Fostering the adoption of electric vehicles by providing complementary services

Wenyan Zhou (TU Darmstadt), Christian Schlereth (Goethe-University of Frankfurt), Oliver Hinz (TU Darmstadt)

1. Introduction

Fuel consumption is one of the main drivers for CO_2 emissions. 10% of global greenhouse gas (GHG) emissions come from road transport (OECD, 2010) and constitute a big challenge for researcher, industry and policy makers. Furthermore, with 98% of all vehicles still running on gasoline or diesel, the pressure on global oil supply is rapidly increasing, and the peak oil demand is predicted to occur no later than 2030. So from a scientific and political point of view it is important to remedy the climate problem and solve the problem of the demand gap.

One effective way to solve both the climate change and energy security problem might be the broad adoption of Electric Vehicles (EVs). Germany as an example, aims to achieve the target of a 40-percent emissions reduction sector wide by 2020 by pursuing a massive electric vehicle strategy, which means they aim to have 1 million electric cars on the country's roads by 2020. Thereby almost 1.5 billion euros ($1.9 billion) are invested into subsidy research and development in e-mobility obviously stimulating the e-mobility industry.

However the reality looks much different. In 2012, cleaner vehicles – hybrids, electrics, and natural gas and ethanol-fueled vehicles combine to make up 3%, while electric vehicles (EVs) make up only 0.2% of vehicle registrations in the European Union (EU). 3 million new vehicles were registered in Germany in 2012, but only 4,157 were electric vehicles. Although it is twice as many as the year before, the situation is not satisfactory (ICCT, 2013).

What are the main barriers for adoption? Previous research pointed out the important roles of price (including purchase price and recharging costs), charging time and ranges play on EVs adoption (Beggs et al., 1981; Bunch et al., 1993). But along with the endeavor of motor companies work on this part, e-technologies have been improved gradually. New battery technologies appear for longer range, more power and shorter recharging time (e.g. lithium-ion technology by TOYOTA; New Water-Based Battery by GE). Also governments' substitution of this technology in form of lower taxes can help to solve the problem from the cost side.

Additionally, complementary mobility services may become increasingly important, but the only influence prior research has documented are costs. Specifically, attributes like repair and maintenance cost (Ewing and Sarigollu, 1998), station service cost (Brownstone et al., 2000) and operating costs (Shepherd et al., 2012) have been in the focus of interest. However, it is well known that not only prices of services but also their availability can significantly affect consumer behavior. Well-tailored complementary services can undoubtedly attract new customers and satisfy existing customers (Lovelock C.H., et al., 2009). As a result, our paper aims to explore the influence of complementary mobility services on adoption, and then discuss how industry and policy makers could use our results to stimulate the adoption of electric vehicles more effectively.

To achieve this aim we conducted a two-step approach with a representative sample: We use a best-worst scaling (BWS) analysis in the first step to rank the consumer preference of complementary mobility services, and use the top ranked attributes as the input for our main study which mitigate the limitations of conjoint analysis (the number of attributes and levels have to be exogenously limited). In the second step, the main study, we conduct a dual-response analysis to explore the influence of complementary mobility services on the adoption of EVs (see e.g. Beggs et al., 1981 for a similar approach).

2. Literature reviews

An electric vehicle (EV), also referred to as an electric drive vehicle, uses one or more electric motors or traction motors for propulsion. To the class of EVs belong plug-in electric cars, hybrid electric cars, and hydrogen vehicles. The interest in electric vehicles has peaked three times in the past few decades. These peaks relate to early concern over air quality (mid-1960s), concern about imported petroleum (1974-1981), and renewed interest in reducing petroleum imports and pollution from automobiles in the last years (about 1985-present) (Deluchi et al., 1989).

Since 1981, after the first study of EV demand was published (Beggs et.al., 1981), scholars started to focus on factors affecting the adoption of electric vehicles by using revealed preferences (RP) and stated preferences (SP). Revealed preferences (RP) can be used to forecast future demand, while stated preferences (SP) can be used to analyze the actual decision made by individuals. In this paper we rely on stated preferences.

Table 1 lists the main studies in the adoption of electric vehicles in past thirty years. We find research from different country, but most of them were conducted in developed countries. Since the wave of studies in 1990s, scholars moved from targeting multicar households to targeting the entire population. All variables included in previous studies can be divided into four categories: technology, economic, environment and additional service.

Table 1 Summary of EVs Studies in Past Thirty Years

Study	Data	Variables	Conclusions
Beggs et al. (1980, 1981)	200 households in the Baltimore	Values, operating cost, size, car age, car classes (e.g. luxury), range, top speed, acceleration, number of seat, air conditioning, warranty, type of fuel	Limited range and long refueling time are significant barriers to adoption of EV.
Calfee (1985)	51 automobile owners in California	Price, operating cost, range, top speed	All attributes affect the adoption of EV.
Bunch et al. (1993)	717 households in California	Purchase price, fuel cost, range, availability of fuel, dedicated versus multiple-fuel capability and the level of reduction in emissions	Most important attributes are range and fuel cost, but emissions level is also a significant adoption factor.
Brownstone et al. (2000)	7387 households in California	Fuel type, range, price, home refueling time/cost, service station refueling time/cost/availability, acceleration, top speed, emissions, size, body types, luggage space	Large heterogeneity in preference for fuel types could be due to respondents' different information set and fundamental uncertainty.
Ewing and Sarigollu (1998, 2000)	881 respondents in Canada	Purchase price, annual repair and maintenance cost, acceleration, cursing range, refueling rate, pollution	Relative vehicle prices and performance levels as well as differential commuting costs

		emission, commuting cost , commuting fuel and parking cost	and times will have modest effects on vehicle choice.
Dagsvik et al. (2002)	622 Norwegian residents	Purchase price, top speed range, fuel consumption, energy type	Alternative fuel vehicles appear to be fully competitive alternatives. Driving range is an important attribute.
Skippon and Garwood (2011)	58 people in UK	Concern of environment and engagement with cars and driving (affective and symbolic)	Low personal involvement with cars and driving, and high personal concern for the environment.
Hidrue et al. (2011)	3029 respondents in US	Price, driving range, charging time, fuel, cost saving,	Estimating the willingness to pay for electric vehicle attributes.

According to the technology acceptance model (TAM), better technologies would improve the purchase intention by increasing the consumers' perceived ease-of-use and perceived usefulness. For EVs, technological superiority can be expressed by attributes like charging time, range per change, motor power, acceleration, top speed and multiple-fuel capability. Early in 1980s, Beggs et al. (1981) documented that limited range and long recharging time were the most significant barriers to the adoption of EVs. Later other technological attributes also proved to be significantly foster to the EVs adoption (Calfee, 1985). Technological attributes are still used frequently in recent studies (Dagsvik et al., 2002; Lieven et al., 2011) and we also consider them in our study.

Another important factor considered during all research periods is the factor costs. The purchase price of the car worked as an estimate of the used car price in mid-1977, but does not reflect the total costs (should include both purchase price and operating cost) for driving. So later another cost concept, operating cost (fuel costs, other mileage-dependent costs, and time-dependent cost) was introduced by Beggs et al. (1981). The fuel cost in the context of electric vehicles means electric cost or costs for recharging. Previous research has shown that both the purchase price and the operating costs can explain why individuals hesitate to adopt EVs. Other economic factors like parking costs, commuting costs, repair and maintain costs are also mentioned in later research (Ewing and Sarigollu, 1998). As is well-known, price always directly connects with the levels of performance, so the newest studies start to estimate the willingness to pay for not only electric vehicle but also the performance delivered by high technology (Hidrue et al., 2011). In our study, we focus on the two most important cost factors: the purchase price and the fuel cost.

As the EVs are supposed to solve the emission problem, the environmental aspect is also regarded as a crucial part. Scholars not only take the CO_2 emission (Shepherd et al., 2012) or reduction of pollution (Bunch et al., 1993) into account, but also the consumers' level of environmental consciousness (Ewing and Sarigollu, 1998). Ewing and Sarigollu (1998) found out that more than a third of respondents were willing to pay at least CAN$1000 more for a vehicle with substantially lower emissions.

Nowadays, services become the key not only to satisfy consumers but also to promote new products in the market. Unfortunately, there is little research on this topic, a gap that this study aims to close. To the best of the knowledge of the authors, previous research has only integrated the availability of recharging stations as complementary mobility service. Although the fuel availability (Shepherd et al. 2012) and station availability (Ewing and Sarigollu, 2000) are crucial ones, research should catch up with the development of newest services. Based on talks with experts and industry reports, we examine nine important complementary services (see Table 2). We believe that these services could work as complements to EVs technologies to increase consumers' perceived ease-of-use and perceived usefulness, and reduce the time-dependent cost (saving the time of payment and parking) at the same time.

For examples, "Intelligent charging stations" could be an instrument of the Demand Side Management (DSM) and could be used to improve the energy system on the consumption side. "Intelligent charging station" can a) improve energy efficiency, b) reduce the time of use, c) allow quick demand response and d) enlarge the spinning reserve (Palensky et al., 2011). Vehicle-to-Grid (V2G) is an energy system realizing large synergies between the vehicle fleet and the electricity system. The societal advantages of developing V2G include an additional revenue stream for cleaner vehicles, increased stability and reliability of the electric grid, lower electric system costs, and eventually, inexpensive storage and backup for renewable electricity (Kempton and Tomi´c, 2005). Head-up displays (HUDs) for automotive is a technology using the windshield as a projection surface for displaying virtual content. HUDs can help drivers to faster detect and response to traffic changes, as well as increased navigation's accuracy (Fadden et al., 1998).

Table 2 Complementary Mobile Services

Complementary Services	Explanation
IT-based parking and payment	IT-based parking systems can guide drivers to find the parking space directly and pay easily and automatically.
Intelligent charging station	Public stations that can distribute energy in an efficient and intelligent way to e-vehicles easily without overloading the grid.
Drive-through for bills payment	Bills can be paid directly from the vehicle for certain products or services (e.g. fuel bills, parking fees or tolls).
Connection to mobility providers	By contracting with mobility providers, drivers can rent and switch vehicles offered by mobility providers. Moreover, mobility providers can offer intelligently services, such as traffic or travel information, which can be also booked.
Remote diagnostics and update supply	The software (e.g. operating system) adopted in electronic vehicles can be remotely controlled and updated by car repair shops. Meanwhile, remote diagnostics can be offered in case of errors or defects.
In-car Apps, purely vehicle-related function	In-car apps are software applications that equip the vehicles with additional functions directly related to driving (e.g. driver logs, fuel costs logs).
In-car Apps, not purely vehicle-related function	In-car apps that are not directly related to driving, e.g. social media or music apps.
Vehicle-to-Grid	To realize large synergies between the vehicle fleet and the electricity system, V2G refers to the return of electricity from the battery of an electric vehicle into the electric grid.
Head-up displays	A head-up display uses the windshield as a projection surface for displaying virtual content. So drivers can view information with the head positioned "up" and looking forward, instead of angled down looking at lower instruments.

3. Survey, sampling and study design

The entire investigation is divided into two parts: a preliminary study and a main study. The best-worst analysis adopted in the preliminary study aims to find the complementary services which individuals prefer more, while we aim to identify whether these complementary services would enhance consumer's willing to pay by using another discrete choice analysis (dual-response analysis) in the main study. Both surveys were created using the DISE survey platform (Dynamic Intelligent Survey Engine) and conducted online. In the following description of the methodology, these two methods will be described independently.

3.1 Best-Worst Scaling Analysis (Case 1)

BWS based on the random utility (RUT) is one kind of a discrete choice experiment. In 1992, Finn and Louviere introduced this method to measure concerns or preferences regarding attributes (case 1), levels of attributes (case 2) or profiles of attributes (case 3). Our study uses case 1 to identify the top three complementary services consumer prefer. These findings will serve as input for the main study. In BSW we show a series of discrete choice with different attributes randomly to the respondents. Then, in contrast to regular discrete choice analyses, respondents not only choose the most preferred combination but also the least preferred one.

BWS has several advantages: 1) it offers more information about consumers' preferences as it identifies out the most and least important attributes. 2) Consumers do not use numerical scales (e.g. agree-disagree scaling), so BSW is scale-free which can reduce the bias in both, mean value and variance. 3) Rating "importance" of each attribute is not ask respondents choose ones against another ones, so we cannot distinguish the true preference with minimal differences. 4) Easily understand and quick perform, and the results are also valid. 5) The limitation of co-joint analyses that we adopt in the main study is that they cannot deal with a large amount of attributes at the same time. Based on the outcome from the BWS analysis, we can reduce the number of attributes to make accurate and effective conclusions.

3.2 Experiment design and data collection

The pre-study consisted of three parts: 1) the definition of electronic vehicle, 2) the BWS analysis, and 3) a series of demographical questions.

Before making choices, we provide the participants basic information on EV, which contains an understandable definition and typical cases. In the BWS part, we use Balanced Incomplete Block Design (BIBD) to design the comparison set. We provided 12 comparison sets to every respondent. Each set contains 3 attributes, so every attribute occurs 4 times across the 12 sets (see Table 3 for illustrative purposes). We describe the complementary services and provide pictures so that every respondent could easily understand the services. Respondents are then supposed to choose the most and least preferred attribute.

Table 3 Survey BWS for Complementary Mobile Services

Most preferred	Complementary mobile services	Least preferred
X	IT-based parking space and payment	
	Intelligent charging station	

As a first assessment, a simple count analysis may then be used. The analysis can be either conducted on the individual or on the aggregate level across all respondents. We first count how often each complementary service called as the “Best” and the “Worst”. We also named the differences between these two values as “Best-Worst”. “Best-Worst” value is reinforced by the sample size and the display frequency of an additional mobile service (in this case four) divided. The result measures the importance of a complementary service and can be used for prioritization.

3.3 Dual-response Analysis

The main study explores the customer preference in EVs. We conduct a choice-based conjoint analysis (CBC) which is a multiple method of preference measurement. In its strictest sense, CBC is not a conjoint analysis, but is a method of discrete choice analysis (DCA), which is applied to a conjoint design. We also add no-choice option to the choice sets as an integral part to CBC. Without a no-choice option, participants are forced to choose a product option which might yield rather useless information about the real preference of potential consumers. Moreover by adding the no-choice option the choice set better reflect a real purchase situation.

The main study consists of three parts: 1) basic information on the context of the survey, like the definition of the term “electronic vehicle” and the top three complementary services, 2) actual dual-response analysis with various choice sets, and 3) a series of demographical questions.

Direct and projective methods are used to determine potentially relevant properties of preference. Comparative method, however, are able to detect determinant immediately. In this study, the so-called document analysis is used. This is associated with the direct method. As sources for the identification of properties coming previous studies, literature, journals, and test and experience reports on the use. As a result, we choose only five most important attributes: range change, price, change time electric cost for 100km and motor power. They are the main factors fostering the adoption of EVs according to previous studies. Table 4 summarizes these attributes and their levels. Most of the attributes are self-explanatory. We further add the top three complementary services to the list to explore their effects on purchase-decision process. Then interviewees would repeatedly select their highest preference in defined choice sets that consist of different products configurations (see an example in Appendix). The choice sets designs created using third-party software.

To express the utilities of various attributes and services, we use a part worth model. Specifically, a logit model is adopted in our analysis. It assumes a Gumbel distribution of the stochastic component of the utility function. The probability $\mathrm{Pr}_{h,i}^{a}$ of h-th customer to select i-th product of a-th choice set is denoted by:

$$Pr_{h,i}^{a} = \frac{exp(u_{h,i})}{exp(u_{h,0}) + \sum_{i' \epsilon C_a} exp(u_{h,i'})} \qquad (h \in H, i \in I)$$

Where C_a is the all choice alternatives in a-th choice set without the no-choice option; $\mathrm{Pr}_{h,i}^{a}$ is the probability of h-th customer choosing i-th product in a-th choice set; $u_{h,i}$ is the use value of i-th product for h-th users; $u_{h,0}$ is the use value of the no-choice option for the h-th consumer.

By using a hierarchical Bayesian approach, we can estimate the parameter of utility function for respondents individually. We receive the aggregated parameters by calculating the mean value over all respondents.

An important indicator in dual-response analysis is the importance weight of each attributes which is determined by dividing the span of the part-worth of the attribute and the sum of the span of the part-worth of all attributes.

Table 4 Attributes and Their Levels Included in Our Main Study

	Unit	Range	Levels
Range per change	km	4	100, 175, 250, 325
Purchase price	€	4	15.000, 20.000, 25.000, 30.000
Change time	h	2	1, 4
Electric cost for per 100 km	€	4	1, 3, 5, 7
Motor power	kW	2	40, 80
IT-based parking space and payment	[ ][1]	2	have, do not have
Intelligent charging station	[ ]	2	have, do not have
Augmented reality via Head-up-Displays	[ ]	2	have, do not have

In addition, the weight of the total sample results regarding the adoption and preference of the results are also examined for the influence of demographic variable. For this purpose, a simple analysis of variance (ANOVA, Analysis of Variance) is used later.

4. Data analysis

4.1 The results of pre-study (BWS analysis)

The pre-study was conducted from 15.02.2013 to 21.02.2013. We recruited the participants through different channels. The pre-study is however not totally representative and can thus be considered a convenience sample.

We obtained a total of 251 completed questionnaires. The sample consists of 79 females and 172 males, and the age range is from 18 to 60 with an average value of 32.1 years. More than half of the participants are employees (57%) while students also are represented with a relative frequency of 31.9%.

The results of the best-worst scaling to complementary services show that “IT-based parking space and payment”, and “Intelligent charging station” are by far the most desirable choice by the respondents (see Table 6). The complementary services “Augmented reality via head-up displays” and “remote diagnostics and update supply” follow on place three and four. “Drive-Through-Payment” and “In-Car-Apps not for purely vehicle-related functions” do not meet our participants’ preferences. Consequently, we choose the top three services “IT-based parking space and payment”, “Intelligent charging station” and “Augmented reality via Head-up-Displays” as input for our main study.

4.2 The results of main study (Dual-response analysis)

The implementation of the main study’s online survey was carried out in cooperation with a

[1] The supplementary mobile services are recorded as dummy variables, so there is no unit.

survey panel provider. Due to this cooperation, high data validity and a representative, cross-sectional data set could be acquired.

Table 6 Results of the Best-Worst Scaling Analysis

Ranking	Service -Nr.[1]	Additional mobile service	Best[2]	Worst[3]	Best – Worst[4]	Ø(Best – Worst)[5]
1	1	IT-based parking space and payment	530	155	375	0.373
2	2	Intelligent charging station	497	167	330	0.329
3	9	Augmented reality via Head-up-Displays	415	225	190	0.189
4	5	Remote diagnostics and update supply	355	226	129	0.128
5	6	In-Car-Apps for purely vehicle-related functions	346	272	74	0.074
6	8	Vehicle-to-Grid	295	440	-145	-0.144
7	4	Connection to mobility agents	230	438	-208	-0.207
8	3	Drive-Through-Payment	170	515	-345	-0.344
9	7	In-Car-Apps not for purely vehicle-related functions	174	574	-400	-0.398

N = 251

(1) The service no. corresponds with the assignment in Table 2.

(2) Number of best responses

(3) Number of the worst responses

(4) Difference between best and worst responses

(5) Average difference between the best-and worst- attributes

The online survey was available for participants from 19.04.2013 to 25.04.2013. We targeted adult drivers and motorists. The survey started with questions on age, gender, and net income and then we asked whether the participant could in principle imagine buying an electric vehicle. This question served as filter and if the answer was "yes", we tried to learn more on the preferences of this participant. The results can be seen in Table 7.

327 respondents took part in this survey, and 168 of them (51.4%) stated that they would like to buy EV. About a quarter of the participants cannot imagine purchasing an EV. 24 respondents consider leasing the vehicle while 57 respondents could image to use the vehicle through a car-sharing service.

For further analyses we examine the 168 participants, who could imagine buying the vehicle, while we do not consider the remaining participants. Out of this sample, 8 participants did not complete the questionnaire survey. We further excluded 10 respondents because they finished questions in less than 5 minutes while the average time for completion was about 15 minutes. We believe that 5 minutes is not enough for individuals to really understand the context and make a considerable choice. Thus, a total of 150 completed questionnaires will be considered for further evaluations. Table 8 summarizes the respondents' demographic characteristics.

Table 7: Answers to the Initial Question

Answers options	Number	Proportion
Yes, I would like to buy this vehicle.	168	51.4 %
No, but I would like to lease this vehicle.	24	7.3 %
No, but I would like to use this vehicle in a car-sharing services.	57	17.4 %
No, I would not like to use this vehicle.	78	23.9 %

N=327

The initial question is: "Would you think about purchasing this vehicle?"

It was released in conjunction with an illustration of VW Golf. It was made clear to respondents that there should be, for acceptance according to an electric vehicle.

Table 8 Respondents' Demographic Characteristics

Gender	Age	Occupation	Total family income (€)	Household size
Male	18-24 (10%)	Unemployed (1.3%)	Below 499 (4.0%)	1 person (23.3%)
(56%)	25-34 (18.7%)	Employee (45.3%)	500 - 999 (12.0%)	2 persons (42.7%)
Female	35-44 (15.3%)	Workers (7.3%)	1000 – 1999 (30.7%)	3 persons (14.0%)
(44%)	45-54 (23.3%)	Civil Servants (2.0%)	2000 – 2999 (24.0%)	4 persons (16.7%)
	55-64 (22.7%)	Pensioners (20.0%)	3000 – 3999 (10.7%)	5 persons (2.7%)
	65-74 (8%)	Freelancers (8.7%)	4000 – 4999 (2.7%)	6 persons (0.0%)
	75-84 (2%)	Students (8.0%)	Above 5000 (4.7%)	More than 6 persons
		Pupils (0.7%)	No answer (11.3%)	(0.7%)
		Others (5.3%)		
		Unspecified (1.3%)		

Based on the data collected in the dual-response analysis, we estimate the parameter values (part-worth) and derive the importance weights of the attributes (see Table 9). The signs and magnitudes of the estimated utilities provide face validity (e.g. increasing part-worth with increasing distance per change). The selection decisions are determined by the parameters estimated benefit in 92.3 % of all relied for parameter estimation. Choice sets correctly predicted (internal validity). In 75.8 % of all Hold-Out-Choice-Sets, the selection decision is correctly predicted (predictive validity). Both values are significantly higher than the 33% chance criterion. Based on these quality measures we can conclude that the data quality is rather high.

With respect to the importance weights in Table 9, electric cost (for 100 KM) has the highest importance (25.6%) and the range per change is the second most important attribute (21.39%). We observe a huge increase in utility when the range per charge increased from 100km to 175km, the aggregated part-worth increased by 1.922. But then there is no substantial utility increase when the range increased from 175km or from 250km to 325km. And the maximized decline happened when electric cost per 100km rose from 5€ to 7€. Individuals' part-worth decreased by 1.579. Moreover, we found that people are electric cost sensitive. Changes from 3€ to 5€ also leaded to a utility decrease of 1.269.

Surprisingly, purchase price ranks only at the third place (14.43%). Even more surprising, the aggregated parameter of price is positive (0.135), which means consumers' part-worth value would increase 0.135 per 1€ the purchase price increase . This could be an indication that prospective buyers see EVs as luxury products and that they would be proud of being environmental friendly. EVs thus constitute a status symbol and can be used for conspicuous consumption (see Veblen 1899 for a discussion on this topic).

Table 9: Results of Dual-response Analysis

Attributes		Aggregated part-worth	Standard Deviation	Importance weights
Constant		-0.883	5.960	
Range per charge				
	100 km	-1.871	1.208	
	175 km	0.051	0.635	21.39 %
	250 km	0.695	0.687	
	325 km	1.126	0.846	
Purchase price		0.135	0.244	14.43 %
Change time				
	1 hour	0.287	0.493	4.09 %
	4 hours	-0.287	0.493	
Electric cost for 100 KM				
	1 €	1.538	1.230	
	3 €	0.860	0.700	25.16 %
	5 €	-0.409	0.748	
	7 €	-1.988	1.506	
Motor power				
	40 kW	-0.484	0.826	6.91 %
	80 kW	0.484	0.826	
IT-based parking space and payment				
	with	0.795	0.659	11.35 %
	without	-0.795	0.659	
Intelligent charging station				
	with	0.784	0.609	11.19 %
	without	-0.784	0.609	
Augmented reality via Head-up-Displays				
	with	0.383	0.566	5.47 %
	without	-0.383	0.566	

It is also noteworthy that, the importance weights of all three complementary services ("IT-based parking space and payment", 11.35%; "Intelligent charging station", 11.19%; "Augmented reality via Head-up-Displays", 5.47%) exceeds the importance of the electric cost, reaching 28.01%. The part-worth will increase by 1.59, when electric cars start to offer "IT-based parking space and payment" service. And the similar thing happened to "Intelligent charging station" service, the part-worth increased by 1.568. The results pointed out those complementary services can have a significant impact on the adoption of electronic vehicles, although most of the interviewees (72.7%) had no knowledge about complementary services in electric vehicles before. This result shows that it might be quite crucial to subsidize and promote complementary service offered by EVs or EVs producers.

We further conduct an ANOVA (analysis of variance) that shows gender has an influence on the importance weight of "Augmented reality via Head-up-Displays" (see Table 10), while age shows a significant impact on the importance weight of "IT-based parking space and payment" and "Intelligent charging station" (see Table 11). It is clear that men have more passion in high technologies like "Augmented reality via Head-up-Displays" and older person prefer the complementary services which offer more convenience. The other socio-demographic characteristics have no significant effect on the level of importance weights.

Table 10: Influence of Gender on the Importance Weight of Properties

Additional service	Female n=66	Male n=84
Augmented reality via Head-up-Displays	5.65 %**	7.47 %**
N=150 *) Significance level 0.05; **) Significance level 0.1		

Table11: Influence of Age on the Importance Weight of Properties

Additional service	18-24 year n=15	25-34 year n=28	35-44 year n=23	45-54 year n=35	55-64 year n=34	65-84 year n=15
IT-based parking space and payment	8.64 %*	9.14 %*	10.37 %*	10.19 %*	9.00 %*	18.03 %*
Intelligent charging station	10.94 %*	10.58 %*	7.36 %*	8.77 %*	12.04 %*	14.48 %*
N=150 *) Significance level 0.05; **) Significance level 0.1						

5. Conclusions

Building upon the best-worst scaling and the dual-response analysis we empirically measure the preferences for complementary services and the important weights of various attributes. The conclusions we got are as follows: Firstly, the adoption rate of EV is expected to be relatively low, specifically, only 44.7% respondents actually could imagine buying an EV. Secondly, instead of purchase price, the fuel cost is the most important characteristic that individuals consider when they think of adopting EVs. Thirdly, "IT-based parking and payment", "Intelligent charging stations" and "Head-up displays" are the top three services consumers prefer and these top three services can significantly affect the adoption of electric vehicles and should thus be in the focus of policy makers and industry.

5.1 Theoretical contribution

Our study adds new insights into the adoption of electric vehicles. Other than prior studies, we examine the influence complementary services on the adoption of EVs. Nine popular complementary services in electronic vehicles have been collected and tested. Results showed that consumers' most favorite complementary services, "IT-enabled parking space and payment", "Intelligent charging stations" and "Augmented reality on head-up displays", would significantly improve the intention to purchase electric vehicles. This is a new perspective for EVs adoption research and further studies could explore the influence of complementary services on adoption in more detail.

Another contribution is that we successful propose and empirical demonstrate a two-step approach: First, we adopt a best-worst scaling analysis to determine the most important services that we then use as input for a dual-response analysis. BWS is particularly helpful when preference heterogeneity can be captured by a relatively small sample, since we not only capture the most but also the lowest preference data. And at the same time, the set of alternatives can be reduced to an acceptable level and can serve as input for methods such as the CBC. As a result, the main study could effectively determine the importance weights of the most important complementary services. It is noticeable that, the conclusions we got from best-worst analysis and dual-response analysis are consistent. The top three complementary services we picked from the pre-study together also have high importance weights (aggregated 28.01%) in the main study which supports the feasibility of this two-step approach. We therefore expect that this two-step approach will also be useful in other research domains.

5.2 Practical contribution

We found that the acceptance of electric mobility is low. About 44.7% of respondents can imagine purchasing an EV at this point of time. It is therefore important to learn more about the preferences of prospective buyers so that policy makers and the automotive industry can effectively stimulate the consumption. As previous studies concluded, electric cost and range per charge are two of the most important factors that foster or hinder the adoption of EVs. According to the results of our study, range per charge should be 175km or more, and electric cost should be reduced as much as possible.

However, different from other studies, we found that the purchase price plays a minor role for the respondents from a German sample. Compared to importance weights of the complementary services (28.01%), the electric cost (25.16%) and the range per charge (21.39%), the importance weight of the purchase price with 14.43% appears to be relatively low (see Table 9 for full information). This finding should be taken into account and it might be beneficial to offer the EV for a higher purchase price and subsidize by this means the variable costs like the electric costs. It might also make sense to use the best and most expensive technology to drive down the electric costs. Prospective buyers are willing to pay more for the initial purchase but are timid of the operating costs.

Therefore, introducing these complementary services could provide opportunities to foster the adoption and the sales of electric vehicles. Such innovations should not be restricted to luxury EVs. Rather, they should be integrated into all EVs to effectively foster the adoption of this technology. Meanwhile, since 72.7 % of the respondents could not imagine complementary services for electric vehicles, the first and most important step is educational work.

Moreover, the analysis of the obtained data shows that for automakers and other (potential) market participants, the potential consumers' demands are various because of the heterogeneous preference structure. For example, men are significantly more interested in EV and electric mobility in general and show more passion in augmented reality via Head-up-Displays than women do, while older consumers would be attracted by good parking and charging services. Thus a segmentation strategy could be fruitful in the EVs market.

5.3 Limitations and further study

This study has the following limitations. First, though our sample size of 150 respondents is sufficient to provide an estimate of consumers' preference for complementary mobile services, it is relatively small. Second, the fast pace of technological innovations could mean that the results of this work are obsolete in a few years.

Based on the results of the dual-response analysis, various further analyses can be performed. Thus, for example, market simulations or willingness to pay for complementary services should be carried out. An important issue concerns the implementation of various business models and the integration of various complementary services in electric vehicles. Here, a detailed analysis of the complementary services subject to electronic processes should be carried out. In particular, the integration of accounting, billing and payment processes requires a detailed investigation. Finally, for automobile manufacturers, technologies should be improved to lower the electric cost which is the most effective way to improve EVs adoption.

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Appendix

Attributes	EV 1	EV 2	EV 3
Range per charge	250 km	100 km	175 km
Purchase price	€ 25,000	€ 35,000	€ 15,000
Charging time	1 hours	4 hours	1 hours
Electricity costs per 100 km	€ 5	€ 3	€ 1
Power	40 kW (~ 54 hp)	80 kW (~ 109 bhp)	80 kW (~ 109 bhp)
IT-based parking space and payment	✗	✓	✓
Intelligent charging station	✓	✗	✓
Augmented Reality a head-up display	✗	✓	✗
Please choose the electric vehicle for which you have the greatest preference.	⊙	⊙	⊙

Would you selected electric vehicle actually buy?

	Yes
	No