

A Work Project, presented as part of the requirements for the Award of a Master Degree in Management from the NOVA – School of Business and Economics.



CONSUMER PERCEPTIONS OF ELECTRIC VEHICLES: AN INVESTIGATION TO
DEVELOP A NEW BUSINESS MODEL FOR THE AUTOMOTIVE INDUSTRY

Fabian Weidner 3024

A Project carried out on the Master in Management Program, under the supervision of:
Luis Manuel da Silva Rodrigues

06.01.2017

Abstract

The automotive industry is influenced by a change in climate regulations and a reconfiguration of individual mobility solutions. Therefore, automotive stakeholders need to rethink their business model to remain competitive. Battery powered electric vehicles are a viable near-term solution to overcome environmental concerns and promote alternative propulsion technology. The aim of this study is to identify perceptions and concerns of 'early adopters', who might be willing to purchase an electric vehicle in the near future. Based on the results a business model is developed to address customer perceptions and promote the adoption of battery-powered electric vehicles.

Keywords: Electric vehicle, automotive industry, business model, customer perception

1. Introduction

After a century of optimising combustion engines, manufacturers have reached a technical boundary—there is no combustion without exhaust gases. Transport emissions account for 14% of global greenhouse gases and the proportion will increase to 50% by 2030 (IEA, 2010). This projection implies a transformation of the global vehicle industry to reduce climate change and dependency on fossil fuels. Due to higher emission standards, rising oil prices, and improvements made in battery technology, car manufacturers are beginning to realise the increasing potential of battery-powered electric vehicles (Kley et al., 2011). At this stage, battery-powered electric vehicles cost at least twice as much as gasoline-powered cars, while managing to travel only half the distance. Automotive managers and scientists expect major technological developments within the upcoming decade in order to meet customer needs. However, the boards of manufacturers hesitate for other reasons. Firstly, upfront funding for production facilities and R&D are high, therefore manufacturers are interested in operating

existing production facilities as long as possible. Secondly, they fear a phenomenon that threatens their market position—their knowledge and value chain is based on the development of fossil-fuelled motors, whereas the most valuable part of an electric vehicle is its battery. So far, manufacturers have little or no experience with the production of batteries. Finally, charging infrastructure is underdeveloped and major investments are necessary to guarantee comprehensive coverage (Frenken et al., 2004; Kley et al., 2011).

As the future is in electric transportation, it is important for automotive car manufacturers to act quickly. Should traditional car manufacturers hesitate to develop sustainable solutions, companies may go out of business, jobs may be lost, and global automotive industry hotspots will likely face economic downturns.

Despite the potential benefits of battery-powered electric vehicles, attitudes of customers must be addressed to promote the adoption of electric vehicle technology. Previous research suggests that fragmented charging infrastructure, underdeveloped battery technology, and high initial purchase costs currently dissuade consumers from buying a battery-powered electric vehicle (Kley et al., 2011). Thus, it is important to identify the social and functional barriers—and attributes desired by consumers—to designing a profitable business model for the automotive industry. This research investigates potential socioeconomic differences in perceptions towards battery-powered electric vehicles. Using an online survey administered to early adopters of battery-powered electric vehicles, the research examines functional and symbolic attributes of consumers to gain valuable insights for stakeholders in the electrification ecosystem.

2. Background

2.1 Reinvent the automotive business model

The basic idea of a successful business model is to design a product that is aligned with the demand of customers and gives the supplier a competitive advantage in order to sustain profits.

In the past, the objective of most manufacturers was to deliver quality products, with a focus on decreasing cost and ensuring timely delivery. Companies today seek to develop innovative products that cater to individual customer ideals to sustain global market leadership in a competitive economy. This innovative strategy transforms business models from a pure product-oriented solution to a business model based on a combination of product and service to retain customers. This approach has been defined as ‘product/service systems’ in research literature (Matzen et al., 2005). The underlying principle is not simply to offer the customer a product, but rather accompany the customer with individual services throughout the customer journey.

A structural approach to defining the prevailing automotive business model is divided into three elements to further explain the current model of how companies create, deliver, and capture value (Timmers, 1998):

Value proposition: The traditional automotive manufacturer promises his customer a high-quality vehicle with individual equipment features to offer a safe and comfortable driving experience. The product technology is based on an in-house powertrain production combined with a supplier network delivering materials and components for the vehicle. Thus, key players position themselves as pure hardware providers.

Value chain: The increasing level of internationalisation and globalisation leaves its mark in the value chain of automotive manufacturers. Influencing factors such as the emergence of new markets, fierce competition, exchange rate fluctuations and industry specific requirements change how and where cars are manufactured. Given the changing framework conditions the industry faces a shift from an export oriented business model to carrying out the value chain processes more proximally to the target market. Hence, it results in a re-configuration of traditionally-established value chain structure. Original Equipment Manufacturer (OEM) rely

on deep networks with their Tier 1 supplier. It enables them to quickly react to and adjust their business to changing customer demands in order to drive innovation, production, and logistic processes (Sturgeon et al., 2008). Other stakeholders operate a dense network of petrol stations to enable ongoing mobility for the customer.

Revenue concept: The automotive distribution channel is a combination of vehicle manufacturers and a network of franchise dealers who directly sale or lease the product to their customer. However, the industry has been disrupted by the increasing importance of internet technology. As it results in lower entry barriers for innovative companies challenging the old model of revenue generation. This transformation leads to a shift in power from traditional manufacturers to an innovative retailer network; in this case, one who offers customers the opportunity to find, evaluate, and buy a new vehicle at the lowest price (Biller et al., 2005).

To overcome the challenging market environment characterised by environmental policies and changing customer demands, new market entrants' automotive manufacturers need to transform their business models into a sustainable solution that guarantees ongoing profits and is aligned with customer perceptions. This involves a revision of the current business model in terms of value proposition, value chain, and revenue concept. Moreover, manufacturers still have a stable income from their traditional business model, which enables them to cross-subsidize a new business model. The introduction of a new sustainable technology has a high potential to reduce emissions and therefore is desirable to society. However, the business model must overcome market and customer barriers to challenge prevailing practices of value generation. Electric vehicles might be a sustainable solution for the future, but the consumer also needs to believe this. Car manufacturers should implement a business model that compensates for the higher initial cost compared to petrol cars. Thus, it should represent a shift from a product-based to a service-based approach.

2.2 Battery-powered electric vehicle characteristics

To create a holistic business model for the automotive industry, it is necessary to understand the key components that influence the implementation of battery-powered electric vehicles. By understanding the relationships between different shareholders, obstacles can be surmounted. Research literature identifies two key barriers, which impede the mass adoption of electric vehicles:

- Vehicle characteristics including battery technology
- Charging infrastructure

Battery-powered electric vehicles operate solely on a rechargeable electric battery. The battery represents a carbon-free mode of transportation if the energy is generated from renewable sources. Nevertheless, the technological commercialisation of these vehicles is limited and faces barriers due to a trade-off among different vehicular characteristics including power, energy, longevity, cost, and safety. However, the challenge leads to conflict between the demanded performance goals of automotive car manufacturers and consumers, and the battery manufacturers' ability to meet current technological requirements (Axsen et al., 2010; Andermann, 2008). Research indicates that the primary concern of battery manufacturers is energy storage. Therefore, a combination of energy storage and energy density determine the range of a vehicles battery. The range is used as an indicator for the maximum distance that a battery-powered electric vehicle can travel after a single charge. Recent models such as Mitsubishi iMiEV and VW e-Golf are limited to a range under 100 miles, with prices ranging from \$23,000 to \$35,000 depending on range and configuration of the vehicle. The market leader Tesla's model S and X, with a maximum range of 250 miles on a charge, cost between \$70,000 and \$120,000 (Campell, 2016).

As battery cost is a key economic driver for successful implementation, literature reveals that current and future battery prices have decreased from 2007-2014, from above \$1000 per kWh down to around \$410 per kWh. Thus, industry-wide cost declined by approximately 14% annually. The outlook forecasts a continued decline in battery costs as production and technical development increases. The continued trend of automation will further cut labour costs and facilitate an increase in production efficiency and quality. Additionally, individual parts and manufacturing costs will become less expensive due to experience and economies of scale. However, due to the increased demand, the costs of raw materials and standard parts are likely to remain stable (Nykvist & Nillson, 2015). It then follows that by 2020, battery costs will range between \$270 to \$330 per kWh, an overall cost reduction of 60% since 2009 (BCG, 2010).

As battery production does not represent a key competence of automotive manufacturers, two possible scenarios are feasible: one in which an OEM could form strategic alliances with battery manufacturers, and one in which the manufacturers continue to focus on the development of electric engines, and then simply buy the batteries from their suppliers. A few OEMs, such as Daimler and Toyota, have established partnerships with battery manufacturers to guarantee exclusive access to knowledge, technology, and production capacity. Nonetheless, these relationships limit the manufacturer ability to cooperate with other major players in innovative technological advances. In addition, exclusive partnerships decrease scale effects and delay cost reductions for battery manufacturers (Abdelkafi et al., 2013).

In the second scenario, the OEM sticks with their core competence by developing electric engines and purchasing additional parts from their Tier 1 suppliers. Some Tier 1 manufacturers have already established strategic partnerships with battery manufacturers. For instance, the joint venture between Samsung and Bosch is a win-win situation. The partnership leverages the ability to apply automotive expertise within battery production and provides access to OEMs based on long-term relationships with Tier 1 suppliers. For OEMs, this scenario offers the

opportunity to focus on core competences instead of on detailed knowledge of battery technology, but also enables them to leverage scale effects based on a comprehensive network of suppliers. Furthermore, this scenario allows for flexibility, as it reduces upfront investments and potential switching costs to innovative technology (Lim, 2010).

2.3 Infrastructure characteristics

The second component that guarantees ongoing mobility for the vehicle is the charging infrastructure used to supply the vehicle's battery with power. Currently, the literature discusses three different charging models: wireless and wired charging stations, as well as vehicle battery swapping stations (Kley et al., 2011).

Wireless power transfer offers the consumer a safer, more convenient, and more seamless alternative to wired cable-and-plug chargers. Nevertheless, development efforts of Tier 1 automotive suppliers like Delphi or Magna demonstrate that, due to the comparatively high associated investments required as opposed to other solutions, an unwired charging system might not be the most economically feasible solution (Musavi et al., 2012).

The charging infrastructure of wired technologies can be differentiated by mode of accessibility. Vehicles can be charged at a domestic location, such as in private parking places, garages, or at public charging points (Wietschel et al., 2009). Whilst the use of slow-charging solutions guarantees overnight charging while parked, a fast-charging infrastructure has already been debated the public domain. Slow-charging makes use of an on-board plug-in, where electricity is provided by voltage from the grid. Thus, the whole charging process takes around six to eight hours, influenced by thermal considerations and the amount of remaining energy in the battery (Botsford & Szczepanek, 2009).

Fast-charging technology can recharge the vehicle battery within minutes. Nevertheless, the technology requires voltages higher than can be provided by domestic power plugs. Thus, fast

charging is envisaged for public providers that have the capital necessary to install a comprehensive charging network. Public access to this technology has the advantage of encouraging long-term range travels by minimising the consumers range anxiety. Electric vehicle users would be able to recharge their vehicle on public grounds when they run out of battery. Fast-charging infrastructure offers two main benefits. Firstly, the user can easily make plans and conveniently recharge his or her vehicle. Secondly, fast-charging infrastructure offers a business opportunity for new stakeholders and traditional petrol players to enter the new market. However, the new technology is also associated with disadvantages, such as the reduction of the overall lifetime of the battery and the high levels of investment needed to provide a high-voltage charging network for the public (Schroeder & Traber, 2012).

Finally, battery swap stations where drivers can exchange their empty battery for a recharged one could only be managed on a public scheme similar to today's petrol station network. This technology eliminates the time a driver spends waiting for the vehicle battery to recharge. However, the technology would require a standardised battery format and station design to facilitate the swap of batteries. At this stage, car manufacturers have not standardised the accessibility, dimension, or type of battery as technological development is still in its very early stages (Worley & Klabjan, 2011).

In-depth research from Ahman (2006) in Japan and Skerlos and Winebrake (2010) in the United States indicate that public policy support mechanisms and a standardised charging system are crucial to stakeholder investments in a successful charging infrastructure. Possible operators of a charging infrastructure are either private households or public operators such as energy suppliers, petrol stations, OEM's, or new market players. However, the public operator would oversee the installation, maintenance, and billing system for the electric supply unit. In private households, the user would pay the electricity provider for the consumed electricity. In the public charging infrastructure, the payment model could either be free of charge, pay per use,

or a subscription plan. Investments in public charging infrastructure are mainly determined by adoption rates of electric vehicles, standardisation, local use rates, and incentives for private charging points. Additionally, further development of alternative propulsion technologies such as fuel cells and fuel technologies deteriorates investment incentives for public operators (Schroeder & Traber, 2012; Kley et al., 2011).

3. Methodology

3.1 Survey

To identify consumers' perceptions regarding electric vehicles, a quantitative web-based survey was conducted. The reason for the chosen method is that it gathers data in a cost efficient and short time period while accessing a specific and large target group (Blumberg et al., 2011). The questionnaire was distributed via social networks (Facebook, LinkedIn) and sent via email. To conduct and analyse the results in a professional manner, the research software Qualtrics was used. A web-based survey also has its disadvantages, such as when anonymous participants answer incompletely or jokingly. Another methodological weakness might be that participants are not familiar with the software or the topic of the questionnaire, which leads to the so-called 'non-response error' (Zikmund & Babin, 2006). To overcome this issue, follow-up messages were sent and the questionnaire was shortened to 6 minutes with a personal introduction. Another potential disadvantage might be that answers are biased and participants were not randomly selected. The questionnaire was distributed through social media, with the continuous contribution from other users exhibiting the so-called 'snowball sampling procedure'. Those individuals who found the study through social media might have the same social characteristics and interests as they interact in a similar social environment (Blumberg et al., 2011).

The 'target population' refers to private consumers who might be willing to buy an electric vehicle in the future. The participants are young consumers with an academic background. They

represent a customer segment with a high potential buying power who might consider buying a higher priced electric vehicle in the future. According to data from a 2014 study by the National Center for Education Statistics (NCES), the median income of young students aged between 25 and 34 is 66% higher compared to young adults with only a high school degree (NCES, 2016). Those educated young adults are also called the ‘early adopters’. As characterised by Rogers (2003), they have a higher educational background, are younger, have strong social bonds, are financially secure, and are more open-minded about new technologies. The survey is structured in three sections (Appendix 1). Firstly, a short introduction of the topic was provided, followed information for the participants about the time needed to complete the survey and a short notice that the data would be anonymised and only used for academic purposes. Secondly, participants were asked classification questions to determine demographic and geographic characteristics such as age, gender, and nationality. This approach simplifies a targeted and comprehensive segmentation (Question 1-6). Finally, the survey focused on the respondents’ attitude towards electric vehicles in terms of interest, perceptions, and concerns (Question 7-16). The objective of this part is to clarify and identify how a potential business model for electric vehicles could be designed, and if there are statistical differences among the respondents.

The main objective of the research was to identify potential electric vehicle owners based on their perceptions and interest. Furthermore, the research should reveal potential connections between socioeconomic characteristics and individual perceptions of battery-powered electric vehicles based on a statistical test.

3.2 Sample description

Over 170 people answered the survey, but some answers were not considered due to their incompleteness. Hence, 147 answers were used for further research analysis. The sample was

composed of 52% male participants and 48% female participants. With a Median age of 27 and a standard deviation of 3.2 the respondents were relatively young. Over 90% of the respondents were Germans, whereas 8% were Portuguese, and 2% indicated other nationalities. Furthermore, over 68% of the participants live in urban areas with 48% of those urban dwellers living in large cities and 20% live in metropolitan areas and the residual 32% live in rural areas. In sum, the sample collection may not be representative of the general population. However, it represents the targeted population of ‘early adopters’, who are characterised as young, with a higher-than-average educational background and an interest in new technologies.

3.3 Statistical analysis

The chi-square test was employed to identify possible relationships between two qualitative variables. Those variables are divided into two different groups. The first group are sociodemographic variables such as gender, age, education, and residence. The second variable category are different customer perceptions towards electric vehicles. The test based on a two-way table observes how much the cell counts of each variable diverge from the expected values.

Research question: Is there a statistical relationship between the two variables?

Ho: There is no statistical relationship between the row and column variable- Independent

H1: There is a statistical relationship between the row and column variable- Not independent

If the test determines that there is a statistical difference between the expected and observed value in the table, then this supports rejection of the null hypothesis and favours the alternative H1 hypothesis, represented by a significant p-value. Hence, a small p-value of $p \leq 0.05$ presents strong evidence to reject the null hypothesis and indicates a strong association between the two

variables. To run the chi-square test correctly and generate valid results, the sample size and the expected frequencies should be randomised and not too small. To achieve valid results, the expected frequencies in the cells must be greater than five and should account for a minimum of 80% of all possible cells. Since it is not always possible to have a perfect distribution for all possible scenarios, adjustments in the form of combination and exclusion are performed for some tests (Janes, 2001).

4. Results

The chi-square test was performed to identify relationships between the variables, and the results are shown in table 1. The intention of the table is to depict a summary of all relevant results obtained by the test.

Variables	Demographics											
	Gender			Age			Education			Residence		
	Qp	df	p-value	Qp	df	p-value	Qp	df	p-value	Qp	df	p-value
Interest	14.169	1	0.000*	5.552	2	0.062	6.873	1	0.009*	0.766	1	0.381
Purchasing	0.976	2	0.614	12.825	8	0.118	2.061	4	0.724	3.826	4	0.592
Safety	10.868	2	0.003*	4.601	4	0.331	4.196	2	0.123	3.367	2	0.186
External electricity	0.011	1	0.916	0.861	2	0.711	2.272	1	0.132	8.726	1	0.003*

Table 1 Perceptions of battery-powered electric vehicle

*p-value \leq 0.05

Respondents were asked to rate their interest in electric vehicles on a Likert scale from 1 (no interest) to 4 (high interest). With a median of 2.93 and a standard deviation of 0.915, participants showed a moderate level of interest. As the majority of our sample is characterised as ‘early adopters’ the results offer strong evidence that the respondents are interested in new vehicle technology. Further analysis with the chi-square test revealed a statistically significant association between interest in electric vehicles and the gender of the potential buyer (Qp=14.169, df= 1, p-value=0.000) and his or her level of education (Qp=6.873, df=1, p-value= 0.009). In addition, the chi-square table clarified that females showed less interest in electric vehicles than the model would have expected. Participants expressed less interest if their level

of education was below graduate or undergraduate level. Furthermore, the chi-square test indicated no statistical association with regard to the likelihood of purchasing an electric vehicle based on demographic characteristics such as gender ($Q_p = 0.976$, $df=2$, $p\text{-value} = 0.614$), age ($Q_p = 12.825$, $df=8$, $p\text{-value}=0.118$), education ($Q_p=2.061$, $df=4$, $p\text{-value}=0.724$), and residence ($Q_p=2.8$, $df=4$, $p\text{-value}=0.592$). Overall, respondents replied on a Likert scale from 1 (extremely likely) to 5 (extremely unlikely) with a median of 2.49 and a standard deviation of 0.986 that they are considering the purchase of an electric vehicle.

Over 69% of respondents perceived electric vehicles as a safe mode of transport. Nevertheless, statistical analysis displayed significant association between the perceived level of safety and gender. Based on the test results, ($Q_p=10.868$, $df=2$, $p\text{-value}=0.003$) in combination with the frequency deviations in the table, correlation suggests that males place greater trust in the safety of electric vehicles than females do.

The development of a customer-aligned charging infrastructure is one of the key drivers to increase the adoption rate of electric vehicles. Therefore, it is necessary to consider significant sociodemographic differences. This approach could facilitate adoption into the relevant customer segment. A key requirement for home charging is the availability of an external electrical outlet to charge the car during the night. The analysis revealed a statistical association between an external plug and residence. The results ($Q_p=8.726$, $df=1$, $p\text{-value}=0.003$) highlight disparities between urban and rural areas, since people living in urban areas have less access to an external electricity outlet than in rural areas.

4.1 Attributes of electric vehicles

Respondents ranked different attributes of electric vehicles according to their personal preferences. A summary of the results is illustrated in table 2.

Attribute	1 (Most appealing)	2	3	4	5	6 (Least appealing)	Mean (N=147)
Cheaper to operate	29%	29%	22%	10%	8%	2%	
	42	43	33	15	11	3	2.4
No tailpipe emission	42%	10%	16%	11%	6%	16%	
	61	15	23	16	9	23	2.8
Home recharging	9%	20%	16%	24%	21%	10%	
	13	3	24	35	31	14	3.6
Quiet and quick	12%	18%	12%	20%	27%	12%	
	17	27	17	29	39	18	3.7
Less maintenance	3%	14%	21%	13%	24%	25%	
	4	2	31	19	36	37	4.2
Look/style/comfort	7%	8%	13%	22%	14%	35%	
	10	12	19	33	21	52	4.4

Table 2 Ranking of battery-powered electric vehicle attributes

Overall, 42% (n=61) of all participants ranked ‘no tailpipe emission’ as the most appealing attribute of electric vehicles. This attribute is followed by ‘cheaper to operate’, with a median of 2.4 out of 6 based on a Likert scale from 1 (most appealing) to 6 (least appealing).

The attributes ‘home recharging’ and ‘quiet and quick’ ranked in the upper midfield with a mean of 3.6 and 3.7, respectively, while ‘less maintenance’ and ‘look/style/comfort’ were in last place. 35% (n=52) of respondents ranked ‘look/style/comfort’ as the least appealing attribute, suggesting that participants are far more interested in the technological advancements such as operation cost and environmental performance than in the equipment features of their vehicle. Even the vehicle’s performance in relation to engine performance and noise represented by the attribute ‘quiet and quick’ is generally perceived as less relevant, with a mean of 3.7. Nevertheless, 12% (n=17) of the participants still ranked performance as the most appealing attribute. In addition, none of the attributes were perceived as irrelevant, as even the least appealing characteristic ‘look/style/comfort’ has a mean value of 4.4.

Moreover, in two cases, chi-square analysis yielded significant association between socioeconomic variables and electric vehicle attributes (Table 3). Analysis revealed statistically significant differences between gender ($Q_p=4.425$, $df=2$, 0.020) and the attribute ‘no tailpipe emission’. Results from the chi-square cross table indicated that female respondents perceive

‘no tailpipe emission’ to be a significantly more appealing attribute than male respondents ranked it to be. Furthermore, younger respondents, between the ages of 18 and 22, indicate significantly higher levels of interest ($Q_p=15.287$, $df=4$, $p\text{-value}=0.004$) in the vehicle characteristic ‘look/style/comfort’ than older participants. However, analysis indicated that participants have a largely homogenous opinion about the most valued attributes of electric vehicles.

Attributes	Demographics											
	Gender			Age			Education			Residence		
	Qp	df	p-value	Qp	df	p-value	Qp	df	p-value	Qp	df	p-value
Cheaper to operate	1.248	2	0.536	2.751	4	0.621	2.735	2	0.255	1.321	2	0.517
No tailpipe emission	4.425	2	0.020*	6.448	4	0.168	0.236	2	0.889	0.979	2	0.613
Home recharging	1.413	2	0.493	1.908	4	0.753	2.147	2	0.342	2.901	2	0.234
Quiet and quick	2.025	2	0.363	3.014	4	0.555	0.494	2	0.781	2.888	2	0.236
Less maintenance	0.443	2	0.801	1.382	4	0.847	0.788	2	0.674	5.397	2	0.067
Look/style/comfort	1.526	2	0.466	15.287	4	0.004*	4.091	2	0.129	4.361	2	0.113

Table 3 Summary of chi-square results

*p-value ≤ 0.05

Since the development of electric vehicles and charging infrastructure is still at an early stage, consumer concerns about electric vehicles must be more thoroughly researched. Thus, table 4 presents a ranking of perceived concerns to identify key issues for the adoption of the new technology.

Concerns	Number of responses	%
Battery range	108	73%
Charging infrastructure	95	65%
Re-charging takes time	85	58%
Initial cost to purchase	80	54%
Re-charging is inconvenient	33	22%
Limited choice	33	22%
Safety	11	7%

Table 3 Concerns about battery-powered electric vehicle

Overall, over 73% ($n=108$) participants identified battery range as the key concern of electric vehicles, followed by 65% ($n=95$) who cited charging infrastructure, and 58% ($n=85$) who

indicated that the recharging time was a key inconvenience. Moreover, the initial purchase cost is ranked in fourth place, with only 54% (n=80) of participants perceiving it as a major concern. The last third of the table consists of 22% (n=33) of respondents suggesting that the availability of a limited choice of vehicle is a concern, followed by 7% (n=11) of respondents expressing concern for safety. In sum, the table can be split in two relevant groups. While the first group represents key features, which are necessary for a permanent, convenient operation, the second part focus more on the vehicle composition in terms of design and features. Consumers also seem to perceive electric vehicles as a safe mode a transportation, with only a few respondents expressing safety as a concern.

The battery of an electric vehicle requires regular charging due to range limitations. The final part of the survey focused on consumers' tendencies concerning the structural features of a functional and convenient charging infrastructure. One way to reduce customers' upfront cost is to reconsider the ownership model of the battery. However, around 50% (n=72) of respondents were undecided on battery ownership, and 30% (n=45) rejected the proposal to pay for a monthly battery subscription model. However, 74% (n=109) of respondents liked the idea of battery swap stations where drivers would replace a depleted battery with a fully charged one. One issue drivers currently face are long charging times, consequently over 70% (n=103) research participants demand for a convenient solution that quickly recharges their car within 5 to 15 minutes. Finally, over 75% (n=111) of the respondents indicated that they are more inclined to purchase electric vehicles with governmental incentives.

5. Discussion

As the research objective included gaining a broader perspective of consumers' perceptions of battery-powered electric vehicles, the research identified preferences and societal differences in the relevant consumer population to develop a sustainable business model for the automotive

industry. Results of the statistical analysis reveal that 'early adopters' indicate a high level of interest but reflects differences in gender and the level of education. Furthermore, the results suggest that the most valued attributes such as sustainability, operating cost, and a home-charging infrastructure can significantly influence the consumers' adoption of electric vehicles. However, the analysis highlights barriers perceived by consumers; barriers impede the uptake of electric cars. These barriers include range anxiety, caused by a limited battery capacity and a fragmented charging infrastructure. Many responses indicate that consumers expect a convenient, time, and cost-saving recharging model that guarantees ongoing mobility.

There has been a number of research seeking to assess consumer perceptions of electric vehicle. However, this paper aims to provide a holistic view of the perceptions of early adopters, which in the future should be included in a sustainable business model of automotive industry.

The research revealed key attributes valued by consumers. Consumer motivation for purchasing a vehicle is not just functional, but also symbolic in that it can send a message to their peers when driving the vehicle. Most of the participants would value the functional attribute of being able to charge their battery-powered electric vehicle at home. In addition, previous research conducted by Skippon et al. (2011) states that consumers also prefer on-the-spot fast-charging facilities and location for recharging at the workplace. This demonstrates that the availability of proximal recharging points is a key factor in driving consumers to purchase or not purchase a battery-powered electric vehicle.

One major obstacle for the implementation of comprehensive home-charging infrastructure is the absence of an external electrical outlet in urban areas. Public authorities and industry stakeholders need to provide adequate charging solutions to overcome this issue.

The findings of the survey also suggest a symbolic meaning of battery-powered electric vehicles for consumers. This is of particular relevance as it creates a link between product meaning and

self-expression. Heffner et al. (2007) examines the importance of hybrid electric vehicle purchase and use in a study of the Californian market for plug-in hybrid cars. For example, driving a battery-powered electric vehicle might be a signifier of environmental concern about protecting the environment from harmful emissions. Thus, a battery-powered electric vehicle not only provides mobility to its owner, but also a method of self-expression of identity (Kurani et al., 2006).

The results of this study support Kurani et al.'s findings, as 'zero tailpipe emissions' is an attribute highly valued by customers. Moreover, female respondents exhibited significant differences to males in terms of environmental concern. This gender-based bifurcation might be an important factor to note in future marketing and communication campaigns to further promote the adoption of battery-powered electric vehicles in comparison to cars operated by an internal combustion engine.

Many studies examine the assertion that battery technology is not ready for mass adoption in electric vehicles. Previous exploration of Axsen et al. 2010 into plug-in hybrid cars indicates that battery technology and its associated costs remain key barriers to the adoption of electric vehicles. In addition, studies by Andermann (2008) and Duvall (2002) claim that battery technology is not ready for mass commercialisation due to battery characteristics such as cost, reliability, lifespan, and capacity. Nevertheless, current development efforts indicate a strong trend towards decreasing cost and increasing battery range.

Previous research and discussion of further adoption of battery-powered electric vehicle compared to conventional cars has identified three major concerns: high initial purchasing cost, lower range, and inadequate recharging infrastructure. Hence, production and marketing of battery-powered electric vehicle would be more effective if such consumer concerns are addressed. OEMs must seize the opportunity to capitalise on the new technology. In order to

do so, they must respond to consumers concerns and effectively transform and shape an eMobility business model.

6. Conclusions and implications for the automotive industry

The results of the study deliver helpful insights to further promote the adoption of battery-powered electric vehicles. The findings demonstrate that interest and willingness to purchase are high despite several concerns such as battery technology, charging infrastructure, and initial purchase cost. Furthermore, research results suggest that the level of interest in buying electric vehicles differs significantly across gender and the level of education. Evidence provided in this study suggests that attributes such as ‘no emission’, ‘home-charging capability’ and ‘low operating cost’ have a major influence on the future consumer buying decision. These attributes are even ranked above attributes such as performance, design, and maintenance cost. The findings indicate that even though battery-powered electric vehicles still face some major challenges, the automotive industry can adapt to different consumer expectations by meeting functional and symbolic attributes to achieve commercial success.

The complexity of consumer perceptions requires a structured and suitable business model for battery-powered electric vehicle drivers. Furthermore, different stakeholders will participate and profit from the global eMobility expansion. The development and operation of electric vehicles requires a complex interaction between various stakeholders such as OEMs, Tier 1 suppliers, battery producers, energy suppliers, and charging infrastructure providers to further drive the market adoption.

To retain their share of the automotive profit pool, OEMs need to reshape their value proposition from a hardware provider to a mobility service provider. Therefore, OEMs need to focus on a business model that provides different levels of car ownership in order to address

customer demands. Furthermore, improvements in charging infrastructure, range capacity and environmental awareness will promote further adoption of battery-powered electric vehicle.

The collaboration between different stakeholders in the electrification value chain will be crucial for the success of electric mobility. Consequently, OEMs need various partners as to promote electric mobility and reduce customer concerns in terms of battery technology and charging infrastructure. Interconnectivity between Tier 1 suppliers, battery producers, and OEMs is crucial to develop a customer suitable product portfolio by minimising business risk. OEMs will need to explore and invest in collaborations for charging solutions that on the one hand provide home charging points like cooperative parking in urban areas and on the other hand fast-charging networks to reduce customer range anxiety.

Finally, OEMs should install a revenue concept that adequately encourages innovative ownership models for car-sharing or battery rental programs. A charging ecosystem must also be developed to promote mobile payment and billing.

In summary, today's automotive industry needs to further invest in the adoption process of battery-powered electric vehicles as a future based solely on internal combustion engines is no longer imaginable. Therefore, key stakeholders should cooperate in an electrification ecosystem to address the perceptions of customers.

References

Abdelkafi, Nizar, Sergiy Makhotin, and Thorsten Posselt. 'Business model innovations for electric mobility—what can be learned from existing business model patterns?.' *International Journal of Innovation Management* 17.01 (2013): 1340003.

Åhman, Max. "Government policy and the development of electric vehicles in Japan." *Energy Policy* 34.4 (2006): 433-443.

Anderman, M. "PHEV: A step forward or a detour?." *Presentation at SAE 2008 Hybrid Vehicle Technologies Symposium, San Diego, California.* 2008.

Anderman, M. "PHEV: A step forward or a detour?." *Presentation at SAE 2008 Hybrid Vehicle Technologies Symposium, San Diego, California.* 2008.

Axsen, Jonn, Kenneth S. Kurani, and Andrew Burke. "Are batteries ready for plug-in hybrid buyers?." *Transport Policy* 17.3 (2010): 173-182.

BCG, Boston Consulting Group, 2010; Batteries for Electric Cars; <http://www.bcg.com/documents/file36615.pdf>; (06.11.2016)

Biller, Stephan, et al. "Dynamic pricing and the direct-to-customer model in the automotive industry." *Electronic Commerce Research* 5.2 (2005): 309-334.

Blumberg, B., Cooper, D. & Schindler, P. S. (2011). *Business Research Methods*. Mc Graw Hill. 2nd European ed.

Botsford, Charles, and Adam Szczepanek. "Fast charging vs. slow charging: Pros and cons for the new age of electric vehicles." *International Battery Hybrid Fuel Cell Electric Vehicle Symposium*. 2009.

Campell, Peter; Electric cars see range, battery and ease of charging as barriers to mass adoption; <https://www.ft.com/content/8f79ae6e-2400-11e6-9d4d-c11776a5124d>; (5.12.2016)

Duvall, M. "Comparing the benefits and impacts of hybrid electric vehicle options for compact sedan and sport utility vehicles." *Final Report* 1006892 (2002).

Frenken, Koen, Marko Hekkert, and Per Godfroij. "R&D portfolios in environmentally friendly automotive propulsion: Variety, competition and policy implications." *Technological Forecasting and Social Change* 71.5 (2004): 485-507.

Heffner, Reid R., Kenneth S. Kurani, and Thomas S. Turrentine. "Symbolism in California's early market for hybrid electric vehicles." *Transportation Research Part D: Transport and Environment* 12.6 (2007): 396-413.

IEA, International Energy Agency, 2010; Co2 emissions from fuel combustion; <http://www.iea.org/media/training/presentations/statisticsmarch/co2highlights.pdf>; (10.12.2016)

Janes, Joseph. "Categorical relationships: chi-square." *Library hi tech* 19.3 (2001): 296-298.

Kley, Fabian, Christian Lerch, and David Dallinger. "New business models for electric cars— A holistic approach." *Energy Policy* 39.6 (2011): 3392-3403.

Kurani, Kenneth S., Thomas S. Turrentine, and Reid R. Heffner. "Narrative self-identity and societal goals: Automotive fuel economy and global warming policy." *Driving climate change: Cutting carbon from transportation* (2007): 217-238.

Lim, Tae-Yun. "Rapid emergence of rechargeable car battery market." *SERI Quarterly* 3.2 (2010): 23.

Matzen, Detlef, Adrian Ronald Tan, and Mogens Myrup Andreassen. "Product/Service-Systems: Defining a coherent terminology." *DFX 2005: Proceedings of the 16th Symposium on Design for X, Neukirchen/Erlangen, Germany, 13.-14.10. 2005*. 2005.

Musavi, Fariborz, Murray Edington, and Wilson Eberle. "Wireless power transfer: A survey of EV battery charging technologies." *2012 IEEE Energy Conversion Congress and Exposition (ECCE)*. IEEE, 2012.

NCES (National Center for Educational Statistics); Annual earnings of young adults; https://nces.ed.gov/programs/coe/indicator_cba.asp; (28.11.2016)

Nykqvist, Björn, and Måns Nilsson. "Rapidly falling costs of battery packs for electric vehicles." *Nature Climate Change* 5.4 (2015): 329-332.

Rogers, E.M (2003) Diffusion of Innovations. Fifth Edition. Free Press, New York.

Schroeder, Andreas, and Thure Traber. "The economics of fast charging infrastructure for electric vehicles." *Energy Policy* 43 (2012): 136-144.

Skerlos, Steven J., and James J. Winebrake. "Targeting plug-in hybrid electric vehicle policies to increase social benefits." *Energy Policy* 38.2 (2010): 705-708.

Skippon, Stephen, and Mike Garwood. "Responses to battery electric vehicles: UK consumer attitudes and attributions of symbolic meaning following direct experience to reduce psychological distance." *Transportation Research Part D: Transport and Environment* 16.7 (2011): 525-531.

Sturgeon, Timothy, Johannes Van Biesebroeck, and Gary Gereffi. "Value chains, networks and clusters: reframing the global automotive industry." *Journal of economic geography* (2008): 314-378.

Timmers, Paul. "Business models for electronic markets." *Electronic markets* 8.2 (1998): 3-8.

Wietschel, Martin., Kley Fabian, and Dallinger David. "Eine Bewertung der Ladeinfrastruktur für Elektrofahrzeuge." *Zeitschrift für die gesamte Wertschöpfungskette Automobilwirtschaft* 12.3 (2009): 33-41.

Worley, Owen, and Diego Klabjan. "Optimization of battery charging and purchasing at electric vehicle battery swap stations." *2011 IEEE Vehicle Power and Propulsion Conference*. IEEE, 2011.

Zikmund, William, and Barry Babin. *Exploring marketing research*. Cengage Learning, 2006.

Appendix 1

Electric vehicle consumer survey

1. What is your gender?

Male	76	52%
Female	71	48%

2. What is your age?

147 Responses

3. What is your nationality?

147 Responses

4. What is your occupation?

Student	106	72%
Employed	40	27%
Unemployed	1	0.6%
Retired	0	0

5. Please indicate your highest level of education?

High school	4	3%
Apprenticeship	4	3%
Bachelor	64	44%
Master	65	44%
PhD	10	7%

6. Where are you currently living?

Metropolitan area	29	20%
Large city	71	48%
Small city	44	30%
Rural area	3	2

7. How would you rate your interest towards battery electric vehicle?

No interest	5	3%
Little interest	36	24%
Moderate interest	59	40%
High interest	47	32%

8. How likely would you consider purchasing a battery electric vehicle?

Extremely likely	18	12%
Somewhat likely	78	53%
Neither likely or unlikely	26	18%
Somewhat unlikely	20	14%
Extremely unlikely	5	3%

9. How important do you think are governmental incentives to support the diffusion of battery electric vehicle?

Extremely important	53	36%
Very important	58	39%
Moderately important	28	19%
Slightly important	4	3%
Not important at all	4	3%

10. Please rank the following attributes of battery electric vehicles in terms of which appeal to you most (1 being the most appealing and 6 being the last appealing)

- Cheaper to operate
- Home recharging
- No tailpipe emission
- Look/style/comfort
- Quiet and quick
- Less maintenance

11. What are your biggest concerns about battery electric vehicles? (Tick all that apply)

Initial cost to purchase	80	54%
Battery range	108	73%
Safety	11	7%
Charging infrastructure	95	65%
Re-charging takes time	85	58%
Re-charging is inconvenient	33	22%
Limited choice	33	22%
Other, please specify	9	6%

12. "Quick-charging" is capable of charging your vehicle's battery in a shorter period of time. If such chargers were available at public stations, how quickly would you expect your battery to be charged full?

1-5 min	22	15%
5-10 min	60	41%
10-15 min	43	29%
Greater than 15 min	22	15%

13. Would you be more willing to purchase an electric vehicle if the ownership of the battery and the vehicle were separated such that you could purchase the vehicle without the battery for a lower price and instead pay for a monthly subscription.

Yes	30	20%
No	45	30%
Unsure	72	49%

14. Do you like the idea of "battery swap stations" where your depleted battery could be swapped out and replaced with a fully charged battery in one minute?

Yes	109	74%
No	20	14%
Unsure	18	12%

15. Do you have accessibility to an external electrical outlet to charge an electric vehicle where your car is parked at your primary residence?

Yes	27	18%
No	120	82%

16. Electric vehicles are a safe mode of transportation

Strongly agree	47	32%
Somewhat agree	55	37%
Neither agree nor disagree	40	27%
Somewhat disagree	3	2%
Strongly disagree	2	1%