

study of (Schmalfuß et al., 2017), suggesting that *actual system use* as in experience, also influences *perceived usefulness* and *perceived ease of use*.

Currently the total market share of BEVs consists of 0.2% (Rijksdienst voor Ondernemend Nederland (RVO), 2016). According to Rogers' (1995) Diffusion of Innovations, current BEV users can be considered to be *innovators* (see Figure 2). The prerequisites of *innovators* include control of substantial financial resources to absorb the possible loss owing to an unprofitable innovation, and the ability to understand and apply complex technical knowledge (Rogers,1995). Besides *the innovator* must be able to cope with a high degree of uncertainty at the moment of adoption. These characteristics were initially not included in the scope of the Q-study. However, giving a closer look to the job description of respondents, respondents mainly exists of entrepreneurs and company directors. Furthermore, in my personal observation during post interview conversations, most respondents have a substantial understanding on technical aspects of battery technology and life time, challenges and limitations of charging possibilities, and environmental challenges of production. Concluding, it is likely that the P-set used for this study exists predominantly of innovators.

The longitudinal study of (Bühler, Cocron, Neumann, Franke, & Krems, 2014) with early adopters showed that there is no change during a certain period of usage regarding concerns such as range and charging. Taken into account that this study was published in 2014, and the technological improvements of BEVs as in range and charging infrastructure, it is interesting to see that these concerns seem to be of less importance to respondents in this study. Early adopters might have a more positive perception on range and charging possibilities than the critical mass, and still expectations might be met as I do not find dissatisfaction in the results and post interview conversations.

To conclude, the clear results of positive perceptions towards BEV differ from a diversity of perceptions found in literature. Hereby the characteristics of innovators and early adopters, from which the P-set mainly exists, might partially explain the highly positive perceptions found in this study. Furthermore, as the study of (Schmalfuß et al., 2017) suggests, an increase of experience with BEVs could positively influences the perception. However, I do so similarities from the interviews that relates to more than just ''rational'' perceptions on usefulness and ease of use. It felt like respondents were part of a community and share the same interest with other Tesla users, I also recognized characteristics as described by (Rogers, 1995), where cosmopolite social relationships and communication patterns exists between innovators. In this specific situation, it can easily develop as innovators are physically together for 30-40 minutes while charging, where one subject is discussed: *The Tesla experience*.

7. Conclusions and recommendations for future research

This exploratory study primarily serves as a starting point for understanding BEV usage perceptions. It also contributes to a broader context for understanding how perception, experience, attitude and behaviour are related in the adoption process of electric mobility. However, further research is required. As explained in the study of Rogers (1995), a requirement for successful adoption is the acceptance of the critical mass. Reproducing this Q-study with a wider public that does not predominantly consist of innovators and early adopters might produce a different result as presented here. Hereby it can be asked: *Which perceptions exists in further adoption categories*

as early and late majority, and how do they relate to the perceptions of innovators and early adopters?

The presented theoretical framework was based on literature study and shows a positive causal relationship from actual system use, which is also referred to as 'experience', to the perception of BEV users on usefulness and ease of use of their BEV and therewith also the intention to adopt or purchase a BEV. The main barriers for BEV adoption that were found in previous studies, were not found in this Q-study. In short, the respondents in the Q-study perceived these attributes of BEV usage as very positive. From the aforementioned, I conclude that the experienced BEV users that were interviewed for this study are likely to purchase a BEV again if the opportunity arises. This leads us to consider the question whether the same dynamic might apply to non-experienced consumers? Would their perception on usefulness and ease of use improve as well with experience? Practical longitudinal case studies could provide an answer to these questions and give researchers and policy makers valuable insights into potential techniques for changing the consumers' perception on BEV usage.

The aforementioned positive impact of experience on future adoption behaviour of BEV experienced individuals was established after they adopted a BEV. This leads us to consider the following situation. It would be interesting to select a certain group of potential users and to question them before and after BEV adoption. Researchers could search for changing perceptions and thus establish whether or not perceptions on BEV attributes change over time. Certain research might answer the following question: *Does the perception on BEV usage change on an individual level after adopting a BEV?*

Secondly, the theoretical framework also includes a potential influence of experienced users on perceptions of non-experienced consumers. This could happen by communication and exchange of knowledge of BEV usage. Theoretically speaking, there are endless possibilities to bring non-experienced users in touch with experienced users. I could imagine using the continuous flow of experienced users who are charging their vehicle at super charger stations for certain events where they can interact with non-experienced users who are interested. Obviously, this is brand dependent, but as current BEV-users are limited, it is an easy way to facilitate the interaction.

It was established that BEV user experience is an important factor for user perceptions on BEV attributes. However, a German field study indicates that attitudes, knowledge and perceptions differ across gender, age and education, with males and higher educated individuals being more interested. (Plötz, Schneider, Globisch, & Dütschke, 2014). Therefore, it is important to consider that user experience is not the only relevant factor. If mass market adoption becomes reality, future quantitative empirical studies will have to prove the most important factors. *Which other factors are relevant* in *understanding adoption behaviour if it comes to battery electric vehicles?*

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