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Electric Vehicle Adoption: Empirical Analyses

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Saiful Hasan
Bodø, June 2021

To my caring mother and father

Abstract

Economic development, industrialisation, and the growing population are contributing to the increased demand for transportation, particularly road transportation, which in turn leads to severe environmental and energy challenges. This is because transportation is responsible for consuming a large percentage of fossil fuels and greenhouse gas emissions. Policymakers worldwide are attempting shift to electrification of transportation to mitigate environmental and energy challenges caused by transportation. Consequently, policymakers in many countries are implementing sets of generous policy packages and investing in infrastructure to promote widespread adoption of electric vehicles (EVs). However, many consumers are still sceptical about this transport innovation. Consumers are some of the key participants in the transition process of electrified transportation because it is they who must ultimately accept this technological innovation. More scientific studies are necessary to gain an in-depth understanding of EV users' and potential EV buyers' behaviour to evaluate the demand for EVs and their use. Moreover, the efficacy of policy measures remains inconclusive. In addition, other potential factors such as regional accessibility and the climate, have received limited attention in EV literature.

This thesis comprises four articles that aim to contribute to the knowledge base related to EV adoption. Article 1 investigates regional differences in the adoption of EVs in Norway. It finds that accessibility, climate, and exemption of ferry significantly affect the EV adoption rate. Article 2 investigates the differences in EV use between two subgroups of EV users (owners who own only EVs and owners who own both EVs and internal combustion engine vehicles). The findings of this study indicate that economic aspects impact the EV use of the owner who owns only an EV, and perceived operating barriers impact the EV use of the owner who owns both an EV and ICEV. Article 3 attempts to bring some insights into identifying the attributes of EVs that need to be improved for it to be more attractive to consumers, thus contributing to the establishment of a greener road transport system. In this study, the importance–performance analysis models suggest that policymakers and car manufacturers should focus on improving instrumental aspects (e.g. driving range, safety features, fuel efficiency, recharging duration), winter driving performance, and cost aspects related to purchasing and driving EVs to make EVs more attractive to consumers. Article 4 endeavours to investigate the factors that play a critical role in shaping EV users' behavioural intention to repurchase EVs. The findings of this study posit that EV users' satisfaction affects their behavioural intention through their attitude and perceived functional barriers. Moreover, users' attitudes towards environmental and economic aspects of EV use have greater effects than subjective norms and perceived functional barriers on their behavioural intention.

This thesis uses multiple methods to conduct empirical analyses. Article 1 and Article 2 use the ordinary least squares regression models, whereas Article 3 and Article 4 use quadrant–diagonal importance–performance analysis models and structural equation models, respectively. The data sets of the articles were collected from multiple sources. Data sets from secondary sources were used for the first article's analysis, whereas survey data sets were used for the second, third, and fourth articles.

The combined findings of four articles suggest that the functional, environmental, and economic aspects of EVs are the most important factors that dominate consumer behaviour. In other words, these aspects are the main drivers of the demand for EVs and their use. Moreover, publicly accessible charging infrastructures, regional accessibility, and climate play a critical role in driving EV demand. The findings of this thesis are of interest to policymakers and makers of

electric cars. The insights from this thesis are useful not only in comprehending consumers' behaviour and the effects of policy measures, in-depth but also in allocating limited resources in the promotion and production of EVs.

Table of Contents

List of Tables

List of figures

1. Introduction

The depletion of fossil fuels, growing dependency on fossil fuels, increased environmental challenges caused by the fossil-fuel-dominated transport sector, advancement of battery technology, and their manufacturing process have promoted a transition towards the electrification of transport (Gönül et al., 2021). Twenty-four percent of direct CO_2 emissions from fuel combustion are caused by the transportation sector (Teter, 2020). Road transport (e.g. cars, trucks, buses, two wheelers, and three wheelers) is responsible for nearly three-quarters of transport emissions. The increased CO_2 emission contributes to poor air quality and increasing global temperatures, which leads to climate change (Milev et al., 2021). Climate change impacts agriculture, sea levels, human health, the economy, and human migration (Black et al., 2011; Erickson and Jennings, 2017; Incropera, 2015; Sachs, 2015). It is claimed that the impacts of climate change will be lessened by keeping the increase in global temperature to 1.5 °C or less (IPCC, 2018).

Javid et al. (2014), Javid et al. (2017), and Javid and Nejat (2017) classified the strategies to mitigate the emission caused by transport into three categories: reduce greenhouse gas emissions per passenger kilometre; avoid unnecessary energy consumption and encourage the use of public transport, walking, and cycling; replace fossil fuels with alternative fuels that emit less CO_2. CO_2 emissions can be reduced by the electronification of transport replacing fossil fuel-driven transportation.

Electric vehicles (EVs) have potential considerable societal and individual benefits when compared to conventional vehicles driven by internal combustion engines (ICEs) (Noel et al., 2019). EVs are more fuel-efficient than their counterparts – conventional cars with IC engines, have less or zero tailpipe emissions, generate little engine noise, and have comparatively lower operating costs; they, thus, improve the overall driving experience for EV owners (Bradley and Quinn, 2010; Casals et al., 2016; Degirmenci and Breitner, 2017; Javid and Nejat, 2017). The electrification of transport reduces not only local CO_2 emissions but also oil dependency (Casals et al., 2016). Electricity used to run EVs can be produced from multiple sources allowing diversification of energy sources in transportation (Y. Zhang et al., 2016). In contrast, ICEVs depend solely on fossil fuels, thus, creating dependency on a singular energy source.

Despite its merits and benefits, there is concern that if electricity that runs EVs is sourced from burning conventional fossil resources, the mass EV adoption will transfer the pollution from tailpipe to smokestacks to an extent (Larcher and Tarascon, 2015; Onat et al., 2015). Therefore, the true environmental impact of EVs depends on non-tailpipe emissions from fuel and energy production (Casals et al., 2016; Logan et al., 2020; Morrissey et al., 2016). In addition, the extraction and treatment of various metals for battery production, and their recycling and disposal may have considerable logistical, energetic, and environmental impacts (Notter et al., 2010; Richa et al., 2014). However, Orsi (2021) anticipates that continuous technological advancement and targeted policy measures can solve these issues. Casals et al. (2016) cited that all European countries have already put considerable effort into decarbonising their electricity-generating sectors. As of 2020, Norway and Iceland have the capacity to provide EVs with nearly 100% renewable electricity (Wappelhorst and Tietge, 2018). However, as emphasised by Felice et al. (2021), the reduction of greenhouse gas emissions following a transition towards more use of EVs depends on both decarbonisation of the electricity sector and the individual's driving behaviours.

1.1 Types of Electric Vehicles

EVs are designed to be propelled entirely, or at least partially, by electric energy. Although EVs have gained popularity in recent decades, they are not new inventions as they were introduced more than 100 years ago (Matulka, 2014; Niestadt and Bjørnåvold, 2019). However, the lack of advanced battery technologies, weak electrical networks, and cheap fossil fuels have led to the rapid development of ICEVs over EVs for years (Gönül et al., 2021). In recent decades, EVs have gained popularity mostly because of the growing concern over environmental and energy challenges, improved battery technology, the implementation of financial incentives in many countries, and consumer behaviour supporting the transition towards electric mobility (Baur and Todorova, 2018; Gönül et al., 2021; IEA, 2016, 2018, 2020; Mock and Yang, 2014).

Generally, EVs are categorised as battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). BEVs (e.g. Nissan Leaf, Tesla Model 3, Renault Zoe) are also labelled as pure EVs or all-electric vehicles in which one or more batteries store energy and power the electric drivetrain (Campanari et al., 2009; Larminie and Lowry, 2003). The batteries on BEVs are recharged from the electric grid and by the braking system when the vehicle is decelerating (Villalobos, 2016). Moreover, the architecture of BEVs is less complex than that of PHEVs, HEVs, and ICEVs (Nieuwenhuis et al., 2020; Villalobos, 2016).

HEVs (e.g. Lexus RX450h, Honda NSX, Toyota Yaris Hybrid) combine an ICE with an electric motor. As such, HEVs have better fuel efficiency than similar-sized ICE vehicles. However, all its energy originates from liquid fuel (Egbue and Long, 2012; Schuitema et al., 2013).

PHEVs (e.g. Mitsubishi outlander, Fiat 500e, BMW i8) are equipped with more powerful electric batteries than HEVs and can be plugged into the electric grid to recharge the battery. In addition, the battery onboard the vehicle can partly be recharged by the regenerating braking system (Schuitema et al., 2013).

It is also worth mentioning that some scholars categorise fuel-cell electric vehicles (FCEV) (e.g. Toyota Mirai, Volkswagen Crafter HyMotion) as EVs which have both a battery pack and a fuel cell powered by hydrogen onboard (Offer et al., 2010; Thomas, 2009; Villalobos, 2016). The fuel cell device on the FCEV converts hydrogen and oxygen (obtained from the air) into electricity, heat, and water. The hydrogen in the fuel cell is refilled from the hydrogen station. Usually, an FCEV does not require an external charging system, although automakers could design it with plug-in capabilities to recharge the battery (Das et al., 2020; US Department of Energy, n.d.). FCEVs use onboard batteries to recapture the regenerating braking energy to provide additional power during short acceleration events, and smooth out the power delivered from the fuel cell with the option of idle or turning off the fuel during low power needs (US Department of Energy, n.d.). Similar to BEVs, FCEVs have zero tailpipe emissions.

1.2 Global Electric Vehicle Market

The electric car stocks reached 7.2 million in 2019 of which 4.79 million were BEVs (IEA, 2020). The total BEV stock increased by 1.5 million over a year from 2018. This is a great increase from the numbers in 2005, when the total BEV stocks were only 1670 worldwide (IEA, 2016). EVs accounted for 2.6% of the global car sales in 2019. Although BEVs are the dominant EV technology in the United States and Europe, they represent a smaller market share than in China (Deloitte Insights, 2020). In 2019, China held the leading position in terms of numbers of BEVs with a total of 2.58 million BEV stocks in the market whereas, in terms of BEV market share of all new car sales, Norway topped worldwide with 42% market share (IEA, 2020; Norsk Elbilforening, 2019). In the United States, the BEV stocks increased to 0.88 million in 2019 from 0.64 million in 2018 (IEA, 2020). In 2019, Europe had significantly more EV market growth than any other region. This growth continued to 2020 (Deloitte Insights, 2020; Irle, 2021). In 2020, the EV market share in Europe, combining both BEVs and PHEVs, increased from 10.2% to 3.3% in 2019 (Irle, 2021). Gönül et al. (2021) find that EV sales are generally higher in economically more developed countries and that GDP per capita and EV market share are positively correlated in EU countries. They further noted that the EV market share is less than 1% in EU countries where the GDP per capita is less than € 29,000 and more than 3.5% in EU countries where GDP per capita is more than € 42,000. However, despite its relatively low GDP per capita, Portugal has managed to have a considerably higher EV market share with its generous and effective policy measure.

As of 2020, 17 countries have indicated the target of 100% zero-emission vehicles or, in other words, phasing-out of ICE vehicles by 2050 (IEA, 2020). According to Wappelhorst (2020) and Wappelhorst and Cui (2020), Norway aims to phase out ICEVs by 2025, Iceland, Ireland, the Netherlands, and Sweden by 2030, Scotland by 2032, Denmark and the United Kingdom by 2035, France and Spain by 2040, and Costa Rica by 2050. Moreover, carmakers are setting targets for EV manufacturing. For instance, BMW aims to deliver 2 million pure EVs or BEVs worldwide, with approximately 90% of its vehicle lines to be all-electric by 2023; Ford has invested in EV initiatives to have approximately 40 EV models in their model line-up by 2022; Volvo and General Motors plan to become carbon neutral by 2040; Hyundai promises to introduce 23 EV models worldwide by 2025; Volkswagen targets 60% EV sales in the European market by 2030; Jaguar plans to go climate neutral by 2036; Mazda, Mitsubishi, and Nissan plan to reach net-zero emissions by 2050 (Ghosh, 2021; Levin, 2020; White, 2021). In 2020, Volkswagen ID.3, Tesla Model 3, Renault Zoe, Hyundai Kona EV, and Renault Captur PHEV were the top five EV models sold in Europe, whereas Wuling HongGaung Mini EV, Tesla Model 3, Great Wall Ora R1, BYD Han EV, and Baojun E-Series were the top five EV models sold in China (Pontes, 2021a, 2021b).

Globally, several countries have formed a multi-governmental policy forum called the Electric Vehicle Initiative (EVI) to accelerate the adoption of EVs (IEA, 2021). These countries are Canada, Chile, China, Finland, France, Germany, India, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, and the United Kingdom. In 2017, the EV30@30 campaign was launched with a target to reach at least 30% of new EV sales by 2030.

The fuel cost for EVs is much cheaper than that for ICEVs, particularly in Europe and the United States. Orsi (2021) illustrates that in Europe, driving 100 km with ICVEs would cost, on average, 8.2 euros of gasoline, whereas with BEVs, it would cost, on average, 3.4 euros of electricity and savings on fuel cost would be similar in the US.

However, in most countries, EVs are more expensive to buy than ICEVs, primarily because of the high battery price. However, the cost of batteries used on EVs is shrinking faster than what was expected a few years ago. Recent technological advancement and the growth of the EV market, which leads to economies of scale, is driving the battery price below $100/kWh (Henze, 2020). The lithium-ion battery pack price fell by 89% to, on average, $137/kWh in 2020 from, on average, $1,100/kWh in 2010. Based on the current growth in technological advancement and battery demand, the price of an average battery pack is expected to be approximately $62/kWh by 2030 (Goldie-Scot, 2019). Furthermore, with the improvement of technology, batteries have become more powerful, longer-lasting, more efficient, and less expensive. Consequently, the introduction of new models with improved battery performance and lower upfront cost can be expected to reduce the residual value of existing EVs (Alten and Gosling, 2020).

IEA (2020) indicates that most EVs are charged at home and workplaces, but installing publicly accessible charging facilities is outpacing EV sales worldwide. In 2019, almost 37% of private EV slow chargers were in China. In addition, IEA's (2020) data suggest that, with respect to publicly accessible slow and fast chargers, China stands ahead of other countries, followed by the United States. In 2019, there were approximately 7.3 million EV chargers worldwide, of which approximately 6.5 million were private EV chargers for light-duty vehicles (IEA, 2020).

1.3 Norwegian Electric Vehicle Market

In 2020, Norway reached its highest EV market share of 74.7% worldwide (Statista, 2021). Norway retained its top position in terms of the market share of all new car sales over the past several years. The market share of BEV for all new car sales was 54.3% in 2020 which was a 29% increase from the market share in 2019. In 2020, 346,822 BEVs and 142,847 PHEVs were sold in the Norwegian market. The continuous success in EV adoption in Norway is the result of a generous policy package that has consistently been motivating consumers to choose EVs over ICEVs (Fearnley et al., 2015; Figenbaum, 2017; Figenbaum et al., 2015; Holtsmark and Skonhoft, 2014). However, Fridstrøm (2020) argued that stiff taxation on ICEVs and fossil fuel is, in fact, the main driver of growing EV demand in the Norwegian EV market rather than generous subsidisation.

Norway started implementing policies to benefit EV owners in 1990 by introducing temporary exemptions from purchase or import taxes (Figenbaum, 2017). Gradually, over the years, it broadened the scope of the policy (Table 1.1). However, the policy measures were continuously revised over the years. The reduction taxation on a company's electric cars was revised multiple times since it was introduced in 2000. Since 2017, local governments had the authority to decide policy incentives regarding access to bus lanes and municipality parking (Norsk Elbilforening, 2020). Local governments have already started charging EV owners discounted road tolls, municipal parking fees, and ferry fees. However, the rule is that municipalities cannot charge more than 50% of the price of ICEVs on road tolls, municipality parking, and county ferries. The Norwegian government expects all new cars to be either fully electric or hydrogen-driven by 2025 by strengthening the green tax system which is based on the polluter pays principle (Norsk Elbilforening, 2020). The polluter pays principle suggests that cars with high emissions should pay higher taxes than cars with lower or zero emissions. This tax system on polluting cars serves two purposes: demotivates the purchase of fossil fuel cars and helps to finance incentives for zero-emission cars by collecting taxes from people who still decide to own cars driven by fossil fuels.

Table 1.1: EV Policy measures development in Norway

1990–2000	Exemption from purchase or import tax Reduced annual vehicle license fee Exemption from road tolls Exemption from parking fees in public parking places Reduced taxation on company's electric cars
2000–2015	VAT exemptions on purchase and leasing Access to bus lanes Exemption from ferry fees Exemption congestion charges for EV
2017–Present	Local governments are given authority to decide the policy incentives regarding access to bus lanes, exemption of fees for municipal parking facilities, and ferry services

Source: (Figenbaum et al., 2015; Norsk Elbilforening, 2020)

In a study on Norwegian BEV owners (private), Fevang et al. (2020) found that BEV owners tend to live in larger cities and their suburbs, with only 30% of BEV owners living in rural areas. In addition, the findings indicate that BEV owners earn more than ICEV owners. BEV owners tend to belong in the age group of 25–44 years old and tend to be more educated than owners of ICEVs. Finally, BEV ownership is comparatively higher among couples with children than in single-adult households.

1.4 Factors Influencing EV adoption

To achieve widespread adoption of EVs, both policymakers and carmakers need to have an in-depth understanding of the influential factors and potential barriers in the market. The literature on EVs has endeavoured to analyse the adoption of EVs by applying theories from various domains and using various societal and geographical contexts. Researchers have investigated the role of several factors in understanding their influence on consumers' EV buying behaviour. These include purchasing and operating costs (Caperello and Kurani, 2012; Egbue and Long, 2012; Graham-Rowea et al., 2012; Sovacool and Hirsh, 2009; Y. Zhang et al., 2011); density of charging stations (Byun et al., 2018; Javid and Nejat, 2017); distance to charging stations (Rasouli and Timmermans, 2016); recharging duration and frequency (Globisch et al., 2013); environmental awareness (Smith et al., 2017); availability of EV models (Hasan and Mathisen, 2021; Hoen and Koetse, 2014); perceived accidental risk (Simsekoglu and Nayum, 2019); public awareness about EVs and incentives (Figenbaum et al., 2015; Figenbaum and Kolbenstvedt, 2013; Y. Zhang et al., 2011); instrumental attributes (Azadfar et al., 2015; Neubauer and Wood, 2014); policy incentives (Langbroek et al., 2016; Lévay et al., 2017; Qian and Soopramanien, 2011; Sierzchula et al., 2014); and symbolic attributes (Gjøen and Hård, 2002; Heffner et al., 2007).

The impact of charging infrastructure on the widespread adoption of EVs is still not clear. Sierzchula et al. (2014) analyse EV adoption in 30 countries and conclude that charging infrastructure is the main predictor, followed by financial incentives. Illmann and Kluge's (2020) study on German data identifies a positive long-run relationship between charging infrastructure and EV diffusion. However, the findings indicate that consumers respond more to charging speed than they do to the number of public chargers. Globisch et al. (2013) find that consumers express positive attitudes towards charging at home, whereas they express concern about the charging duration and frequency. In Norway, 75% of EV users have private chargers, and for longer distances, they tend to use ICEVs to avoid the limited driving distances of EVs (Figenbaum, 2017; Figenbaum and Kolbenstvedt, 2016; Illmann and Kluge, 2020).

Policy incentives, particularly purchase-based incentives, are critical in motivating consumers to purchase EVs (Fearnley et al., 2015; Lutsey et al., 2015; Sierzchula et al., 2014). Norway, Iceland, the Netherlands, Sweden, and Finland have the highest EV market share of all new car sales in 2019 (Gorner, 2020). Having a look at the policy measures they implement to promote mass EV adoption could provide some insights for other countries to plan strategies. Norway has a comprehensive package to benefit BEV owners, such as exemptions from purchase tax, VAT, annual road tax, exemption or discounted road tolls, ferry fees, and fees at municipal parking places (see Table 1). Iceland exempts vehicles with low emissions from import duties, VAT exemptions or discounts, free recharging, and time-limited free parking in targeted cities (Wappelhorst and Tietge, 2018). Another top runner, the Netherlands, waives registration tax and annual ownership tax for BEV owners (Wappelhorst, 2021). In addition, EV owners can claim up to 4000 euros from the government when they purchase BEVs. Likewise, Norway and the Netherlands also opt for BEVs and implement higher taxes for gasoline cars to demotivate consumers (Wappelhorst, 2021). Santos and Rembalski (2021) claim that purchase incentives that reduce EV purchase costs play an effective role in promoting BEVs in the UK. Lévay et al. (2017) find that policy incentives led to the lowest total cost of ownership (TCO) for EVs in Norway, and close to the TCO of the ICEVs in the Netherlands, France, and the UK. Furthermore, in a study comparing the total cost of ownership (TCO) between Norway and Italy, Scorrano et al. (2019) observed that BEVs are more competitive in Norway than in Italy because the annual TCO/km is lower in Norway. The study further argues that higher taxes on ICEVs also play a role in the adoption of EVs in Norway. Consequently, previous studies indicate that countries need to invest heavily in lowering the cost aspects of EV use to keep users satisfied and increase the likelihood of their repurchase intention. Moreover, it is suggested that proposing different policy incentives for different types of EVs rather than providing homogenous policy incentives is necessary to achieve substantial EV market growth (Hardman et al., 2017). However, despite its potential benefits, financial incentives have been criticised. It is argued that financial incentives drive financial pressure on local governments and they are similar to social welfare but can only be enjoyed by purchasing BEVs, which can be deemed as an unfair approach (Li et al., 2020; N. Wang et al., 2017). Moreover, use-based policy incentives, such as exemption from road tolls, parking fees, and allowing access to bus lanes, might have a rebound effect (Langbroek et al., 2016) as they reduce the operating cost of EV use, leading to an increased level of travel activities. It is also important to design diverse policy incentives that target EV types rather than providing homogenous policy incentives (Hardman et al., 2017).

Researchers and policymakers should encourage the technical development of charging infrastructures, EV batteries, and the psychological effects on consumers (Q. Zhang et al., 2018). X. Zhang et al. (2013) indicated that the performance attributes of EVs are more crucial to consumers' willingness to buy compared with financial benefits.

Besides the availability of charging infrastructures and high upfront purchase price, EV battery range or capacity is another critical factor from a consumer's point of view (Gönül et al., 2021). Low battery range, long recharging duration, and limited publicly accessible charging infrastructures cause psychological stress known as range anxiety (Melliger et al., 2018). However, vehicle owners tend to overestimate their range needs for their day-to-day driving pattern (Franke and Krems, 2013; Rauh et al., 2017). For instance, Norwegian car owners drive, on average, 21 miles a day (Statistics Norway, 2017); American car owners drive, on average, 37 miles a day (Kopestinsky, 2021); a British car owner drives, on average, 20 miles a day (Yurday, 2021); and Icelandic car owners drive, on average, just under 24 miles a day (Wappelhorst and Tietge, 2018). However, most EV models in the market have more battery range on a single charge than users usually drive a day on average. For example, as of January 2021, Tesla Model 3 Standard Range, Tesla model S Long-range, Audi e-tron, BMW i3, Nissan Leaf S, Chevrolet Bolt EV, and Kia Nitro Electric have ranges of 263, 405, 222, 123, 150, 259, and 239 miles, respectively (EV Adoption, 2021).

The influence of psychological and behavioural factors on EV adoption has also been investigated in the existing literature on consumer EV adoption (Liao et al., 2017; Noppers et al., 2015; Rezvani et al., 2015; Schuitema et al., 2013; Simsekoglu, 2018; Simsekoglu and Klöckner, 2018). Scorrano et al. (2019) posit that besides the monetary benefits of owning EVs, non-monetary factors such as attitudes, beliefs, and perceptions also play vital roles in EV acceptance in Norway. In addition, EVs are associated with their symbolic features. Symbolic meanings were salient to early consumers of BEVs in Norway and Austria as well as early American buyers of HEVs in California (Gjøen and Hård, 2002; Turrentine and Kurani, 2007). Owning an EV symbolises an attitude towards the environment, personal status, self-identity, and a new sense of mobility (Axsen and Kurani, 2012; Gjøen and Hård, 2002; Heffner et al., 2007). In addition, environmental values and beliefs encourage individuals to engage in actions that positively contribute to the environment, and owning EVs can be considered a way to communicate such interests and values (Egbue and Long, 2012; Heffner et al., 2007). Furthermore, policymakers need to ensure the availability of different EV models and brands in the local market to meet the stimulated EV demand. Chorus et al. (2013) and Hoen and Koetse (2014) reckoned that having more EV models available in the market increases the probability of people choosing an EV.

Kumar and Alok (2020) argued that recent EV literature is mostly focused on survey-based studies, optimisation techniques, and predictions on second-based data analysis to investigate EV adoption in a specific country or region. The study also added that the understanding of the relationships among the factors is still limited.

1.5 Research Questions

Although the number of EVs is growing worldwide, a study by Krishna (2021) finds that consumers are still sceptical about this new transport innovation, to a certain extent. Nevertheless, the diffusion of EVs largely depends on individuals' attitudes and preferences for EVs (Ozaki and Sevastyanova, 2011; S. Wang et al., 2016). Achieving mass adoption of EVs requires more focus from policymakers and carmakers. Policymakers are implementing policy packages to make EVs attractive to consumers. However, the literature reviewed above suggests that the influence of the policy measures is not yet clear. Consequently, there are still knowledge gaps that need to be filled to gain an in-depth understanding of the drivers of EV demand and proper allocation of limited resources. Hasan et al. (2019) find that consumer behaviour (e.g. consumption, range anxiety, and travel behaviour) is a topic that received comparatively less attention in the literature between 1995 and 2018. During this same period, the effects of EV policies received attention, to a certain extent, but still fell short of other topics, such as the environment and types of EVs.

Consequently, the overall research question to be addressed in this thesis is: *'How do policy measures and consumers' behavioural factors influence the transition towards electric mobility?'* I investigated this question using four different assessments in four scientific articles. As Norway had the highest EV market share over the past several years, insights from this market should be helpful for other countries. Therefore, this thesis explored the Norwegian EV market in all four studies. A summary and discussion of each article is provided in Section 4, and the articles themselves are presented in Section 5, 6,7 and 8.

Articles 1 and 4 investigated various factors to help comprehend their effects on EV purchase demand, Article 3 examined the importance and performance of various factors affecting EV demand and provided insights for resource allocation, and Article 2 assessed various factors to understand the demand for EV use among EV owner groups. The details of the factors, included in the studies and their findings, are presented in Sections 3.2 and 4.2, respectively.

Article 1: 'Electric Vehicle adoption in Norway: Impact of accessibility, climate, and policy measures'

This study investigates the effects of accessibility, use-based policy measures, climate, and other factors on regional variations in the EV adoption rates in Norway. It includes accessibility, climate, policy measures, and other relevant factors, such as charging infrastructure, travel demand, income, and municipality size, to address the heterogeneity of EV uptake in different regions.

Article 2: 'The role of psychological factors on the vehicle kilometres travelled (VKT) for the battery electric vehicle (BEV) uses'

This study examines the differences in the influences of various psychological factors on the use of EVs between groups categorised as sole EV owners and owners with both EVs and ICEVs. The focus on the use of EVs is relevant, realising the importance of the post-purchase use of EVs to evaluate the ultimate success of EVs.

Article 3: *'Electric vehicles: An assessment of consumer perceptions using importance–performance analysis'*

This study aims to answer three related questions using an important performance analysis. First, what are the most important factors when considering what car to buy? Second, how well do EVs perform with these factors? Third, which of these factors should policymakers and car manufacturers focus on improving to make EVs more attractive to consumers?

Article 4: 'Assessment of electric vehicle repurchase intention: A survey-based study on the Norwegian EV market'

This study examines EV users' repurchase intentions using an extended TPB. This study extended the theory of planned behaviour by adding consumers' overall satisfaction with EV use.

1.6 Outline of the Thesis

This thesis consists of five chapters. The rest of this thesis is structured as follows: Chapter 2 presents the theoretical frameworks for the studies, including traditional transport demand theory, generalised cost notion, and theory of planned behaviour (TPB). In Chapter 3, the applied methodologies, empirical data, and context of the studies are outlined. A summary of the articles, their contribution to the EV literature, key findings, and a discussion of the findings are presented in Chapter 4. The chapter also discusses how the results of each article relate to each other, some suggested implications, limitations, and proposed further research. The four articles in this thesis are presented in Chapter 5.

2. Theoretical Framework

This thesis assessed the demand for EVs and their usage in the Norwegian market using various factors within the framework of transport demand theory, generalised cost notion, and TPB. This chapter provides a brief presentation of these theoretical frameworks. This chapter starts with the transport demand theory, which explains how passenger car demand changes with price, income, and substitute modes. Then, it presents a generalised cost notion that discusses the importance of the monetary value of operating costs in an individual's travel behaviour. Finally, the TPB briefly explains a framework in which individuals' attitudes, perceptions, and peers impact their buying behaviours. In addition, the relevance of these theories in EV diffusion analysis is briefly explained.

2.1 Transport Demand Theory

The monetary interest of consumers strongly influences their travel mode use (Verplanken et al., 2008). However, financial costs impact passenger car transportation by affecting vehicle ownership and vehicle use (Button, 2010). By summarising the results of empirical research worldwide, Annema (2013) posits that transport consumers are price and cost sensitive, and the extent of their responsiveness to price and cost depends on many relevant factors (e.g. income, time) and their responsiveness to price changes is relatively modest in most cases. Total motoring costs consist of fixed costs (e.g. purchase cost, import tax) and running costs (e.g. maintenance cost, fuel cost, road toll, parking fee) (Dargay, 2002). Moreover, Dargay (2002) suggests that car ownership is influenced by the purchase prices of cars, cost of car use, and fares of alternative transport modes.

Economic theory is useful for explaining the rationale behind the demand models used to analyse the transport market. In line with this, travellers are perceived as choosing among alternatives to maximise their utility, bearing in mind the various constraints that might be imposed on their choice (Balcombe et al., 2004). In reality, the consumer's travel choice is a very complicated mechanism, and therefore, in practice, any explicit mathematical representation of it is grossly simplified (Balcombe et al., 2004). Button (2010) defines demand as an abstract concept which reflects what individuals would like to consume under various scenarios. Generally, the demand for a commodity or service can be formally expressed as a function of its price, the price of other goods, its tastes, and the income of consumers. Therefore,

$$\text{Demand} = \text{f (price, price of other goods, tastes, income)}$$
$$\text{or } D_{\mathrm{e}} = \mathrm{f}\,(P_e, P_1, P_2 \ldots. P_n, T, I), \qquad (1)$$

where the demand of a commodity or service, e, is denoted as D_e, its price as P_e, price of other goods as $P\ (P_1, P_2 \ldots P_n)$, tastes, T, and the level of income of consumers, I.

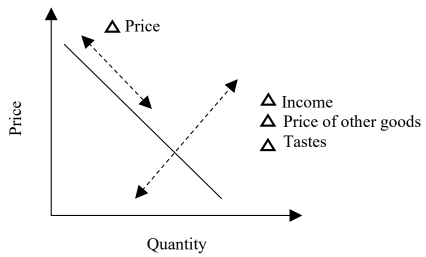

Figure 1.1: Simple Demand Curve (Button, 2010)

The effects of price changes on passenger car transport include vehicle ownership costs and vehicle use costs (Button, 2010). Usually, there is a negative relationship between the price and quantity demanded, provided all the elements in Eq. (1) remains constant. This negative relationship between price and demand creates a downward sloping demand curve (Fig. 1.1), which indicates that if price increases, the demand for a commodity or service tends to fall, and if price falls, the demand tends to increase, holding all other elements constant. Moreover, the demand curve shifts upward or downward depending on factors such as income, taste, and the price of other goods. For instance, a fall in the price of substitutes makes the commodity or service relatively more expensive and pulls down the demand at any price, and the increased income of buyers increases the affordability and results in a shift in the demand upward. Moreover, Button (2010) posited that the factors in Eq. 1 may represent complex compounds with several interacting factors. For instance, the price may consist of all types of costs incurred to obtain a transport service, including time cost, which is generally considered one of the most critical factors in transport economics.

The high purchase price is a barrier to widespread EV adoption (Harvey, 2020; Hasan and Mathisen, 2021). Thus, according to the transport demand theory, if the price of EVs becomes competitive by initiating purchase incentives or lower production costs, it is likely to increase the EV demand in the market. In contrast, if the EV competitor, ICE vehicles' price increases by imposing more taxes and VAT, it is also likely to increase the demand for EVs and decrease the demand for ICE vehicles.

Another factor in the transport demand function is income, which is often expressed by income elasticity theory. Income has a positive influence on car ownership (Button, 2010). Many studies suggest a positive correlation between car ownership and income using statistical data from different countries (Button, 2010; Button et al., 1992; Storchmann, 2005; Wheaton, 1982). This implies that car ownership increases with income. However, previous studies found that the income elasticity of car ownership declines with an increase in income (Dargay, 2001; Dargay et al., 2007; Nolan, 2010). Moreover, people with high income tend to travel more (Dijst et al., 2013).

The economic meaning of the element 'taste' is seldom emphasised in practice, although it often appears in elementary transportation discussions. Taste refers to all possible influences (e.g.

societal orientation towards private transportation, the structure of the national economy) on the demand curve that are not accounted for by the other elements of Eq. 1 (Button, 2010). Taste can also be represented by an individual's preferences. Although the product remains the same, the popularity (i.e. demand) could change over time due to changes in preferences; for instance, in the case of EVs, the move towards sustainable and environmentally friendly products is an example of 'taste' changing demand conditions.

The economic perspective of owning and driving an EV includes purchase cost and related operating costs (e.g. parking fees and road tolls), depreciation cost, insurance cost, time cost (cost of saving time because of having access to a bus lane), and maintenance costs. Policymakers worldwide are establishing various incentive packages to lower the acquisition and operating costs of EV use. Purchase-based incentives (e.g. rebates at registration, sales tax exemption, value-added tax (VAT) exemption, and tax credit) reduce purchase costs. In contrast, use-based incentives (e.g. exemption from toll and ferry fees and access to bus lanes) reduce the operating cost of EV use (Langbroek et al., 2016; Lévay et al., 2017). Consequently, in the long run, these incentives enable the total cost of ownership of EVs to become competitive with that of traditional vehicles with an ICE. Policy incentives, particularly purchase-based incentives, are critical in motivating consumers to purchase EVs (Hardman, et al., 2017; Lévay et al., 2017; Sierzchula et al., 2014). However, Hardman et al. (2017) argued that consumers were unable to calculate the impact of purchase incentives on the total cost of ownership. However, the effects of purchase incentives depend on how consumers interact with them. Eppstein et al. (2011) established a spatially explicit agent-based vehicle consumer choice model to explore the sensitivities and nonlinear interactions between various potential influences, including policy incentives on PHEV market penetration. They found that readily available estimates of the total ownership cost to consumers can significantly influence consumers' purchase decisions.

2.2 Generalised Cost Notion

The generalised cost notion represents the overall attractiveness of a travel alternative which is widely adopted by transport planners worldwide, mostly because of its simplicity (Grey, 1978; Wardman and Toner, 2020). The generalised cost notion suggests that rational car users do not merely consider transport as opposed to the cost of other goods. Instead, buyers may choose a transport mode that gives them the lowest generalised cost for a specific travelling distance (Button, 2010; Hanssen et al., 2012). In line with neoclassic utility theory, in the generalised cost notion, it is assumed that consumers act to minimise their generalised transport cost to maximise their total utility. Button (2010) expressed generalised cost as a single monetary measure, including important distinct costs that form the overall opportunity cost of the trip. The function of the generalised costs is

$$GC = \mathrm{g}(C_1, C_2, C_3 \ldots C_n), \qquad (2)$$

where GC is the generalised cost of a trip and $C_1, C_2, C_3 \ldots C_n$ are the various time, money, and other relevant costs of a trip. Consequently, generalised costs help measure the demand for a trip as a function of a single variable, D_t = f (GC), where D_t is denoted as the demand for the trips. It should be noted that generalised cost assumes a linear relationship to relevant costs (Button, 2010).

Balcombe et al. (2004) summarised the cost of a journey by adding together the various components of time or money spent and represent by

$$GC = a_0 + p + \sum_i a_i q_i, \qquad (3)$$

GC = generalised cost of the journey
P = monetary cost of the journey
q_i = time required to complete the journey divided into various components I of travelling time.
a_i = value of time associated with time component i
a_0 = residual component of the cost of making a journey which is not a function of monetary cost

There are some criticisms of the generalised cost notion. One criticism is that it assumes that the marginal value of time is a function of income, which implies that consumers' willingness to pay to save a unit of time will rise if an individual's income rises (Bruzelius, 1981; Wardman and Toner, 2020). In addition, Grey (1978) argued that the rate of change of demand with respect to any independent variable is not fixed directly by empirical evidence. However, Bruzelius (1981) claimed that generalised cost does not violate any of the basic assumptions of economic theory which constitutes the basis of consumer behaviour theory. Balcombe et al. (2004) argued that generalised cost still offers a useful approximation of an individual's behaviour in choosing travel alternatives and overall travel demand.

2.3 Theory of Planned Behaviour

The influential framework, the TPB (Ajzen, 1991) assumes that consumers' behaviour results from their behavioural intention to engage in that particular behaviour (Dijst et al., 2013). In effect, behavioural intention depends on the consumer's attitude, subjective norms, and perceived behavioural control (Fig. 1.2). Attitude reflects how positively and negatively a consumer evaluates a particular behaviour, and it is usually a reflection of how important the outcome of that behaviour is to them. Social norms reflect the extent to which a consumer believes their peers (e.g. friends, family members, colleagues) and approve or disapprove of a particular behaviour, as well as their motivation to comply with these expectations. Perceived behaviour control reflects a consumer's belief in their capability to engage in a behaviour. Consequently, behaviour or action is a function of behavioural intention and perceived control behaviour (Ajzen, 1991). The TPB assumes that demographics and general values indirectly affect behaviour via attitudes, subjective norms, and perceived behaviour control (Dijst et al., 2013).

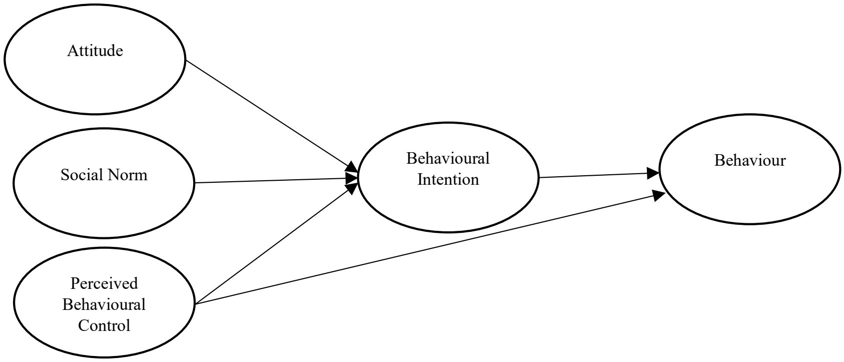

Figure 1.2: Theory of Planned Behaviour (Ajzen, 1991)

The TPB has been effectively used in transportation research to investigate the transport mode choices (Donald et al., 2014; Verplanken et al., 1998; Verplanken et al., 2008; Y. Zhang and Li, 2020). In line with this, it is a valuable and robust theoretical framework and relevant in measuring the demand for EVs. A number of studies (Abrahamse et al., 2009; Degirmenci and Breitner, 2017; Haustein and Jensen, 2018; Moons and Pelsmacker, 2015; Schmalfuß et al., 2017; S. Wang et al., 2016) utilised this framework to explore consumers' intention to purchase EVs. However, although widely used, TPB has some limitations in predicting consumer behaviour, which is apparently the result of insufficient determinants (Tommasetti et al., 2018). Consequently, to gain an in-depth understanding of consumer intention and behaviour, there is a tendency to exploit an extended TPB to account for additional determinants in different fields of study, including transportation. For instance, previously, this framework was extended to include perceived mobility necessity, personal norms, and BEV experiences (Haustein and Jensen, 2018); perceived EV attributes, perceived accidental risk, knowledge about EVs (Simsekoglu and Nayum, 2019); emotions (Moons and Pelsmacker, 2015); environmental concerns and personal moral norms (S. Wang et al., 2016); user experience (Schmalfuß et al., 2017); and cognitive status, product perception, monetary and non-monetary policy incentives (Huang and Ge, 2019) to assess the willingness to purchase EVs.

3. Methodology

This chapter describes the methodological basis of this thesis, data collection, and empirical analysis methods. The thesis comprises both descriptive and numerical presentations, with quantitative analysis conducted primarily based on primary data sets. This chapter starts with a brief description of the scientific positioning of the research methods. Thereafter, a brief discussion of the data collection and data analysis methods is provided. Finally, the reliability, validity, and ethical considerations of this study are presented at the end of the chapter.

3.1 Scientific Positioning of the Thesis

Positivism

Research can be either empirical or theoretical (Remenyi et al., 1998). In empirical research, researchers usually examine a problem based on experiments or observed actions and derive conclusions from their results because, in empiricism, the philosophical assumption is that evidence, in contrast to thoughts or discourse, is necessary to be able to make a convincing claim to contribute to the literature (Remenyi et al., 1998). In contrast, in theoretical research, researchers usually conduct a study based on the research subject-relevant literature and discussions with experts on the subject. Empirical research is frequently associated with a positivist view (Ladyman, 2002; Remenyi et al., 1998). The positivist doctrine perceives researchers as object analysts and interpreters of tangible social reality (Remenyi et al., 1998). Another critical assumption of positivism introduced by Popper (1959) is falsification. This suggests that the evidence established in research is not always perfect or fallible because researchers do not prove a hypothesis – they fail to reject a hypothesis (Creswell, 2014; Remenyi et al., 1998). From 1935 to 1970, it was claimed that almost all economists were positivist (Blaug, 1992). However, Lakatos and Musgrave (1970) claimed that all research occurs within scientific research programs. Lakatos and Musgrave (1970) described scientific research programs as structures for future research with a fundamental set of rules that cannot be falsified and a set of supporting hypotheses that can be falsified (Brekke and Torvanger, 1989; Mathisen, 2008).

Neoclassic paradigm

The inception of economic classicism is marked by the conceptions of Adam Smith, who drives the economy focus from the protection of individuals' own interest to the support of the entire nation's interest (Hudea, 2015). Hudea (2015) further noted classical economic theory's gradual transition towards a distinct theory known as neoclassicism. Blaug (1992) referred to neoclassic economics as *'the mainstream, orthodox economics'*. Demand and supply are essential components in the neoclassic paradigm, considering the rationality of individuals who try to maximise their benefits by relying on available relevant information (Hudea, 2015). Consequently, it becomes evident that the maximisation of utility and profits is the central focus in neoclassic theory. It presumes that market price is the dominant instrument that influences the market, holding all other market mechanisms constant. According to Klette (1989), the neoclassic paradigm assumes that all market participants intend to maximise their utility and are perfectly informed about the relevant factors in the market where the supply and demand mechanism determines the price level. In line with this, transport economics embraces microeconomic theories based on the positivist neoclassic model.

Summary
In line with the above discussion, my thesis is positioned towards a positivistic tradition. This is reasonable as the platform for transport economic models is grounded in the neoclassic paradigm. This study aims to identify relationships with both descriptive and normative explanations. In other words, the thesis aims to provide descriptions of reality and attempts to offer recommendations to the audience about how policy measures and car users' behavioural factors influence widespread EV adoption.

3.2 Empirical Data

A data set is usually classified based on the process employed to collect the data. Researchers generally classify the data set as either a primary or secondary data set. Usually, researchers or a team which the researchers are part of collect data set to test the scientific hypothesis; then, it is defined as a primary data set. In contrast, when someone else collects a data set, not for the purpose of the scientific hypothesis being tested, it is defined as the secondary data set (Boslaugh, 2007; Quoc-Dien Trinh, 2017). According to Easterby-Smith et al. (2012), secondary data sources include company or government reports, advertisements, newspaper articles, archival data, books, websites, and data banks. In contrast, a primary data set includes interviews, surveys, and focus groups. Usually, a primary data set increases the validity of resources to analyse the hypothesis being tested, as it is considered more up-to-date and specifically for research purposes. However, a secondary data set has multiple advantages over the primary data set, such as saving time, cost, efforts (Mooi et al., 2018). Sometimes, it is possible to acquire a more extensive data set from secondary sources than primary sources. Data sets published by companies and governments are considered high-quality sources, and a historical perspective can be obtained from secondary sources (Easterby-Smith et al., 2012).

This thesis used both primary and secondary data sets to answer the research questions. The present thesis used two survey data sets for three out of the four articles and secondary data sets for one article collected from multiple secondary sources, mainly Statistics Norway (SSB), International Energy Agency (IEA), Norsk ebilforening, and TØI. More details on the data sets are presented later of this thesis.

3.2.1 Secondary Data Set for Article 1

We collected the study data of Article 1 using different secondary sources, including Statistics Norway, Norwegian Climate Service Center, National Charging Station Database, and AutoPASS. We collected data on the number of registered passenger electric cars per 1000 residents, accessibility, climate, charging infrastructure, car users' travel demand, income, the presence of fees at public parking places, road tolls, ferries, the presence of bus lanes, and the population. Data were collected at the municipality level. A brief description of the data set is provided in Table 3.1.

Table 3.1: Description of variables and sources

Variable	Data	Source
Number of EVs	The number of registered passenger electric cars per 1000 residents.	StatBank Norway (SSB)
Travel Demand	The average vehicle kilometre travelled by passenger cars.	
Income	Median of income after tax per household.	
Municipality Population	The absolute population count.	
Accessibility index	Accessibility index ranging from 0 to 1,000.	
Climate	Average temperature by regions categorised by the Norwegian Climate Service Center on the temperature references from 1971–2000 [c].	Norwegian Climate Service Center
Charging infrastructure	The number of publicly accessible charging stations.	National charging station database
Parking (yes =1, no = 0)	The presence of the exemption of fees in public parking places for EV drivers	Elbil
Bus Lane (yes =1, no = 0)	Allowing the EV owners to access the bus lane during rush hours	Statens Vegvesen
Ferry (yes =1, no = 0)	The presence of the exemption or reduction of the fees of ferries for EVs drivers	AutoPASS for the ferry

3.2.2 Questionnaire Survey for Article 2

A web survey was used to collect data from both EV and ICEV owners in Norway. Data were collected during the middle of 2016. The Norwegian Public Roads Administration data set was used to obtain random EV and ICEV owner addresses from different parts of Norway. Thus, we have a representative sample. The survey requests were sent to randomly and independently selected participants. The sample included 448 respondents, including owners of both BEVs and ICEVs (n = 220) and owners of BEV only (n = 228). The questionnaire survey was performed by the co-author of Article 2, Özlem Simsekoglu. The socio-demographic statistics of the sample are presented in Table 3.2.

Table 3.2: Socio-demographic statistics of the sample (n=448)

	BEV owners *n = 228*	BEV and ICEV owners *n=220*	Total
Gender			
Male	144(64%)	186 (85.32%)	330 (74%)
Female	81 (36%)	32 (14.68%)	113 (26%)
Income			
Under 250,000 kr.	4 (1.75%)	2 (0.91%)	6 (1%)
250,000–350,000 kr.	13 (5.70%)	3 (1.36%)	16 (4%)
350,000–500,000 kr.	45 (19.74%)	26 (11.82%)	71(16%)
500,000–900,000 kr.	109 (47.81%)	115 (52.27%)	224 (50%)
Over 900,000 kr.	57 (25.00%)	74 (33.64%)	131(29%)
Marital status			
Single	23 (10.75%)	6 (2.76%)	29 (7%)
Married/cohabitating	180 (84.11%)	202 (93.09%)	382(89%)
Separated /divorced	11 (5.14%)	7 (3.23%)	18(4%)
Education			
Primary education	3 (1.32%)	2 (0.91%)	5(1%)
Vocational higher education	29 (12.78%)	29 (13.24%)	58(13%)
General education	20 (8.81%)	16 (7.31%)	36(8%)
Bachelor's degree or equivalent	60 (26.43%)	48 (21.92%)	108(24%)
Master's degree or equivalent	115 (50.66%)	124 (56.62%)	239 (54%)
Inhabitants in living municipalities			
Under 2000 inhabitants	2 (0.88%)	2 (0.92%)	4(1%)
2000–19,999 inhabitants	63 (27.63%)	55 (25.23%)	118 (27%)
20,000–100,000 inhabitants	78 (34.21%)	88 (40.37%)	166 (37%)
Over 100,000 inhabitants	85 (37.28 %)	73 (33.49%)	158 (35%)
Working/Student			
Yes	209 (91.67%)	201 (91.36%)	410 (92%)
No	19 (8.33%)	19 (8.64%)	38 (8%)

3.2.3 Questionnaire Survey for Article 3 and Article 4

Another web survey was developed using a survey platform internally at Nord University Business School to collect data from electric car owners in Norway. Data were collected between March and May 2019. The invitation to participate in the survey was distributed by traditional mail to 4330 car owners randomly drawn from the Norwegian Public Roads Administration data set. The invitation letter included a web address in which they could find the survey. A total of 451 respondents filled out the questionnaire, yielding a response rate of 10.42%. Among them, only 278 (62%) owned electric cars. In the study for both Article 3 and 4, we employ the 278 electric car owners' responses, as both articles focused on electric car owners' behaviour and perceptions. The socio-demographic statistics of the sample are presented in Table 3.3.

Table 3.3: **Socio-demographic statistics of the sample (n=278)**

	Count	Percentage	Cumulative Percentage
Gender			
Male	197	71%	71%
Female	80	29%	100%
Age			
18–30	4	1%	1%
31–40	50	18%	19%
41–50	75	28%	46%
> 51	149	54%	100%
Income before tax			
< 250 000 kroner	3	1%	1%
250 000–350 000 kroner	13	5%	6%
350 000–500 000 kroner	46	16%	22%
More than 500 000	216	78%	100%
Education			
Primary	7	3%	3%
High School, vocational	35	13%	16%
High School, general education	36	13%	29%
≤ 3 years of college/university	77	28%	57%
> 3 years of college/university	123	43%	100%
Household numbers			
Less than 3 members (1 member / 2 members)	137	49%	49%
3 members	57	21%	70%
4 members	54	19%	89%
More than 4 members	8	11%	100%
Marital Status:			
Married/Cohabitant	238	86%	86%
Single	36	13%	99%
Wish not to disclose	4	1%	100%

3.3 Statistical Analysis

Researchers have utilised several quantitative methods to conduct data analyses. In the present thesis, we used ordinary least squares (OLS) linear regression for Article 1 and Article 2, importance performance analysis (IPA)–both the quadrant and diagonal models for Article 3, and structural equation modelling (SEM) for Article 4. Moreover, we tested the underlying assumptions of the models to verify the reliability of the model results. Finally, we interpreted the results and discussed the implications for stakeholders in interest – policymakers and electric car makers.

3.3.1 Linear Regression

Linear regression is the most straightforward technique for evaluating the relationship between dependent and independent variables (Wooldridge, 2012). For our multivariate regression analysis, we examined whether our model violates the assumption of the multivariate regression model – the normality of residuals, constant variance (homoscedasticity) of residuals, independence of the residuals, non-multicollinearity among the variables, and linear relations between dependent and independent variables. In addition to the graphical representation, we used statistical tests, including Shapiro-Wilk's test to assess normality, Breusch-Pagan/Cook-Weisberg test, White's test to evaluate homoskedasticity, and VIF test to examine multicollinearity. The various tests we utilised are described in econometric books (Washington et al., 2003; Wooldridge, 2012). Furthermore, we evaluated the goodness of fit and statistical significance of the estimated parameters and F-test value for the models. We used goodness of fit (R-square), analyses of the residuals, and the statistical significance of the F-test for overall model fitness and t-test for individual parameters.

3.3.2 Structural Equation Modelling

SEM is preferred by researchers across disciplines, particularly in quantitative social science (Hooper et al., 2008; Kaplan, 2001). It is a multivariate method used to test hypotheses regarding the influences or relationships among interactive variables (Kline, 2016). In Article IV, we used the SEM considering its beneficial feature of assessing the relationships between multiple factors. The SEM model combines confirmatory factor analysis (CFA) and path analysis with simultaneous inclusion of observed and hidden variables (Kiraz et al., 2020). To verify the SEM model fitness, we evaluated the root mean square error of approximation (RMSEA), the normed chi-square, the chi-square to degree of freedom ($\chi2/df$), the standardised root mean square residual (SRMR), and comparative fit index (CFI) of the model.

3.3.3 Importance–Performance Analysis

The IPA technique was developed by Martilla and James (1977) to identify the attributes that focus on improving customer satisfaction. The IPA with quadrant method implies using a two-dimensional grid with attribute importance on one axis and attribute performance on the other. Subsequently, each attribute is positioned within one of the four quadrants based on its perceived importance and performance. Additionally, to overcome the weakness of the traditional IPA, we used IPA with a diagonal line, which is a 45-degree upward slope line along which importance equals performance. IPA is considered to be a simple and effective technique (Hansen and Bush, 1999), and is used to make resource allocation recommendations in several industries and services, including tourism (Bi et al., 2019; Dwyer et al., 2012), higher education (Hanssen and Mathisen, 2018; O'Neill and Palmer, 2004), trade shows (Tafesse et al., 2010), healthcare (Abalo et al., 2007; Kinnaer et al., 2020), banking (Joseph et al., 2005), technology (Chen and Ann, 2016), and transportation (Das et al., 2013; Esmailpour et al., 2020; Freitas, 2013; Sum et al., 2019). However, the application of IPA in transportation, particularly in the EV literature, is still limited (C. Zhang et al., 2019).

3.3.4 Other Statistical analysis

In addition, for descriptive analysis, we used the t-test, chi-square, and correlation matrix. Furthermore, we performed principal component analysis (PCA) and CFA to measure the constructs used in our model analysis. Cronbach's alpha was used to examine the reliability and internal consistency of the measurement scale. Cronbach's coefficient alpha is widely used in studies to assess the psychometric scale's rightness and reliability for independent variables (Panayides, 2013; Peterson, 1994). In addition, the KMO was calculated to measure sampling adequacy and Bartlett's sphericity test to examine the scale's validity (Mooi et al., 2018; Tommasetti et al., 2018). KMO and Bartlett's sphericity tests were used to determine whether conducting factor analysis was feasible.

3.4 Validity and Reliability

In the quantitative method, reliability refers to the repeatability of the research findings or, in other words, to the extent to which a research instrument consistently generates the same outputs if it is utilised in the same situation on repeated occasions (Easterby-Smith et al., 2012). However, in such a case, the same methodology and assumptions need to be made under the same conditions. The principle of validity is another fundamental cornerstone in the quantitative method and is usually categorised as internal and external validity. External validity measures whether the results of the study can be generalised to other settings or contexts, whereas internal validity measures whether the results are true and conclusions accurate through the elimination of systematic sources of potential bias (Campbell and Stanley, 1966; Easterby-Smith et al., 2012).

In the articles of this thesis, the authors used relevant theoretical frameworks, widely utilised quantitative methods, and appropriate scientific approaches to provide concrete evidence and answers to all hypothesised research questions. In addition, each article examined the reliability of the model using recommended testing techniques and measures to ensure the accuracy of the results. The articles solely focused on the data collected from the Norwegian EV market. Although the Norwegian EV market is setting examples for other countries for EV uptake, its market is different from that of other countries in terms of socio-demographic characteristics, government policies and investment strategies, geographic location, and so on. For instance, driving performance in winter weather is an important EV attribute in Norway which might not be important for many countries. Moreover, its EV market is comparatively more mature than many other countries; hence, the effects of variables in Norway might be different from those in other countries.

3.5 Ethical Consideration

Ethics is the standard of behaviour that guides an individual’s moral choices about their behaviour and relationships with others (Cooper and Schindler, 2014). In research, ethical guidelines ensure that no one is harmed by the research. The National Committee for Research Ethics in the Social Sciences and the Humanities (NESH) (2019) defines research ethics as the codification of science morality in practice and asserts that researchers are obliged to comply with recognised norms of research ethics. According to general guidelines of research ethics (Research Ethics Committees, 2019), there are four principles that researchers need to follow: 1) all research participants should be treated with respect; 2) researchers need to ensure that their activities produce good consequences and any adverse consequences that may result are within the acceptability limits; 3) all research projects should be planned and executed fairly; 4) researchers should practice recognised norms and act responsibly, openly, and honestly. In addition, it is necessary that researchers respect the research participants' autonomy and integrity, and researchers should obtain their consent explicitly provided that they are adequately informed about the result research field, research purpose, and data processing plan. Researchers need to process personal data confidentially – generally de-identify the data and store them responsibly.

The survey data sets were collected and processed according to the guidelines provided by the NESH and Norwegian Centre for Research Data (NSD). The data sets did not have any identifiable personal data to register either directly or indirectly. In addition, all information was processed using electronic equipment, and all information remained anonymous throughout the process. To inform the participants about the research project, purpose, and data processing plan, we sent the participation invitation in the Norwegian language. However, participants had the option to complete the survey questionnaire, either in English or Norwegian. This thesis comprises four articles, and for the purpose of publications in international journals and presentation of research in conferences, seminars the articles have been written in English.

4. Summary and Discussion of the Articles

This chapter summarises the articles in two sections. The first section presents a summary of the four articles, and the second section discusses the key findings of the articles and their implications. This chapter ends with a table including the summary of methodologies, main contributions, and key findings of all the articles.

4.1 Summary of the Articles

4.1.1 Article 1: Electric vehicle adoption in Norway: Impact of accessibility, climate, and policy measures

Article 1 estimated the effects of policy measures, accessibility, and climate on regional differences in EV adoption. This article adds to the knowledge of the role of accessibility and climate in EV diffusion to the literature. Furthermore, this study investigated the variation in the effects of use-based policy measures in small and large municipalities by using interaction effects in a model. This study provides insights into regional differences in the EV adoption rate. The findings of this study are of interest to policymakers and carmakers in preparing strategies and resource allocation based on regional knowledge.

This study used a Norwegian data set at the municipality level. As of 2019, Norway had 422 municipalities, and each municipality differed in characteristics such as accessibility, policies, socio-demographic characteristics, car owners' travel behaviour, transportation infrastructure, and climate. The purchase-based incentives were excluded from the analysis model because they are national incentives and equal for all municipalities. Different secondary sources were used to collect the data. The sources include Statistics Norway, Norwegian Climate Service Center, national charging station database, and AutoPASS. Finally, based on the reviewed literature, multiple factors were incorporated into the model. This study incorporated accessibility, municipality size, income, climate, travel demand, and use-based policy measures, such as exemption from parking, ferry fees, and allowing EV owners access to bus lanes in a cross-sectional OLS regression model to test their effects on EV adoption rates per municipality. The results indicate that accessibility, climate, charging infrastructure, and exemption of ferry fees in smaller municipalities positively affect the EV adoption rate.

This article was initially presented by the European Transport Association, 2018. Later, it was written together with Bert Van Wee and Eric Molin with new data, variables, and models. This study is currently under consideration by a scientific journal.

4.1.2. Article 2: The role of psychological factors on the vehicle kilometres travelled (VKT) for the battery electric vehicle (BEV) uses

Article 2 estimated the effects of multiple behavioural factors on EV use. To determine a model for this estimation, this study utilised EV owners' vehicle kilometres travelled (VKT) to measure their EV use, and multiple other perceived aspects of EV use. This study adds to the knowledge of how factors such as economic aspects, symbolic attributes, self-environmental identity, perceived operating barriers, perceived environmental benefits, and general environmental beliefs play a role in post-purchase EV use. Post-purchase EV use is critical in achieving the ultimate targets policymakers are aiming for in transport electrification. If consumers mostly use EVs as their secondary transport means and keep using conventional cars as primary transport means, it would not have the desired contribution policymakers are looking for to mitigate environmental and energy challenges. However, a very limited number of studies have focused on post-purchase EV use and have incorporated the behavioural factors we studied in this article. Moreover, we studied two subgroups of EV owners – one group that only owned EVs and one group that owned both EVs and conventional vehicles. Although only a few previous studies have studied EV subgroups, this study emphasises the importance of adding in-depth knowledge of EV users' travel behaviour.

This study used a data set of a sample of 448 respondents that included EV users who own both BEVs and ICEVs (n = 220) and EV users who own only BEV (n = 228), and the data were collected through an online questionnaire. First, sample t-tests and chi-square tests were conducted to examine the differences in travel behaviour and demographic characteristics between the two driver groups. In the second step, a PCA, using varimax rotation, was conducted to identify the dimensional structure of the scale measuring different perceived attributes related to EV use. Finally, to examine the influence of factors such as economic aspects, symbolic attributes, self-environmental identity, perceived operating barriers, perceived environmental benefits, and general environmental beliefs on annual VKT by BEVs, an OLS regression analysis was carried out. The results indicate that the economic aspect plays a statistically significant role on VKT by EVs for sole EV owners, and the perceived operating barrier is statistically significant for owners that have both EVs and ICEVs.

This article was published in a scientific journal in 2020. Previously, it was presented in a research seminar at Nord University.

4.1.3 Article 3: Electric vehicles: An assessment of consumer perceptions using importance–performance analysis

Article 3 aimed to reveal the key EV attributes that require more attention from policymakers and manufacturers to improve consumer satisfaction. This study answered three questions: first, what are the most important factors when considering what car to buy? Second, how well do EVs perform with these factors? Third, which of these factors should policymakers and car manufacturers focus on improving to make EVs more attractive to consumers?

In this study, we analysed the survey data of 278 Norwegian EV owners. We used both quadrant and diagonal models of the IPA technique. The results of IPA are straightforward and effective for assessing consumer acceptance of product attributes that have been used in various fields. The novelty lies in the methodology because, to the best of our knowledge, no other studies have utilised IPA models to analyse the EV market. Moreover, a few studies have examined the satisfaction of EV owners with the attributes and aspects of this study. In addition, there appears to be a gap in the knowledge related to the disparities between the importance assigned to the factors (such as instrumental attributes, cost aspects, environmental aspects, availability of different EV models, winter driving functions, and policy incentives) by consumers when purchasing a car and satisfaction with EV use with regard to the same factors. The findings of this study add knowledge to identify the attributes of EVs that need to be improved to be more attractive, thus contributing to the establishment of a greener road transport system. Based on the results from IPA models, policymakers and car manufacturers should focus on improving EVs' instrumental attributes, winter driving performance, and cost of owning and maintenance.

This article is written with Thor-Erik Sandberg Hanssen and is currently under consideration by a scientific journal.

4.1.4 Article 4: Assessment of electric vehicle repurchase intention: A survey-based study on the Norwegian EV market

Article 4 evaluated EV users' EV repurchase intention utilising the TPB model. The TPB framework was extended by consumers' overall satisfaction with EV use, and we incorporated the SEM model to evaluate EV users' behavioural intentions. This study adds to the current literature on attitudes towards EVs in two main ways: first, by extending the TPB by including satisfaction; second, by exploiting Norway's maturing EV market to study repurchase intentions rather than first purchases only. In addition, this study adds value by establishing a model to comprehend the interrelations among relevant factors and the complete pathway of their influences, and finally by identifying the attributes of EVs that determine EV users' satisfaction with EV use.

Consequently, in addition to the three elements (subjective norms, attitudes, and perceived barriers) of the TPB, this study includes EV users' satisfaction with relevant aspects such as range-recharge, environmental attributes, cost, EV availability, symbolic attributes, and use-based policy measures. An SEM was established to analyse the survey data set of 278 Norwegian EV owners. Only the responses from actual EV users were studied to assess satisfaction with EV use and the behavioural intention of EV repurchases. This is important because consumers with no prior experience tend to portray their interest in a new product or service inaccurately. Among the EV owners, 256 (92%) were BEV owners, 15 (5%) were PHEV owners, and only 7 (3%) were HEV owners. The results indicate that EV users' overall satisfaction affects their EV repurchase intention via attitude and perceived functional barriers, and users' positive attitudes towards economic and environmental values have dominant effects on their EV repurchase intention.

I am the sole author of this article and is currently under consideration by a scientific journal. Previously, it was presented in the 43rd meeting of the Norwegian Association of Economists, 2021.

4.2 Discussion on the Key Findings and Implications

The findings of Article 1 indicate that EV adoption is positively associated with accessibility, climate, publicly accessible charging stations, and use-based policy (both monetary and time use), such as the exemption of ferry fees for EV owners. We argue that accessibility usually offsets the limitation of the low battery range of EVs and the lack of publicly accessible charging stations. In addition, we found that consumers living in municipalities with comparatively high temperatures are more likely to purchase EVs than those living in municipalities with low temperatures. The low performance of EVs in cold weather may play a role in this causation. Furthermore, fewer people live in colder areas in Norway. This leads to less developed infrastructure and longer travel distances and transit times which could challenge range limitations. The exemption of ferry fees for EV owners has effects in comparatively small municipalities. The impacts of publicly accessible charging stations have been well documented in previous studies. However, in line with the findings of this study, we argue that densely installing publicly available charging infrastructure could possibly play a role in low accessible areas to offset the limited battery range of EVs. This could improve the EV adoption in low areas with low accessibility. Although users tend to overestimate their range needs in relation to their day-to-day driving pattern, readily available charging stations would, to a certain extent, give confidence to EV users and potential EV buyers. Furthermore, technological advancement could possibly improve the EV performance to be operated desirably in low temperatures and winter weather.

In Article 2, we found that economic aspects play a statistically significant role for sole EV owners' (who have only EVs) EV use, while operating barriers of EV use are statistically significant influential for EV owners who also own conventional vehicles. It is reasonable that the operating barriers of EV use are not significant for sole EV owners; rather, economic aspects motivate them to use it. Our study established that economic benefits not only encourage consumers to purchase EVs but also motivate them to use them in the post-purchase period. However, if EV owners solely use EVs for their economic benefits, there is a concern about how they would react when policymakers would eventually revise or eliminate policy incentives. Moreover, the regression results indicate that increasing the economic benefits would increase the EV use, which would possibly induce the rebound effect – driving more will demand more energy consumption and affect environmental concerns depending on primary energy sources to produce electricity. Moreover, increasing the number of EVs on the road and driving EVs could raise other issues such as congestion and the crisis of public parking places. Eventually, this would jeopardise the implementation of use-based policies, such as giving access to bus lanes to EV users and exempting fees from public parking places. Not surprisingly, it is already happening in Oslo, the capital of Norway. The authorities have already restricted access to EVs in bus lanes for certain areas. Moreover, the operating barrier of EV use affects, to a significant extent, EV use negatively for owners who own both EVs and ICEVs. We argue that perhaps the perceived operating barriers are the underlying reason for having additional cars. The technological advancement of EVs is the primary way to tackle this challenge. Because merely owning an EV does not solve the problems we are concerned about – we need to use it and substitute the use of ICEVs.

In Article 3, the analysis results indicate that Norwegian consumers consider the instrumental attributes, winter driving quality, and environmental aspects of a car to be the most important factors when deciding to purchase a car. Moreover, it reveals that EV users are satisfied most with EVs' environmental contributions, winter driving performance, and interior and exterior design. Based on IPA analysis, we urge policymakers and car manufacturers to focus on improving the following to make EVs more attractive to consumers: (1) instrumental aspects (e.g. driving range, safety features, fuel efficiency, recharging duration); (2) winter driving performance; and (3) cost aspects related to purchasing and driving EVs. These results, to a certain extent, iterate the results from Article 2. Considering the instrumental aspects and winter driving performance as the functionality of EVs and cost items as economic aspects, we argue that both studies point to the importance of economic and functional aspects of EV use.

In Article 4, interestingly, we find that satisfaction does not directly affect EV users' behavioural intention to repurchase EVs at a statistically significant level. Instead, it affects via consumers' attitudes and perceived functional barriers. The findings indicate that attitudes related to EVs' environmental and economic values have a greater impact than subjective norms and perceived functional barriers. Not surprisingly, perceived functional barriers that include adverse assessments regarding the performance, safety, speed, and low battery range negatively influence EV repurchase intention. Moreover, this study reveals that cost aspects have the strongest effect on overall satisfaction. Policy measures, range-battery, environmental attributes, and EV model availability play a significant role in formulating consumers' overall satisfaction. Similarly, in Articles 2 and 3, this study also emphasised the economic aspects of EVs in addition to their functional and environmental attributes.

Based on the combined findings of four articles, our studies suggest that the functional, environmental, and economic aspects of EVs are the most important factors that dominate consumers' behaviour. In other words, these aspects are the main drivers of the demand for EVs and their use. Moreover, publicly accessible charging infrastructures, regional accessibility, and climate play a critical role in driving EV demand. Although charging infrastructure is an important factor, we need to observe behavioural changes in consumers' charging preferences and take measures accordingly. Improved battery performance is likely to offset the limitations of low regional accessibility and driving performance at low temperatures. However, the battery performance easily falls into the functional aspects, which we have already pointed to as a dominating factor. The economic benefits consumers receive at this point are mostly due to generous policy incentives. However, as discussed in Section 1.4, and Article 2, policy incentives might be exposed to social and economic burdens for society. Consequently, implementing homogenous policy incentives for all EV types and places might not be the best practice. Moreover, as environmental attributes play a crucial role, it would be best for policymakers to take measures to promote the environmental benefits of EV use to mass people. It could be promoted in combination with other relevant information about EVs, which can create a positive impression about EVs.

It is evident that like any other innovative product, EVs have some limitations and barriers, as they are still in the developing stage. However, as mentioned in Section 1.2, we see that constant technological advancements not only improve driving performance but also reduce the cost of production. The gradual cost reduction in EV production also indicates that policymakers might not need to merely depend on incentives to promote mass EV adoption in the future.

With the enthusiasm and investments from policymakers and carmakers, it is expected that the number of EVs on the road will increase, to a certain extent, in the coming years. Achieving goals related to the transition towards electromobility might be threatened without widespread consumer acceptance. In addition, as we discussed before, ultimately, the benefits of EVs will depend on a few things – the primary energy used to produce electricity to meet the growing demand due to EV use, the mitigation of emissions from EV production, mainly the battery, and consumers' travel behaviour with their EVs.

Table 4.1: Summary of four articles

Article 1: *'Electric vehicle adoption in Norway: Impact of accessibility, climate and policy measures'*
Methodology: This study used data collected at the municipality level for the number of registered EVs, municipalities' accessibility level, population, annual median household income, climate, average travel kilometres, and use-based policy measures such as exemption from parking and ferry fees and allowing EV owners access to bus lane. Data were collected using multiple secondary sources. Finally, we incorporated multiple factors, in a cross-sectional OLS regression model to test their influences on EV adoption rates per municipality.
Main Contribution: The main contribution of this article is to add knowledge of the role of accessibility and climate in EV diffusion to the literature. Furthermore, we investigated the variation of effects of use-based policy measures in small and big cities.
Findings: EV adoption rate is positively associated with accessibility, climate, publicly accessible charging stations, and use-based policy – exemption of ferry fee for EV owners.
Article 2: *'The role of psychological factors on the vehicle kilometres travelled (VKT) for the battery electric vehicle (BEV) uses'*
Methodology: This study used a data set of a sample of 448 respondents, including EV users who own both BEVs and ICEVs and EV users who own only BEVs. The data were collected through an online survey questionnaire. To examine the influence of behavioural factors on annual VKT by BEVs, an OLS regression analysis was carried out. The constructs we included in the model are economic aspects, symbolic attributes, self-environmental identity, perceived operating barriers, perceived environmental benefits, general environmental beliefs.
Main Contribution: The main contribution of this study is adding knowledge of factors playing a significant role in post-purchase EV use in two subgroups of EV owners.
Findings: Economic aspects play a statistically significant role for sole EV owners' (who have only EVs) EV use while perceived operating barriers of EV use are statistically significant for EV owners who also own conventional vehicles.
Article 3: '*Electric vehicles: An assessment of consumer perceptions using importance–performance analysis'*

Methodology: In this study, we analysed survey data of 278 Norwegian EV owners. We used an important-IPA framework with both quadrant and diagonal models. The constructs we included in this model are environmental aspects, winter driving performance, instrumental aspects, interior and exterior design, cost aspects, availability of EV models, use-based policy measures, and symbolic aspects.
Main Contribution: This study answered three questions – first, what are the most important factors when considering what car to buy? Second, how well do EVs perform concerning these factors? Third, which of these factors should policymakers and car manufacturers focus on improving to make EVs more attractive to consumers? Moreover, this study addresses the research gap in the literature related to the disparities between the importance assigned to the factors by consumers when purchasing a car and satisfaction with EV use regarding the same factors.
Findings: Firstly, the most important factors when considering what car to buy are: (1) instrumental aspects of the vehicle; (2) winter driving quality; and (3) the environmental aspects of the car. Second, EVs perform best with respect to their: (1) environmental aspects; (2) winter driving quality; and (3) interior and exterior design. Third, based on the IPA, policymakers and car manufacturers should focus on improving the following to make EVs more attractive to consumers: (1) instrumental aspects; (2) winter driving performance, and (3) cost aspects related to purchasing and driving EVs
Article 4: *'Assessment of electric vehicle repurchase intention: A survey-based study on the Norwegian EV market'*
Methodology: An SEM was established to analyse the survey data set of 278 Norwegian EV owners. The constructs we included in our model are cost satisfaction, range-recharge satisfaction, use-based policy satisfaction, environmental attribute satisfaction, symbolic attributes satisfaction, availability of EV models satisfaction, subjective norms, attitude, perceived functional barriers, and repurchase intention
Main Contribution: This study adds knowledge to the current literature on attitudes towards EVs mainly in two ways: first, by extending the TPB by including satisfaction; second, by exploiting Norway's maturing EV market to study repurchase intentions rather than first purchase only. Furthermore, it adds values by establishing a model to comprehend interrelations among relevant factors and complete pathway of their influences; and finally, by identifying the attributes of EVs that manipulates EV users' satisfaction with EV use.

Findings:
Satisfaction does not directly affect EV users' behavioural intention of EV repurchase at a statistically significant level. Instead, it affects it via consumers' attitudes and perceived functional barriers. The findings indicate that positive attitudes related to EVs' environmental and economic values have more substantial effects than subjective norms and perceived functional barriers. Moreover, this study reveals that cost aspects have the strongest effect to manipulate the overall satisfaction. Besides, policy measures, range-recharge, environmental attributes, EV model availability play a significant role in formulating consumers' overall satisfaction

Finally, it should be noted that like all other empirical studies, the studies in this thesis have some limitations. The secondary data set of Article 1 and survey data sets of Articles 2, 3, and 4, which we analysed in this thesis are from the Norwegian EV market, which has a higher EV penetration rate than most other car markets and numerous policy measures to make EVs more attractive. Therefore, in markets where the preferences of car owners and purchasers differ or where some EV functions are considered less important (e.g. winter-driving battery range), the effects of some of the factors could differ. However, in general, the insights from these studies are of interest to other countries as well. All studies discussed the usefulness of the findings and how these could be implemented in other counties in general. Second, for survey data sets in Articles 2,3, and 4, some respondents might have answered tactically, which might pose some bias in the stated importance and satisfaction. Future research can include other relevant behavioural, sociodemographic, and geographical factors in models to further expand our understanding.

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5. Article 1: Electric vehicle adoption in Norway: Impact of accessibility. climate and policy measures

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Abstract
Electrification of vehicles is a promising measure to mitigate the increased environmental and energy challenges caused by the growing road transport demand. Countries worldwide are considering generous policy measures to make electric vehicles (EVs) attractive to mass people. The academic literature reveals many factors influencing EV adoption. However, to the best of our knowledge, the empirical analysis of accessibility and climate is often overlooked in these studies. Our study empirically investigates the role of several factors, including policy measures, accessibility, and climate in EV adoption using a dataset at the local municipality level for the Norwegian EV market. Our findings suggest that accessibility and EV adoption rates are strongly correlated and that accessibility plays a critical role in the uptake of EVs. Besides, climate, income, and the exemption of ferry fees significantly influence EV adoption.

Keywords: accessibility, climate, policy incentives, electric vehicle adoption, electric vehicles

5.1 Introduction

The number of electric cars on the road has been growing rapidly over the past decade, with the global stock of electric cars surpassing 7 million in 2019, representing 1% of the global car stock. In 2019, electric cars accounted for 2.6% of global car sales, which is a record high (International Energy Agency [IEA], 2020). The recent increasing trend in electric car adoption is the consequence of the continued technological advancement, implementation of generous financial incentives, growing awareness about environmental challenges, fuel prices, and the enthusiasm of the automobile industry and consumers' behavior supporting the transition toward electric mobility (Baur and Todorova, 2018; IEA, 2016, 2018a, 2020; Matulka, 2014; Mock and Yang, 2014).

Various types of electric vehicles (EVs) are available in the market—battery EVs (BEVs), hybrid EVs (HEVs), and plug-in HEVs (PHEVs). Among them, only BEVs operate entirely on electricity stored in an onboard battery pack, and hence, these vehicles are known as pure- or all-EVs (Campanari et al., 2009). By contrast, HEVs combine an internal combustion engine (ICE) with an electric motor and are more fuel-efficient than similar-sized ICE vehicles (Egbue and Long, 2012; Schuitema et al., 2013). PHEVs are equipped with a more powerful electric battery than HEVs and can be recharged via the electricity grid (Schuitema et al., 2013). Therefore, only BEVs have zero-tail pipe emissions.

Policymakers in several countries have been implementing different sets of policy measures to increase the attractiveness of EVs (Langbroek et al., 2016; Lieven, 2015; Sierzchula et al., 2014). Most policy measures directed toward consumers are designed to stimulate the purchase of EVs and lower the marginal cost or the disutility of waiting while charging EVs for use. Purchase-based incentives (e.g., rebate at registration, sales tax exemption, VAT exemptions, and tax credit) reduce the purchase cost of EV, whereas use-based incentives (e.g., waiver of parking fees, toll fees, and ferry fees and free access to bus lanes) reduce the marginal cost of EV use (Langbroek et al., 2016; Lévay et al., 2017). Previous studies suggest that policy measures, particularly purchase-based incentives, are critical in motivating consumers to buy EVs (Fearnley et al., 2015; Lutsey et al., 2015; Sierzchula et al., 2014). However, households that already have a car are less sensitive to the purchase price but more responsive to the financial subsidies whereas households yet to own a car are more sensitive to purchase price and less responsive to the financial subsidies (Qian and Soopramanien, 2011). Use-based policy incentives are effective to increase the EV market share to some extent (Bakker and Trip, 2013; Fearnley et al., 2015). In contrast, Mersky et al. (2016) and Chorus et al. (2013) find no statistically significant impact of road tolls and access to bus lanes on EV adoption prediction. Apparently, the efficacy of policy measures is not conclusive and further regional analysis is necessary to derive actionable insights. Another determinant that has proven useful in increasing EVs' adoption is the availability of charging infrastructure (Bakker and Trip, 2013; Sierzchula et al., 2014). It is argued that publicly accessible charging infrastructure possibly reduces consumers' range anxiety, contributes to elevate consumers' satisfaction with EV use and consequently builds confidence in the future of EV market (Greene et al., 2020; Kumar et al., 2021). In addition, car users' behavioral factors, social attributes and their perception about EVs play potential role in EV acceptance (Liao et al., 2017; Rezvani et al., 2015; Wang et al., 2021). EV is more than a mean of transport, it symbolizes a better attitude towards environment, personal status, self-identity and a new sense of mobility (Axsen and Kurani, 2012; Gjøen and Hård, 2002; Heffner et al., 2007).

Policymakers implement EV policy measures at both the regional and national levels. Nation-wide policy measures benefit all EV owners regardless of their city or municipality, whereas locally targeted policy measures benefit only EV owners in specific local areas. However, we argue that the impact of nation-wide policy measures on regional EV adoption could differ due to the heterogeneity of the local regions. For instance, the presence of lanes dedicated to bus use, public parking places with fees, road toll points, and (in some countries) ferry facilities—and consequently, related national privileges for the use of such facilities—differ among different municipalities or regions, depending on their size, other geographical characteristics, and local/regional policies. Besides, in some countries (e.g., Norway), although use-based policy measures are nation-wide measures, regional administrations have the authority to decide whether or not to implement those in their particular region.

There could be several factors playing role in the regional heterogeneity in EV uptake. One cluster of factors is accessibility related. Focusing on passenger transport, accessibility can be defined as "the extent to which land-use and transport systems enable individuals to reach desired destinations using available transport modes" (Geurs and van Wee, 2004, p. 128). Accessibility is an important indicator to evaluate the effects of changes in the land-use and transport system (Geurs and van Wee, 2004; Kasraian et al., 2019). In line with the definition of accessibility, car ownership, travel behavior of car owners, and transport infrastructure are interrelated with the concept of accessibility. In a study on travel survey data of Beijing, Zhang et al. (2020) claimed that car ownership and use are largely associated with accessibility level. Thus, arguably, the uptake of EVs could be partly explained by accessibility as well. For instance, in regions with high accessibility levels, people might not need to travel long, increasing the uptake of short-range EVs and reducing range anxiety by avoiding detours to charge and the inconvenience of having less publicly available charging infrastructure.

Nevertheless, to the best of our knowledge, previous studies have not considered the role of accessibility in the regional EV uptake. We argue that by including accessibility in the analysis, we should be able to identify its influence on the variance of EV adoption rates among various regions. Besides, the impact of climate on EV adoption has received limited attention in the EV literature. Studies reckon that low temperature impacts the battery range and performance adversely (Bullis, 2013; Engström et al., 2019; Motoaki et al., 2018; Zhang et al., 2018). Therefore, we incorporated climate in our empirical model to examine the regional heterogeneity in the EV uptake. Consequently, our primary aim in this study is to investigate the impact of accessibility and climate, in addition to use-based policy measures on regional variations in the EV adoption rates. Further, other factors that could influence EV acceptance and correlate with our central variables are measured and controlled for in our analysis.

For our study, we used a Norwegian dataset at the municipality level. We choose Norway because this country, to the best of our knowledge, has implemented the largest number of EV policies and has the highest per capita uptake of EVs worldwide (Norsk Elbilforening, 2019). As of 2019, Norway had 422 municipalities. Each municipality differs in characteristics such as accessibility, policies, socio-demographic characteristics, car owners' travel behavior, transportation infrastructure, and climate. We excluded purchase-based incentives in our model because these are national incentives and are equal for all municipalities.

The remainder of this paper is structured as follows. Section 2 presents a brief overview of the literature on factors related to the uptake of EVs. Section 3 describes the methodology—data collection and statistical analysis. Section 4 presents the results of the empirical studies and discussion. Finally, Section 5 provides conclusions and implications.

5.2 Literature Overview

This section presents a review of the literature related to the Norwegian EV policy measures, accessibility component and measures, and other factors relevant for EV uptake, such as charging infrastructure characteristics, travel demand, climate, and income. Such a review is important to understand which factors impact EV adoption and should be considered while analyzing at the municipality level.

5.2.1 Overview of Norwegian EV policy measures

The diffusion of EVs in the Norwegian market started with an effort to commercialize Norwegian-made EVs during the early 1990s and a widespread belief that EVs are more environmentally friendly than vehicles powered by fossil fuels (Figenbaum et al., 2015; Holtsmark and Skonhoft, 2014). Norway is known for its history of offering extensive EV incentives to stimulate EV sales. Norway's continuous high market share of EVs results from several policy measures that consistently motivate consumers to purchase EVs instead of ICE vehicles (Fearnley et al., 2015; Figenbaum et al., 2015; Holtsmark and Skonhoft, 2014). Norway has world's highest share of BEVs in its vehicle stock – as of 2020, BEVs comprise 12.06% of its vehicle stock whereas BEVs, HEVs and PHEVs together comprise 21.89 % of its vehicle stock (Statistics Norway and the Road Traffic Information Council, 2021). The extensive policy incentives are making the price of EVs compatible with ICE vehicles. For instance, a Volkswagen e-golf is slightly cheaper than the comparable petrol model (Norsk Elbilforening, 2020).

The Norwegian transportation sector is heavily taxed. Consumers have to pay registration taxes on new vehicles, annual taxes, and taxes on fuels; besides, the country has numerous toll roads and locations with paid parking. This regime makes it possible to introduce EV policy measures by selectively foregoing taxes (Fearnley et al., 2015; Figenbaum, 2017). The implementation of policy measures dedicated to the EV uptake began in the early 1990s and has evolved (Figenbaum, 2017; Norsk Elbilforening, 2018; Serafimova, 2015). Furthermore, by strengthening the green tax system, which is based on the polluter pays principle, Norway expects all new cars sold from 2025 onward will be either fully electric or hydrogen cars (Norsk Elbilforening, 2018). The market share of BEV in Norway is significantly higher than in any other country primarily because of its EV policy incentives (Bjerkan et al., 2016; IEA, 2018b). However, these incentives have some unintended effects (Aasness and Odeck, 2015). For example, the exemption from registration tax, VAT, road tolls, and public parking has resulted in a reduction in government revenues, access to bus lanes has resulted in congestion on bus lanes leading to increased travel times for public transport users. Consequently, recently policymakers are revising the policy measures regularly. Norway also implemented the 'polluter pays principle' in the car tax system to finance the incentives for the zero-emission cars which raises the tax for high emission cars (Norsk Elbilforening, 2020).

Table 5.1: Development of EV policy measures in Norway

Year	Policy measures
1990	Temporary exemption from the purchase or import tax
1996	Final exemption from purchase tax; Reduced annual vehicle license fee
1997	Exemption from road tolls
1999	Exemption from parking charges in public parking places
2000	Reduced taxation on electric company cars
2001	VAT exemptions
2003	Trial period of providing access to bus lanes (Oslo and Akershus)
2004	Renewed annual vehicle license fee
2005	Renewed reduced taxation on electric company cars; Introduced access to bus lane nation-wide
2009	Further reduction of reduced taxation on electric company cars; Exemptions from ferry fees
2011	Legalization of double parking for smaller EVs; Exemption from congestion charges for EVs
2017	Local governments are given authority to decide the policy incentives regarding access to bus lanes, exemption of fees for municipal parking facilities, and ferry services
2017	Establishment of at least two multi-standard fast-charging stations every 50 km on all main roads except the Northern part of Norway.

Source: Serafimova (2015); Elbilforening (2018)

5.2.2 Transport accessibility

This subsection provides a brief overview of accessibility components and measures. Accessibility comprises several components—the land-use components reflecting land-use system, transportation components reflecting transport system, temporal components reflecting temporal constraints, and individual components reflecting the needs, abilities, and opportunities of individuals (Geurs and van Wee, 2004). The relationship among the components is complex and comprises direct and indirect relations as well as feedback loops, thereby indicating the inter-dependence of these components. Moreover, such relationships also describe how changes in various components, directly and indirectly, change accessibility.

Depending on the components included in specific accessibility measures, Geurs and Van Wee (2004) distinguish between infrastructure-based, location-based, person-based, and utility-based accessibility measures. Our study focuses on location-based accessibility measures as it is more relevant for the study objectives—we need to include both the land-use and the transport system to understand regional variations in accessibility that are relevant for the EV uptake. Contour measures are among the most straightforward classes of location-based accessibility and are prevalent in urban planning and geographical studies (Bruinsma and Rietveld, 1998; Gutiérrez and Urbano, 1996; Wachs and Kumagai, 1973; Wickstrom, 1971). This measure type counts the number of opportunities (e.g., activities, destinations, and services) that can be reached within a given travel time, distance, or generalized cost threshold value. This measure also has the advantage of relatively easy operationalization, interpretability, and communicability (Geurs and Van Wee, 2004). Consequently, the higher the number of opportunities that can be reached within a given threshold value for travel time, distance, or generalized transport costs, the higher the value of accessibility of any given city or municipality. In line with this, we argue that a high level of accessibility could positively influence the market share of EVs because EVs have limited battery range and high levels of accessibility mitigate this range limitation.

5.2.3 Climate

Wind speed, temperature, and precipitation (rain and snow) have been identified as important weather indicators affecting all types of road transport (Agarwal et al., 2005; Bardal and Mathisen, 2015) and EVs are not an exception. However, EVs are more vulnerable to colder weather as low temperatures adversely impact the battery range and battery performance. Low temperature tends to degrade the battery charging rate and extend the charging duration, potentially challenging the EV operation in cold regions (Bullis, 2013; Motoaki et al., 2018). Moreover, in low temperatures, additional energy is needed for the heating system, further reducing the vehicle range (Bullis, 2013; Engström et al., 2019; Zhang et al., 2018). In a study, Noel et al. (2020) reveal that winter weather has been identified as one of the barriers to EV adoption and was frequently discussed in the context of its impact on range. In another study, EVs' functionality during the winter period is identified as one of the least satisfying characteristics (Solvoll et al., 2010).

5.2.4 Income

In many countries, EVs are more expensive than ICE equivalents. Previous studies reveal that EVs’ higher purchase price compared to ICE vehicles is one of the main barriers to large-scale EV adoption (Axsen et al., 2013; Daziano and Chiew, 2012; Graham-Rowea et al., 2012; Noel et al., 2020). Of all the socioeconomic and demographic variables, income is probably the most important for the adoption of EVs because it influences car ownership and car type choice. Therefore, we include this variable in our study. Many studies suggest the positive correlation between car ownership and income using statistical data from different countries (Button, 2010; Button et al., 1992; Storchmann, 2005; Wheaton, 1982). Previously, Chen et al. (2020) and Brückmann et al. (2021) concluded that a high income level is one of the important predictors for potential EV adoption.

5.2.5 Travel demand

EVs are more attractive because of purchase and use-based EV policy incentives, higher energy efficiency, and lower maintenance cost compared to ICE cars (Helmers and Marx, 2012; Langbroek et al., 2016; Larminie and Lowry, 2003; Lévay et al., 2017). Use-based incentives such as exemption from parking fees and road tolls and allowing access to bus lanes reduce the generalized cost of driving EVs. Both vehicle ownership and usage strongly depend on the monetary value of owning and operating vehicles (Button, 2010; Verplanken et al., 2008). Therefore, the lower generalized cost is arguably a motivation for people who want to drive more. Thus, including travel demand as a predictor in the model should reveal consumers' preference for EVs based on their travel demand.

5.2.6 Charging infrastructure

Policymakers within the European Union (EU) have been developing public charging infrastructure as a way to stimulate the adoption and use of EVs. The EU Parliament specifies at least one publicly accessible charger per 10 EVs as an appropriate number (EU Parliament, 2018; Illmann and Kluge, 2020). Publicly accessible fast-charging facilities save drive time and search costs for EV users, as well as relieve their range anxiety (Liao et al., 2017). Achtnicht et al. (2012) indicated the effect of charging infrastructure on EV adoption to be non-linear, with a diminishing marginal utility. Illmann and Kluge (2020) found evidence of a long-run positive and causal relationship between EV uptake and charging infrastructure and emphasized the importance of charging speed. By contrast, battery capacity improvements will probably reduce the importance of a dense charging infrastructure network. Thus, the impact of charging infrastructure on EV adoption is not conclusive.

5. 3 Methodology

5.3.1 Data collection

Based on the literature review, we collected data on the EV adoption rate, accessibility, climate, charging infrastructure, travel demand, income and use-based policy incentives—such as exemption of parking fees, and ferry fees—and EV owners access to bus lane for all the 422 municipalities of Norway. Data for accessibility and climate were collected for year 2019 whereas for other variables data was collected for year 2018 due to limited data availability. We used a cross sectional data set for our study. Cross-sectional data are widely used in social sciences and economics, particularly in applied microeconomics fields such as transport economics (Wooldridge, 2012).

Due to the use of logarithmic transformation in the model specification, we excluded six municipalities with zero registered BEVs from our analysis. In this study, the index of centrality published by Statistics Norway has been referred to as the index of accessibility. According to Bloch (2018), the centrality index accounts for the number of workplaces. and different types of service functions (goods and services) in each basic populated district can be accessed within 90 minutes using a car (90 minutes is set as a cutoff point as it has been estimated that less than 1% of all work-related trips [commuting, business] trips are longer than 90 minutes).

We collected the data for this study using different secondary sources, including Statistics Norway, Norwegian Climate Service Center, national charging station database, and AutoPASS. Table 5.2 presents an overview of the data and sources for each variable.

Table 5.2: Description of variables and sources

Variable	Data	Source
EV adoption [a]	The number of registered passenger electric cars per 1000 residents.	StatBank Norway
Accessibility	Accessibility index ranging from 0 to 1,000.	Classification of centrality (Bloch, 2018)
Climate	Average temperature by regions categorized by the Norwegian Climate Service Center on the temperature references from 1971–2000 [c].	Norwegian Climate Service Center (2019)
Charging infrastructure	The number of publicly accessible charging stations.	National charging station database (NOBIL, 2019)
Travel Demand	The average vehicle kilometer traveled by passenger cars.	StatBank Norway (SSB, 2018c)
Income	Median of income after tax per household.	StatBank Norway (SSB, 2018a)
Parking [b] (yes =1, no = 0)	The presence of exemption of fees in public parking places for EV drivers	Elbil (2018)
Bus Lane [b] (yes =1, no = 0)	Allowing the EV owners to access the bus lane during rush hours	Statens Vegvesen (2018)
Ferry [b] (yes =1, no = 0)	The presence of exemption or reduction of fees in ferries for EVs drivers	AutoPASS for the ferry (2018)
Municipality size (population count above the median of national population counts = 1, population count below the median of national population counts = 0)	The absolute population count.	StatBank Norway

[a] Based on the absolute numbers of EVs and population size, we calculated the adoption per 1,000 residents. Population size was extracted from StatBank Norway (SSB, 2018b).

[b] These are dummy variables (yes/no). For instance, if a municipality exempts the fees of public parking places fully or partially for EVs, then it is "yes =1," otherwise "no =0."

[c] The entire country was categorized into six regions based on temperature data from 1971–2000

5.3.2 Ordinary least squares (OLS) regression model

Regression analysis is a widely used statistical techniques to model a relationship between a dependent variable and a set of independent variables (James, Witten, Hastie, & Tibshirani, 2013; Wooldridge, 2012). The aim of performing regression analysis is to reveal a set of statistically significant independent variables (denoted as x) and the sensitivity of the dependent variable (denoted as y) to these input variables. Thus a regression model brings insights about how the dependent variable will change given changes in the independent variables, controlled for all other variables in the model. A multivariate regression equation is presented below (Eq. 1) where α is a constant, β is coefficient determining to what extent dependent variable Y changes by 1 unit change in the independent variable X.

$$\hat{y} = a + \beta_1 x_1 + \beta_2 x_2 \qquad (1)$$

In line with the literature, we have incorporated the factors listed in Table 2—accessibility, municipality size, income, climate, travel demand, and use-based policy measures such as exemption from parking and ferry fees and allowing EV owners access to bus lane—in a cross-sectional econometric model (Eq. 2) to test their influences on EV adoption rates per municipality.

In the dataset, the EV adoption rate and charging infrastructure had a right-skewed distribution. Therefore, the natural-log transformation of our dependent variable (*EV adoption rate)* and the predictor *charging infrastructure* was used to normalize the right-skewed distribution. In our model, the use-based incentives are denoted as dummy variables (1 represents yes, else 0). The dummy variables represent a shift in the ln-curve by the respective β (unstandardized) coefficient.

Similarly, urban and rural regions as well as large and small municipalities tend to differ in several aspects, such as policies, transport preferences, socio-demographic characteristics, and infrastructure. Therefore, to test whether the effect of any independent variable on the dependent variables is different between larger and smaller municipalities, we incorporated related interaction effects in our models.

We measured the interaction effect by including an interaction component which is basically the multiplication of both variables of interest. Thus, such interaction effects will help to gain an in-depth understanding of the influences of the predictors on the heterogeneity in EV uptakes across regions. Municipality size is coded as a dummy variable, where 1 represents municipalities with a population size higher than the median value, and 0 represents the smaller municipalities. However, as exemptions for parking fees are only present in larger municipalities, we did not include the interaction effect for parking fees.
Our final model is next:

$$log(EV\ adoption_i) = \alpha + \beta_1\ climate_i + \beta_2\ accessibility_i + \beta_3\ parking\ fee_i + \beta_4\ bus\ lane_i + \beta_5\ ferry\ fee_i + \beta_6 * log\ (charging\ infrastructure_i) + \beta 7\ travel\ demand_i + \beta_8\ income_i + \beta_9\ municipality\ size_i + (\beta_4 + \beta_{10} * municipality\ size_i) * bus\ lane_i + (\beta_5 + \beta_{11} * municipality\ size_i) * ferry\ fee_i + (\beta_6 + \beta_{12} * municipality\ size_i) * charging\ infrastructure_i + \varepsilon \quad (2)$$

where i denotes the municipality, α the constant, β the coefficient, and ε the error term.

5.4. Results and Discussions

5.4.1 Correlation analysis of model variables

Table 5.3 presents the Pearson's correlation coefficients and statistical significance ($p < 0.01$, $p < 0.05$) between the variables used in our base linear regression model. Table 5.3 shows that all identified factors except *travel demand* and *ferry fees* have a statistically significant correlation with *EV adoption*. Among the predictors, *income* and *accessibility* have comparatively stronger correlations with *EV adoption*. Although it is not statistically significant, surprisingly, the exemption of *ferry fees* shows a negative correlation with *EV adoption*. However, *ferry fees* is also negatively correlated with accessibility at the 1% statistical significance level. It implies that the exemption of ferry fees has comparatively less presence in higher accessible regions than in lower accessible regions; hence, most of the ferry-transport services exist in regions with lower accessibility.

Table 5.3: Pearson's correlation coefficients between model variables

	EV adoption	Accessibility	Climate	Charging station	Travel demand	Income	Parking	Bus lane	Ferry	Municipality size
EV adoption	1									
Accessibility	0.61**	1								
Climate	0.28**	0.19**	1							
Charging station	0.22**	0.33**	0.01	1						
Travel demand	0.017	0.11*	−0.04	−0.10	1					
Income	0.65**	0.43**	0.39**	−0.03	0.01	1				
Parking fee	0.16**	0.35**	−0.05	0.36**	−0.07	−0.011	1			
Bus lane	0.10	0.21**	0.006	0.02	−0.22	0.09	0.19**	1		
Ferry fee	−0.06	−0.27**	0.13**	0.01	−0.46**	0.02	0.06	0.09	1	
Municipality size	0.42**	0.73**	0.11*	0.17**	−0.07	0.30**	0.26**	0.16**	−0.08	1

** $p < 0.01$; * $p < 0.05$

The correlation matrix shows the importance of accessibly and this is consistent with the reviewed literature in previous sections. All correlations between accessibility and other predictors are statistically significant. EV adoption has moderate to strong correlations (between 0.30 and 0.70) with accessibility and income, charging infrastructure, and exemption of parking fees. Unsurprisingly, *EV adoption* and *accessibility* are moderately correlated (0.61) at the 1% significance level: the higher is the accessibility level, the higher is the EV adoption. As expected, municipality size and accessibility are strongly correlated and this correlation is significant at the 1% significance level. All factors except ferry fees and travel demand are statistically significantly correlated with municipality size. The EV adoption rate, accessibility, household income, availability of publicly accessible charging stations are likely to be higher in large municipalities than in small municipalities.

5.4.2 OLS regression results

The variables from Table 5.2 are incorporated into an OLS regression model, in which, the dependent variable EV adoption is regressed against predictors such as accessibility, municipality size, income, climate, travel demand, exemption from parking and ferry fees, and allowing EV owners access to bus lane. In addition to the natural-log transformation for the variables *EV adoption rate* and *charging infrastructure* to normalize the skewed distribution, we calculated the variance inflation factor to confirm the absence of multicollinearity between variables (Vu et al., 2015), and Shapiro–Wilk test to check the normal distribution of residuals of our model (Jurečková and Picek, 2007). The statistical properties of the tests are satisfactory and indicate that the estimation results from the OLS regression can be trusted. The model produces a satisfactory R^2 value of 64%, indicating a good model fit. Table 5.4 presents the results of the regression analysis, the EV adoption rate of municipalities being the dependent variable.

Table 5.4: Regression analysis results

Predictors	**Unstandardized Coefficient (Standard Error)**	**Standardized Coefficient**
Temperature	0.187 (0.066) **	0.138
Accessibility	0.004 (0.000) **	0.549
Parking fee	−0.077 (0.082)	0.082
Bus lane	0.291 (0.437)	0.083
Ferry fee	0.358 (0.140) *	0.179
Charging infrastructure	0.087 (0.039) *	0.040
Travel demand	0.069 (0.042)	0.070
Income	0.006 (0.001) **	0.321
Municipality size	0.023 (0.103)	0.013
Bus lane* larger municipality	−0.448 (0.442)	−0.117
Ferry* larger municipality	−0.346 (0.154) *	−0.143
Charging station* larger municipality	0.000 (0.000)	0.014
Constant	−4.358(0.625)**	-

** $p < 0.01$; *$p < 0.05$

As expected, the unstandardized coefficient of temperature, accessibility, ferry fee, income, and the interaction effect between municipality size and ferry fee are statistically significant. The unstandardized coefficients represent the change in a EV adoption rate due to a change of one unit of an independent variable, e.g., temperature, accessibility, charging infrastructures. The coefficient results indicates that the increase of one unit of accessibility likely increases the EV adoption rate by 0.04%[1]. Likewise, as log-transformed, the one percent increase in publicly available charging stations likely increases the EV adoption rate by about 0.09%. For example, if a municipality manages to increase their accessibility index from 600 to 650, it is likely to improve their EV adoption rate by $(50 \times 0.04)\ \% \approx 2\%$ and if a municipality manages to increase their publicly accessible charging stations by 20%, the EV adoption rate is likely to increase by $(20 \times 0.09)\ \% \approx 1.8\%$[2]. Furthermore, the unstandardized coefficient of income (0.006) implies that a high income level is associated with a high EV adoption rate.

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[1] As our dependent variable is natural log-transformed, we would infer that a one unit increase in an independent variable is associated with a change in the dependent variable by $100 \times (e^{\beta_i} - 1)$ percent (Feng et al., 2014).

[2] For *charging infrastructure,* both as a dependent and as an independent variable being natural log transformed, a one percent increase in the independent variable is associated with a change in the dependent variable by $100 \times (e^{\beta_i} - 1)$ percent (Feng et al., 2014).

Furthermore, interaction effects explain that the presence of ferry fees in smaller municipality would likely increase the EV adoption rate significantly.

Our model incorporates variables measured with different scales. Therefore, to correct for the fact that predictors are measured using different scales, Table 4 shows standardized coefficients, which allow comparisons in terms of weight or importance of impact (Siegel, 2017). We can observe from the results that *accessibility* has the strongest impact on the EV adoption rate, followed by *income*. The standardized coefficient of *accessibility* implies that with an increase of one standard deviation in accessibility, the EV adoption rate rises by 0.549 standard deviations.

The interaction component *ferry fees * larger municipality* has a standardized coefficient of −0.143 and is significant at the 5% significance level. According to model (1), the interaction component is interpreted by the equation of (0.179 − 0.143 * municipality size) * Ferry. Thus, it implies that the impact for small municipalities is 0.179[3] whereas that for large municipalities is 0.036. It indicates that ferries in small municipalities increases EV uptake. The reasoning could be that in those areas people have to use ferry anyway to commute to some extent and the exempted or reduced ferry fee reduces their travel cost. Moreover, ferry commute in low accessible regions reduces the number of kilometers travelled by car, and thus convince people to purchase low-range EVs.

The temperature has a positive impact on the EV adoption rate at the 1% significance level. It has a standardized coefficient of 0.138. Based on the standardized coefficient, the temperature is the third most important variable in the model. The result suggests that municipalities with higher temperatures have higher EV adoption rates than municipalities with lower temperatures, as expected, for the reasons explained above.

Not surprisingly, income has a positive and statistically significant impact on EV adoption. It has a standardized coefficient of 0.321. The result indicates that a higher income tends to increase the EV adoption rate. This impact of income on EV adoption is consistent with Holtsmark and Skonhoft's (2014) findings that high-income families are the most likely in Norway to have EVs, which is logical as the price of EVs is still higher than the price of similar class ICE vehicles. This also applies to other countries. Using comparatively higher fiscal incentives, policymakers could reduce the impact of the EV purchase price, and consequently, downplay the importance of income.

In our study, the impact of publicly accessible charging infrastructure is relatively (compared to other factors) low. It has a standardized coefficient of 0.040. EVs need to be recharged and

[3] The *ferry fee* coefficient for smaller municipality:

$(\beta_c + \beta_{cp} * \text{ municipality size}) * \text{ferry fee} = (\beta_c + \beta_{cp} * 0) * \text{ferry fee} = \beta_c \text{ ferry fee}$

The *ferry fee* coefficient for larger municipality:

$(\beta_c + \beta_{cp} * 1) * \text{ferry fee} = (\beta_c + \beta_{cp}) * \text{ferry fee}$

charging infrastructure can be both publicly accessible and privately owned at homes or workplaces. Relatively low importance of publicly accessible charging infrastructure indicates the preference for charging infrastructure at homes or workplaces. This finding is consistent with survey reports that reveal that participants in Nordic countries prefer to charge their EVs at home. More than 90% of EV owners in Norway and Sweden charge their cars daily or weekly at home (IEA, 2018b). In Norway, 75% of EV users have private charging facilities (Figenbaum, 2017). Therefore, in Norway, charging opportunities at home are observed to matter more than publicly accessible fast-charging facilities. Globally, home chargers have recently outnumbered public chargers (IEA, 2018a), which suggests that EV owners have begun to prefer charging at home to public places. Publicly accessible charging facilities require significant and expensive infrastructural changes. Therefore, our finding underscores the importance of home and work charging facilities and suggests that policymakers should avoid overinvesting in public charging facilities at the cost of investing in home and work-based facilities. Nonetheless, installing publicly accessible charging facilities are needed, especially in areas where home chargers cannot be installed, such as in dense apartment areas.

5.5 Conclusion

Policymakers have been implementing different packages of policy measures to make EVs more competitive vis-à-vis ICE vehicles. However, in some countries, the EV market share remains below expected levels. Therefore, it is necessary to highlight policy measures and other relevant factors likely to be effective for mass-market EV adoption.

In our study, we primarily investigated the role of accessibility and climate in addition to policy measures in heterogeneous EV uptakes. Our empirical analysis indicated that accessibility, climate, charging facilities, income, and the exemption of ferry fees influenced EV acceptance to some extent. According to the findings, accessibility plays a very strong role in EV adoption. Accessibility refers to a cluster of factors and reflects the differences between urban and rural areas. Transport preferences, policies, socio-demographic characteristics, and infrastructure vary between regions with high and low accessibilities. Our findings suggest that EV adoption rates tend to be higher in regions with high accessibility levels. As we discussed in section 2, high accessibility reduces the disadvantage of EV's limited range. However, as policymakers target a nation-wide zero-emission transport system, they need to focus more on regions with low accessibility levels. Options to motivate consumers living in those regions to buy EVs could be implementing relevant and generous policy incentives and taking initiatives to increase charging facilities according to EV users' preference. Moreover, our results are relevant for EV manufacturers as well, the main lesson being that an increase in the range of EVs (likely: higher battery capacity) could overcome the inconvenience of low accessibility levels in some regions, at least to a certain degree.

Norway has substantial variation in climatic conditions with the annual average temperature in some regions being nearly zero degrees Celsius. Therefore, unsurprisingly, temperature plays a critical role in nation-wide EV uptake. EV adoption in colder regions would benefit from technological progress making the range of EVs less impacted by temperature. Among the use-based policy measures, only the exemption of ferry fees has a positive and statistically significant impact on the EV uptake. However, its correlation with accessibility shows that the exemption of ferry fees positively influences the current EV market share primarily in rural areas.

The importance of income for EV adoption will remain high until EVs become cheaper than ICE vehicles. EVs can become less expensive because of technological advancements as well as fiscal incentives.

Another important predictor of EV uptake is the availability of publicly accessible charging infrastructure. This availability is relevant not only because of its use by EV users but also because it reduces consumers' range anxiety. However, as the standardized coefficients suggest, the importance of publicly accessible charging infrastructure is relatively low. Accessibility, income, and climate have a greater impact on the heterogeneity in EV uptakes. The relatively low importance of publicly accessible charging infrastructure is probably explained by the Norwegian consumers' preference for charging options at homes or workplaces.

Norway has the highest adoption rates of EVs worldwide, has already completed the early adoption phase, and is moving toward the majority stage of adoption. Therefore, our findings mainly apply to other countries approaching similar phases of EV adoption. Our findings are useful for policymakers who need to decide where and which policies to implement to stimulate EV adoption and help EV automobile manufacturers to increase their market share. The findings reveal several factors, including policy measures, accessibility, climate, and socioeconomic determinants relevant for increasing the market share of EVs. However, the magnitude of the influence of each factor and the interplays between the factors may differ between countries, depending on contextual factors. The growth of the EV market is expected to increase much faster in the coming years, largely because the technological advancement in production is expected to lower the cost for EVs and increase the driving range. Identifying other potential factors, along with this technological advancement, could help increase the speed of EV adoption beyond expectation.

Future research could investigate other types of EVs, such as PHEVs and HEVs. Further, it would be interesting to revisit our study when Norway moves toward saturation in EV adoption rates. In addition, because adoption rates and related factors are country-specific, we recommend studies on factors influencing EV adoption rates in other countries before implementing policies to increase EV adoption rates. Moreover, we recommend panel data analyses to gain insights into factors that result in changes in EV adoption rates over time.

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6. Article 2: The role of psychological factors on vehicle kilometres travelled (VKT) for battery electric vehicles (BEVs)

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Abstract

Electric vehicles (EVs) are related to various symbols, identities, and beliefs, and are considered much more than a means of transport. Existing literature has investigated the contribution of financial incentives and various psychological factors to the EV purchase decision. However, few studies investigate the effect of psychological factors on post-purchase EV use. We emphasize that the ultimate success in the widespread acceptance of EVs depends acutely on their post-purchase use. This study empirically addressed the effect of perceived attributes related to EVs, perceived accidental risk, self-environmental identity, and general environmental beliefs on the annual vehicle kilometres travelled (VKT) by battery electric vehicle (BEV) owners. This study compared drivers who own only BEVs and those who own both internal combustion engine vehicles and BEVs to identify the role of psychological factors in BEV use in a Norwegian sample. The dataset was analysed using an ordinary least squared regression model. The socio-demographic characteristics and mobility patterns of the two groups are investigated. The findings indicate that economic aspects are positively associated with annual VKT for sole BEV owners, whereas perceived operating barriers have a negative effect on annual VKT for the other group. The results suggest the inclusion of psychological factors in predicting a more precise model of the induced travel demand of EV owners, which, in turn, is necessary to estimate energy demand accurately and to take steps in establishing the required infrastructure.

Keywords: battery electric cars, travel demand, perceived attributes, EVs, psychological factors, vehicle kilometres travelled, mobility pattern

6.1 Introduction

Electric mobility is increasing worldwide as it contributes to the reduction of greenhouse gas emissions and oil dependency caused by road transport. Electrified vehicles (EVs) have comparatively less or zero tailpipe emissions as well as higher fuel efficiency than internal combustion engine vehicles (ICEVs) (Degirmenci & Breitner, 2017; Mersky et al., 2016) and are one type of alternative fuel vehicle in which entire or at least partial propulsion is powered by electric energy. Battery electric vehicles (BEVs) usually come to mind first when we think of EVs, although there are various types of EVs on the market, for example, hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) (Table 6.1)

Table 6.1: Brief description of different types of EVs

Types of EVs	Characteristics
BEV	Energy is stored solely in onboard electric battery packs which propel the electric drivetrain. It has zero tailpipe emissions and comparatively better energy efficiency than HEVs, PHEVs, and ICEVs.
HEV	It has both an IC engine and a small battery pack, although all of its energy is generated through the IC engine by burning liquid fuel. The battery cannot be recharged through an external charging outlet.
PHEV	Similar to the HEV, it has both an IC engine and electric battery pack which can be recharged through an external charging outlet. Its battery pack is comparatively larger than the HEV's battery pack.

In line with Hirschman's (1982) proposed product innovations that may arise from either or both of two independent sources —symbolism (intangible attributes) and technology (tangible attributes)—Axsen and Kurani (2012) describe EVs as both functional and symbolic innovations. Evidently, EVs incorporate functional innovations—higher fuel efficiency, reduced tailpipe emissions, and no traffic noise—that, in effect, improve the overall driving experience. In addition, energy efficiency, lower electricity cost, as well as use-based EV policy incentives, reduce the marginal cost of driving EVs. Over and above this, technological differences mean that EVs require less maintenance compared with conventional vehicles (Egbue & Long, 2012; Palmer et al., 2018). By contrast, the symbolic attributes (e.g. expressing self-identity, community involvement, portraying personal status) that consumers associate with their EVs are linked to further personal connotations, such as ethics, maturity, concern for others, and individuality (Heffner et al., 2007).

However, some consumers are concerned about the driving range of EVs and their charging facilities, such as charging time and availability of charging outlets. One very commonly perceived operating barrier is range anxiety. Range anxiety or range stress is often addressed as a fear of becoming stranded in the middle of a trip because of the depletion of battery energy (Neubauer & Wood, 2014; Tate et al., 2009). The phenomenon of range anxiety is best described as a specific form of psychological stress, which occurs to manage a present or anticipated critical range situation where the EV driver anticipates insufficient available driving range for the remaining travel distance (Franke et al., 2016). Franke and Krems (2013); Rauh et al., (2017) posit that vehicle owners tend to overestimate their range needs for their typical mobility pattern and this reflects in their range preferences. The availability of charging infrastructure and battery performance are key parameters that influence the driving behaviour of BEV drivers (Azadfar et al., 2015; Neubauer & Wood, 2014). Moreover, concern for values related to driving EVs and technological risks contribute negatively to the probability of accepting EVs (Kim et al., 2014).

Evidently, in existing literature, substantial numbers of studies have endeavoured to investigate the influence of psychological factors in EV purchase (Liao et al., 2017; Noppers et al., 2015; Rezvani et al., 2015; Schuitema et al., 2013; Simsekoglu, 2018). Arguably, similar to the purchase decision, the use of vehicles is not merely induced by utility maximization aspects; rather, on some occasions, it is stimulated by related preferences and attitudes (Kitamura et al., 1997). Nevertheless, few studies investigate the role of various psychological factors on the travel behaviour of EV owners. Moreover, being a transport innovation, policymakers are still unaware of how EVs may change their owners' travel behaviour. The ultimate success of mass EV adoption depends acutely on the post-purchase use of EVs because it is a critical factor for the evaluation of energy and emission reduction introduced by electric powertrain technology. In addition, estimating the use of EVs on the road is also critical in precisely predicting travel demand in the desired electrified transport system which, in effect, is an important factor for predicting energy demand and the necessity of building transport infrastructures. Consequently, our study aimed to examine the differences of the influences of various related perceived attributes on the use of EVs between groups categorized as sole EV owners and owners with both EVs and ICEVs. Such categorization of EV owners includes consumers who purchase EVs as their main or additional vehicle, whilst the majority of the existing studies focus on EV use without differentiating subgroups. We argue that subgroup differentiation is important when studying the psychological factors of EV owners. We measured EV use by estimated annual vehicle kilometres travelled (VKT) because it is one of the factors that reflects the driving behaviour of the vehicle owners (Hou et al., 2013). Furthermore, comparing the socio-demographic characteristics and mobility patterns between the two identified groups of drivers is an additional aim of this study. For these empirical analyses we conducted a survey in the Norwegian EV market, which leads other countries in achieving the highest number of EVs per capita (Fearnley et al., 2015). The Norwegian EV market sets an example in the mass adoption of EVs. In 2018, Norway's EV market share was 49% of all new car sales, which includes 30% BEVs and 19% PHEVs (Elbilforening, 2018).

The remainder of this paper is structured as follows. Section 2 presents a brief literature review of perceived attributes related to EVs, perceived accidental risk, self-environmental identity, and general environmental beliefs. Section 3 describes the methodology—samples, measurement of scales, and selected statistical analysis. Section 4 presents the results of the empirical analyses and section 5 includes discussion thereof. Finally, Section 6 provides conclusions and implications.

6.2 Literature review

An individual's behaviour depends jointly on intention (motivational factors) and perceptions of control (non-motivational factors) in relation to that particular behaviour (Ajzen, 1991). The intention to achieve a particular behaviour is, in effect, influenced by salient beliefs, such as behavioural, normative, and control beliefs (Ajzen, 1991; Fishbein & Ajzen, 1975). Moreover, using an expected value model of attitudes, Fishbein and Ajzen (1975) exemplify that individuals form beliefs about an object by associating certain relevant attributes, for example, characteristics or comparisons with other objects. In line with this, previous studies indicate that individuals have different types of beliefs and perceptions related to EVs which play profound roles in the recent developments in EV adoption (Egbue & Long, 2012; Klöckner et al., 2013; Schuitema et al., 2013; Simsekoglu, 2018; Simsekoglu & Nayum, 2019). This study focused on the role of some psychological factors, such as various perceived attributes and risks related to EV use.

6.2.1 Symbolic attributes

Sherman (1967) argues that in practice people use private motorcars even when a cheaper alternative transport mode is available. EVs are much more than a means of transport; they symbolize ideas and have significance beyond the private level. Limited studies investigate the potential of EV acceptance through symbolic-affective motives (Heffner et al., 2007; Rezvani et al., 2015; Schuitema et al., 2013). Plausibly, automobile advertisements, TV commercials, and specific automobile magazines demonstrate symbolic-affective appeals (e.g. self-esteem, social status, independence, and superiority), either explicitly or implicitly (Steg et al., 2001). Owning an EV symbolizes the widely recognized ideas of a better attitude towards the environment, opposing conflicts over resources, personal status, self-identity, and a new sense of mobility (Axsen & Kurani, 2012; Gjøen & Hård, 2002; Heffner et al., 2007). Symbolic meanings were salient to early BEV consumers in Norway and Austria, as well as early American buyers of HEVs in California (Gjøen & Hård, 2002; Turrentine & Kurani, 2007).

6.2.2 Self-environmental identity

In addition to perceived attributes, how individuals relate EV use to their self-identity and self-image is also critical for the adoption of these vehicles. Sirgy's (1982, 1986) self-image congruency theory suggests that consistency in perceived product image and self-image positively influences product acceptance. The likelihood that a specific product will satisfy an individual's symbolic needs is higher when the product image is consistent with his/her self-image (Schuitema et al., 2013). Environmental beliefs and consumer awareness of environmental issues influence the widespread adoption of EVs (Egbue & Long, 2012; Rezvani et al., 2015; Skippon & Garwood, 2011). Consequently, consumers who express environmental self-identity can relate the buying and use of EVs to their "green" image, which gives them the impression of contributing to society in reducing environmental and energy challenges. Moreover, both the automobile industry and policymakers are promoting the environmental contribution of electric mobility to attract consumers with environmental concerns by defining the electrification of transport as a green or sustainable transport system.

6.2.3 General environmental belief

Normative theories such as value-belief-norm (VBN) theory (Stern, 2000) are useful theoretical frameworks to describe consumers' behaviour related to environmental concern and actions aimed at protecting the environment. Kim et al. (2014) posit that the acceptance of EVs is encouraged by attitudes about environmental concerns and levels of technological acceptance. Previous studies explain sustainable transport mode choice, such as public transportation and reduced car use, utilizing VBN theory (Lind et al., 2015; Nordlund & Garvill, 2003; Steg, 2005). However, they argue that consumer concern for the environment does not necessarily result in pro-environmental behaviour all the time (Kollmuss & Agyeman, 2002; Oliver & Rosen, 2010; Stern, 2000).

6.2.4 Perceived accidental risk of electric cars

Perceived accident risk and uncertainty associated with driving electric cars pose a major barrier to their mass adoption (Egbue & Long, 2012; Graham-Rowea et al., 2012; Krause et al., 2013). Drivers tend to be uncertain about EV driving performance and safety-related issues because EVs are relatively new in the market and little is known about their performance, accident history, and characteristics. Existing consumer research suggests that consumers with higher perceived risks related to performance and financial aspects of new products are less willing to adopt them (Aggarwal et al., 1998; Shimp & Bearden, 1982). Previous studies often identify perceived accidental risk associated with a certain travel mode based on the perceived probability of being involved in a traffic accident and severity of the accident consequences while using that mode (Lund et al., 2012; Nordfjærn & Rundmo, 2010).

6.2.5 Economic aspects

The economic aspects address personal perceptions of the economic value of EVs. The economic value indicates not only purchase cost but also perceived depreciation and maintenance costs. Consumers' interest in monetary cost has a strong influence on travel mode use (Verplanken et al., 2008). However, the effect of monetary cost change on passenger car transportation consists of both the effect on vehicle ownership and that specifically on vehicle use (Button, 2010). Evidently, the comparatively higher BEV market share in Norway is the eventual outcome of its incentive-strong nation-wide policy measures which are mostly intended to benefit BEV owners (Bakker & Trip, 2013; Bjerkan et al., 2016; Figenbaum et al., 2015; Holtsmark & Skonhoft, 2014; IEA, 2018). However, it is still important to know how consumers actually realize the benefits of various policy incentives and of driving EVs from an economic perspective. Hence, we argue that by incorporating personal perceptions of economic aspects as a predictor in the analysis, we would be able to comprehend its role beyond the buying decision-making process.

6.2.6 The paradox of vehicle kilometres travelled (VKT) by EVs

Previous studies posit that enhanced energy efficiency increases travel demand because it reduces driving costs (Byun, et al., 2017; Hymel et al., 2010; Plötz et al., 2014). Moreover, according to the economic rationale, lower generalized cost increases travel demand (Button, 2010; Cowie, 2010). In line with these theories, it is expected that higher energy efficiency and user based EV policy incentives would increase the travel demand for EVs. Unsurprisingly, lower operating costs discourage public transport use and induce demand for EV driving. This increase in EV usage due to generous policy measures and technical improvements is known as the "rebound effect," referring to increased consumption as a result of increased energy efficiency and reduced marginal operating costs for consumers (Byun et al., 2017; Hymel et al., 2010). The rebound effect works against a traveller's willingness to save fuel costs or reduce travel distance. Travelling more kilometres by EVs increases electricity demand and travel activity. Depending on the energy mix of the electricity production and traffic flow capacity of roads, the increased travel kilometres might affect the CO_2 emission and fossil fuel dependency reduction process as well as traffic congestion.

On the contrary, Contestabile et al., (2011); Plötz et al. (2014); and Thomas (2012) argue that EVs, particularly BEVs need to be driven a comparatively sufficient number of vehicle kilometres to offer ecological benefits over ICEVs. This is mainly to compensate for the CO_2 emissions due to the additional energy required to produce the EVs, particularly their batteries, by low CO_2 emission during its operation, especially if the EVs are charged using electricity supplied from renewable sources (Hall & Lutsey, 2018; Plötz et al., 2014). Moreover, estimation of the total cost of ownership incorporates both initial purchase cost (investment) and annual operating cost through the estimated periods of usage, which in turn depends on the vehicle kilometres driven (Plötz et al., 2014; Wu et al., 2015). Consequently, in order to compensate for the higher purchase price compared with ICEVs, EVs need to be driven many vehicle kilometres.

6.3. Method

6.3.1 Sampling

A web-survey was used to collect data from both EV and ICEV owners in Norway. The data was collected during the middle of 2016. The Norwegian Public Roads Administration dataset was used to obtain the addresses of random EV and ICEV owners from different parts of Norway. The sample included 448 respondents, including owners of both BEVs and ICEVs (n= 220) and sole BEV owners (n=228). There were 330 male respondents (74.5%) and 113 female respondents (25.5%). Furthermore, 410 respondents (92.6%) of the sample were either employed and/or studying during the survey period. Most of the respondents are married (88.51%) and have an annual income between 500,000 and 900,000 Norwegian kroner (51%). High academic qualification is visible in our sample, with 239 respondents (53.6%) having a master's or equivalent degree and 108 respondents (24.2%) having a bachelor's or equivalent degree. The survey requests were sent to randomly and independently selected participants. Thus, we have a fairly representative sample.

6.3.2 Measures

The data was collected through an online questionnaire. The first section of the questionnaire included questions about the ownership of different types of cars (BEV and ICEV, with a multiple selection option), annual kilometres driven in the car/s they own, frequency of use of different travel modes (train, metro, tram, bus, personal car, bicycle, walking) in a typical week, and the purpose of using their EVs (commuting to work/educational places, long trip outside city, travelling for leisure activities within city area). The annual vehicle kilometres travelled (VKT) is usually calculated by either of two methods: one is by on-board hardware recording equipment or instruments and the other one is through a survey that relies on self-reporting or odometer readings (Hou et al., 2013; Pearre et al., 2011). However, the latter method is widely used in the transport field because of its convenience. For this obvious reason, we have chosen to collect annual VKT through a survey together with other subjective factors.

In the demographic section, questions were posed as dichotomous variables for gender (Male =2; female =1), marital status (married =2; single =1) and currently working/studying (Yes= 2;

No=1). Multiple choices were offered as answers to questions about income, academic qualification, and inhabitant density of the municipalities where the respondents live.

In the next section, the perceived attributes about different aspects of EVs were measured by 21 items using a 5-point Likert scale (1= completely disagree, 5= completely agree). The perceived attributes are economic, symbolic, accidental risk, environmental benefits and operating barriers of driving EVs, and self-environmental identity. The economic attributes related to EV use was measured by 2 items (e.g., "EVs have lower maintenance costs than regular cars"). Symbolic attributes include 5 items (e.g., driving an EV separates me from others). Perceived environmental benefits and operating barriers of EV use were measured by positive attributes (e.g., "EVs contribute to reducing air pollution") and negative attributes (e.g., "a disadvantage of driving an EV is its limited range"). Both positive and negative attributes included 5 items each. Self-environmental identity was measured using 3 items (e.g., "being environmentally friendly is an important part of who I am"). General environmental beliefs of BEV owners were measured by 13 items (e.g., "the balance of nature is very vulnerable and easy to interfere with").

The items of the constructs were developed based on previous studies which measured various attributes related to EVs (e.g. Barbarossa et al., 2017; Graham-Rowea et al., 2012; Haustein & Jensen, 2018; Kaplan et al., 2016; Kim et al., 2014; Noppers et al., 2015; Schuitema et al., 2013; Simsekoglu, 2018; Simsekoglu & Klöckner, 2018). In line with previous studies, perceived accident risk was constructed by multiplying the value of perceived accident possibility and perceived seriousness of accident consequences (e.g. "how likely do you think it is to be exposed to traffic accident when you use an EV?"; "If an accident occurs with an EV, how serious do you think the consequences might be?").

6.3.3 Statistical analysis

First, frequency distribution and mean values are calculated to examine the differences in demographic characteristics and travel behaviours (e.g., the frequency of using various transport modes and the purposes of EV use in a typical week) between the two BEV groups. BEV owners were categorized into two groups – sole BEV owners and owners with both BEVs and ICEVs. Two sample t and chi-square tests were conducted to examine the differences in travel behaviour and demographic characteristics between the two driver groups. In the second step, principle component analysis, using varimax rotation, was conducted to identify the dimensional structure of the scale measuring different perceived attributes related to EV use. Kaiser's "eigenvalue >1" criterion was utilized to determine the number of dimensions. In the third step, Cronbach's Alpha coefficient and average inter-item correlation were calculated to examine the reliability of the scales and scale dimension. Finally, to examine the influence of psychological factors on annual vehicle kilometres travelled (VKT) by BEVs, an ordinary least squares (OLS) regression analysis was carried out.

According to the literature reviewed in the introduction, the anticipated influence of various psychological determinants on the annual vehicle kilometres travelled *(VKT)* by BEVs can be expressed as:

$eVKT = f\,(SA, EA, SE, AR, EB, OB)$ (1)

where, $eVKT$ = vehicle kilometres travelled by BEVs; SA = symbolic attributes; EA = economic aspects; SE=self-environmental identity; AR= perceived accidental risk; EB = perceived environmental benefits of driving EVs; OB = perceived operating barriers of EVs; and GE = general environmental beliefs

In our study, the empirical investigation of Eq. 1 is conducted utilizing an econometric model, Eq. 2, which incorporates four control variables, such as inhabitants, H, of the municipalities where the BEV owners live, their income, I, and commuting distance, C, and the distance between home to public transport service, P. Existing literature posits that travel behaviour is influenced to some extent by the residential density, income elasticity, and distance between the origins and destinations of trips and public transports nodal points (Akar & Guldmann, 2012; Giuliano & Dargay, 2006; van Wee, 2011; van Wee et al., 2013).

$$\log\,(eVKT_i) = \beta_0 + \beta_1 SA_i + \beta_2 EA_i + \beta_3 EN_i + \beta_4 OB_i + \beta_5 EB_i + \beta_6 GE_i + \beta_7 AR_i + \beta_7 H_i + \beta_8 I_i + \beta_9\, C_i + \beta_{10} P_i + \varepsilon_i \quad (2)$$

where i = 1,2,3…n; $i \neq 0$

Assuming a non-linear relationship between dependent and independent variables and to achieve normal distribution of dependent variable values, eVKT was log-transformed. Consequently, Eq. (2) suggests that one unit change in any psychological factor will change a BEV owner's travel demand or eVKT, on average, by $100\beta_i$ percent.

6.4 Results

6.4.1 Scale Characteristics

We used Cronbach's alpha and average inter-item correlations to examine the reliability and internal consistency of previously validated measurement scales. Cronbach's coefficient alpha is a widely used measure for assessing the rightness and reliability of the psychometric scale designed for independent variables (Panayides, 2013; Peterson, 1994). Thresholds for Cronbach's coefficient alpha are still under debate, with different authors suggesting different thresholds. Nunnally (1978) recommends a reliability coefficient value of 0.7 or more. However, contemporary researchers illustrate reliabilities in the .60s and .70s as good or adequate (Dekovic et al., 1991; Holden et al., 1991). In our study, the reliability of the scale of all constructs is more than 0.70, with the exception of the economic aspects construct having a reliability level of 0.62 (Table 6.2). In respect of the average inter-item correlation, the prevalent correlation range between items is 0.15-0.50 (Briggs and Cheek, 1986; Clark and Watson, 1995). All constructs met the recommended threshold with the exception of self-symbolic attributes (0.56) and environmental identity (0.65).

Table 6.2: Cronbach's alpha and Average inter-item correlation of all constructs

Constructs	Number of items	α	$\bar{c}$
Perceived Economic Aspects (EA) *e.g.* by driving an electric car you can save money in the long run	2	0.62	0.46
Symbolic attributes (SA) *e.g. d*riving an electric car says something about me	5	0.87	0.56
Self-environmental identity (EN) *e.g.* I am the type of person who acts environmentally friendly	3	0.85	0.65
Perceived Operating Barriers (OB) *e.g.* the long time it takes to charge an electric car makes them impractical in use	5	0.75	0.37
Perceived Environmental Benefits (EB) e.g. Use of electric cars will reduce traffic-related air pollution in residential areas	5	0.76	0.38
General Environmental Beliefs (GE)	13	0.80	0.23

***Note: α** Cronbach's alpha**, $\bar{c}$** Average inter-item correlation*

6.4.2 Comparison of demographic characteristics between BEV driver groups

The comparative socio-demographic characteristics of BEV-owner groups are shown in Table 6.3. There are statistically significant differences between groups by gender, income, marital status, and the number of children in households. According to the sample statistics, comparatively, a greater number of male drivers own BEVs in addition to ICEVs and female drivers mostly prefer to own only BEVs rather than owning both. Sole BEV owners report a comparatively longer distance between home and public transport services. Not surprisingly, the results indicate that owners of both BEVs and ICEVs drive more kilometres than sole BEV owners because the former drive at least two cars. However, annually sole BEV owners (16106.05 km) drive their BEVs more than the other group who own both BEVs and ICEVs (15048.64 km) because they have to depend on only one vehicle to meet all their travel demands. The marital status and the average number of children suggest that larger families tend to possess both BEVs and ICEVs. Moreover, this particular group reports comparatively higher income (33.64% of respondents have an income over 900,000 kr. and 52.27% of respondents earn between 500,000-900,000 kr.) and higher educational qualifications (56.62% respondents have a qualification of master degree or equivalent degree). In addition, the results indicate that the sole BEV owners live mostly in municipalities with high population density. Furthermore, the number of drivers who are currently in an occupational activity or undergoing education was almost equal for both groups.

Table 6.3: A comparison of socio-demographic characteristics between BEV driver groups

	BEV owners *n = 228*	BEV and ICEV owners *n=220*	t test	χ2
	Mean (Standard error)			
Number of Children in household	1.04 (0.01)	2.02 (0.02)	2.94 **	
Annual kilometres driven	16,106.05 (628.58)	24,901.64 (671.05)	0.60	
Annual kilometres driven in BEVs	16106.05 (628.58)	15048.64 (512.54)	0.90	
Distance between home and public transport service	8.78 (0.77)	8.57 (1.00)	1.04	
Distance between home and work place	60.64 (2.67)	63.52 (2.64)	-0.14	
	n (%)			
Gender				21.76***
Male	144(64%)	186 (85.32%)		
Female	81 (36%)	32 (14.68%)		
Income				12.37**
Under 250,000 kr.	4 (1.75%)	2 (0.91%)		
250,000-350,000 kr.	13 (5.70%)	3 (1.36%)		
350,000-500,000 kr.	45 (19.74%)	26 (11.82%)		
500,000-900,000 kr.	109 (47.81%)	115 (52.27%)		
Over 900,000 kr.	57 (25.00%)	74 (33.64%)		
Marital Status				7.66***
Single	23 (10.75%)	6 (2.76%)		
Married/cohabitating	180 (84.11%)	202 (93.09%)		
Separated /divorced	11 (5.14%)	7 (3.23%)		
Widow/widower	0	2 (0.92%)		
Education				2.04
Primary education	3 (1.32%)	2 (0.91%)		
Vocational higher education	29 (12.78%)	29 (13.24%)		
General education	20 (8.81%)	16 (7.31%)		
Bachelor’s degree or equivalent	60 (26.43%)	48 (21.92%)		
Master’s degree or equivalent	115 (50.66%)	124 (56.62%)		
Inhabitants in living municipalities				2.05

Under 2000 inhabitants	2 (0.88%)	2 (0.92%)		
2000 – 19,999 inhabitants	63 (27.63%)	55 (25.23%)		
20,000 – 100,000 inhabitants	78 (34.21%)	88 (40.37%)		
Over 100,000 inhabitants	85 (37.28 %)	73 (33.49%)		
Working/Student				.025
Yes	209 (91.67%)	201 (91.36%)		
No	19 (8.33%)	19 (8.64%)		

****P< .01: **P < .05*

6.4.3 Comparison of mobility patterns between BEV driver groups

The public transport modes in Norway consist of trains, light-trains, buses, t-banes, and trams. However, only trains and buses are available in most of the municipalities, whereas other modes are only available in selective big cities (e.g. Oslo, Bergen). Based on the responses, we posit that sole BEV owners use comparatively less public transport. On average, 79.17 percent of respondents that are sole BEV owners never use public transport (both bus and train) in a regular week compared with 77.5 percent of respondents who own both BEVs and ICEVs. Evidently, 71.05 percent of BEV owners drive their BEVs five days or even more in a typical week.

The three most frequently reported purposes for using BEVs are daily commuting, long trips outside the city, and short trips within the city area for leisure activities (Table 6.4). The travel purposes for both types of BEV owners are almost similar.

Table 6.4: Frequency (%) of BEV use in a typical week for different purposes

Travel Purpose	BEV owners							BEV and ICEV owners						
	N	*1*	*2*	*3*	*4*	*5*	*NR*	*N*	*1*	*2*	*3*	*4*	*5*	*NR*
Commuting to work/educational place	11.5	4.4	3.1	7.1	7.5	61.5	4.8	10.1	6.9	5.1	6.9	5.5	61.8	3.7
Long trips outside the city	21.8	52.3	11.8	4.1	0.9	5.0	4.1	29.9	47.2	9.8	3.7	0.9	5.6	2.8
Travelling for leisure activities within the city area	11.1	24.4	22.7	17.8	8.4	14.7	0.9	1.9	32.4	24.1	13.0	6.9	19.9	1.9

***Note:** the values refer to the percentage of respondents; N - Never; NR - not relevant;*

1 - 1 day; 2 - 2 days; 3 - 3 days; 4 - 4 days; 5 - 5 days and more

In addition, the survey results indicate that the majority of sole BEV owners (57%) drive, on average, between 10,000 and 20,000 kilometres annually. Evidently, the majority of both groups drive their BEVs, on average, between 27 to 55 kilometres daily. Moreover, 9% of sole BEV owners drive, on average, more than 30,000 kilometres annually compared with 6% of owners of both BEVs and ICEVs.

6.4.4 Predictors of VKT among BEV drivers

Two models are developed by regressing the dataset of the two BEV owner groups utilizing Eq. (2). Both models have satisfactory R^2 values as well as statistically significant F statistics (Table 6.5). The predictors in Eq. (1) explain 21.14% and 11.56% of the variance in BEV owners' annual vehicle kilometres travelled, respectively, for models 1 and 2. The average variation inflation factor of 1.20 and 1.15 for models 1 and 2, respectively, indicate acceptable multi-correlation in both models.

The results indicate that the perceived economic aspects related to EVs have positive effects (at the 1% significance level) on sole BEV owners' annual distance travelled. This implies that the perception of the lower marginal cost of driving and lower maintenance cost induces travel demand among sole BEV owners. This suggests that various policy measures, particularly the use-based policy measures which intend to lessen the EV owners' driving cost in the long run, stimulate annual VKT for sole BEV owners. Moreover, the influences of economic aspects are the strongest amongst all the perceived attributes with coefficient value (β_2) of 0.31. Statistically, this means that if sole BEV owners' beliefs or perceptions related to the economic aspects increase by one unit then it would increase his/her annual VKT by, on average, 31%. Evidently, perceived operating barriers do not have any significant influence on driving their BEVs. In contrast, such perception poses a negative influence (at the 5% significance level) for owners of both BEVs and ICEVs. This indicates that because of range anxiety, longer charging time, and unavailability of charging facilities they tend to drive their BEVs less. Further, this is consistent with the outcome of Table 6.2, which shows that owners with both BEVs and ICEVs have less annual VKT than sole owners of BEVs.

Table 6.5: Regression results

Model specifications	**Sole BEV** *(model 1)*	**Both BEV and ICEV** *(model 2)*
R^2	21.14%	11.56%
F statistics	7.13***	34.77***
Variables	**Coefficient, β_B**	**Coefficient, β_{BI}**
Symbolic attributes (SA)	0.045	0.088
Economic aspects (EA)	0.308***	-0.080
Self-environmental identity (SE)	0.023	0.074
Accidental risk (AR)	-0.009	0.006
Environmental benefits of using EVs (EB)	-0.114	-0.028
Operating barriers of using EVs (OB)	-0.006	-0.145**
General environmental beliefs (GE)	0.020	0.078
Inhabitants (H)	-0.235***	-0.190 ***
Income (I)	0.023	0.072
Commuting distance (C)	0.002**	0.00
Distance between home and public transport service (P)	0.002	- 0.000***

****P< .01: **P < .05*

The number of inhabitants in the municipal area has a significant effect on both groups. The results indicate that in more densely populated areas people drive their BEVs less However, perceived accidental risk, self-environmental identity, perceived environmental benefits of using EVs, and general environmental beliefs of BEV owners do not have a statistically significant influence on annual VKT by BEVs in either of the models.

6.5 Discussion

The number of consumers purchasing EVs as their main or additional car is increasing fast in many countries including Norway. Currently, the market share of EVs, particularly BEVs, in Norway is the highest in the world; however, because of the new technological orientation, it is still difficult to predict market acceptance. Evidently, psychological factors play an important role in deciding to purchase EVs. In line with this, the increasing number of EVs on the road highlights the importance of considering psychological factors in addition to traditional transport economic frameworks in predicting EV drivers' travel demand accurately. In this study, we investigated the role of perceived attributes related to EVs, self-environmental identity, and general environmental belief on VKT by conducting an empirical analysis utilizing the survey results. We categorized the survey participants into subgroups, presuming that the socio-demographic characteristics, psychological orientation, and driving behaviour of sole BEV owners and both BEV and ICEV owners would be different. Subsequently, the socio-demographic results in Table 4 show that both groups are significantly different in gender and income. The number of children between groups suggests that it is usually bigger households that possess both BEVs and ICEVs, which is relevant because one of the drawbacks of BEVs in the market is that they are small in size and hence cannot accommodate larger families. This leads to the possible reasoning that larger families keep ICEVs in addition to BEVs for their family trips.

The OLS regression analysis results show that perceived operating barriers adversely affect VKT for owners of both BEVs and ICEVs. This is in line with the perceived control behaviour concept of the theory of planned behaviour (Ajzen, 1991) and the concept of perceived ease of use of the theory of the technology adoption model (Davis, 1989; Davis et al., 1989). In our survey questionnaire, we asked the participants about perceived barriers related to the functional capabilities of EVs (e.g. limited battery range, lower maximum speed) and barriers related to the support infrastructure (e.g. few charging stations, longer charging time). Moreover, Table 3 suggests that the group owning both vehicle types drives comparatively more kilometres, in total, annually than the other group. This suggests that the demand for travelling longer distances and anxiety related to operating BEVs, are possible reasons for owning both BEVs and ICEVs, allowing this group to switch vehicle type according to their needs. This is an important result, because if people owning both ICEVs and EVs drive their ICEVs more often than their BEVs, then the intended contribution of the BEVs would be undermined. In addition, according to the OLS results, the perceived barriers of operating EVs overpowered the economic aspects for this particular group of BEV owners. This suggests that to some BEV owners, generous policy measures that are directed to benefiting the BEV user are less significant than their perceived barriers related to driving BEVs. Therefore, it is important to note that without improving the BEV technologies related to battery range, acceleration, and installing adequate numbers of fast charging stations to overcome the perceived operating barriers, the ultimate success of mass EV adoption remains questionable.

The strong positive influence of economic attributes among sole BEV owners is consistent with traditional transport demand theory (Button, 2010) and notions of generalized travel cost (Button, 2010; Hanssen et al., 2012), which suggest that consumers tend to prefer to use the transport mode whose cost is comparatively lower. This is also consistent with the studies (e.g. Byun et al., 2017; Hymel et al., 2010; Plötz et al., 2014) that show an increasing travel demand as a result of reducing driving cost due to enhanced energy efficiency. Evidently, most of the economic benefits that BEV owners enjoy come from the generous purchase and use-based policy measures that have been implemented. This highlights another concern for policy-makers; would BEV owners continue to drive their BEVs when the financial incentives are lifted or would they discontinue their use of BEVs and/or switch to fossil fuel driven vehicles again. However, anxiety related to the barriers of driving BEVs does not have a statistically significant effect on sole BEV owners.

As already mentioned—with the help of enhanced energy efficiency, lower maintenance costs, lower energy (electricity) cost, and most importantly user-based policy incentives—EVs offer a lower generalized cost of driving. Consequently, in line with the effect of economic aspects on sole BEV owners, policymakers should also be aware of the rebound effect. Because, if such economic attributes keep increasing travel demand, in effect, it will increase the demand for electricity (secondary energy) which, in turn, will increase the demand for primary energy (oil, gas, coal, renewable energy). Evidently, the energy mix of electricity production is important to determine how much greener BEV driving is. However, in Norway, driving a BEV is comparatively greener than in other countries because 98% of its electricity is produced by renewable sources (NVE, 2016). In addition, technological improvements and building the optimal number of fast charging outlets throughout the country to overcome the psychological barriers of consumers. Interestingly, the causal effect suggests that less concern about operating barriers will lead to more use of BEVs on the road. This might again lead to the rebound effect of using EVs. Therefore, it is plausible that the effect of achieving successful EV adoption would most likely follow the economic diminishing theory; although it will bring greater positive changes to the transport sector and to the environment at the beginning, eventually the positive effect will be eradicated and will perhaps impose other types of problems on us.

The non-statistically significant effects of general environmental beliefs and self-environmental identity indicate an attitude-behaviour gap. As already mentioned in the reviewed literature, consumer concern for the environment does not necessarily result in pro-environmental behaviour all the time. In line with Stern's (2000) reasoning, it is arguable that one possible reason for such an attitude and behavioural gap may be that consumers have other important goals in their life and they act according to the prioritization of those goals.

Comparing the driver groups for the frequency of different travel mode use showed that sole BEV owners tend to use comparatively less public transport. On average 78.33 percent of BEV owners (combining both groups) never use public transport in a typical week. This is also in line with the notion of generalized cost which suggests that BEV owners prefer to drive their BEVs rather than use public transport when driving their BEVs costs comparatively less.

In addition, we find that the sole BEV owners drive their BEVs, on average, 44 kilometres daily, whereas the drivers owning both BEVs and ICEVs drive their BEVs, on average, 41 kilometres daily. Pasaoglu et al. (2014) cite that the average distance driven daily by EVs in other European countries, (e.g. the United Kingdom, Poland, Germany, Italy, Spain, and France) ranges from an average of 40 km to 80 km. Furthermore, this indicates that on a typical day, BEV owners do not usually drive more than the battery range of recent EV models in the market. Hence, it suggests that perceived range-related barriers are mostly psychological in nature. However, it is also possible that they limit their driving to within that perceived range purposefully.

The present study provides some findings that are useful for getting a better understanding of the variables that influence post-purchase EV use; however, there are also some limitations of the study. We examined the linear relations between VKT and predictors using OLS regression technique. However, sometimes consumers' perceptions related to various attributes have interrelationships among them and have indirect and/or nonlinear effects over consumers' ultimate behaviour. Hence, in a future study developing a structural equation model can show the relationships between the variables influencing VKT more comprehensively and thus provide a better understanding of the psychological variables influencing VKT among the BEV owners. In addition, we argue that including some additional variables, (e.g. consumer knowledge about EVs, consumer satisfaction) that are relevant for VKT among the drivers and using a larger dataset could have been useful to increase the explanatory power of our model explaining the VKT among the drivers. In addition, perceptions about EVs may vary across countries because of socio-economic and cultural differences. Therefore, it is necessary to conduct country specific analysis for a deeper understanding of the influence of psychological factors in various countries. Future research should consider including more relevant variables in the model and analyse both the direct and indirect causality of BEV VKT. Moreover, in future research, other types of EVs, such as PHEVs, HEVs, and FCEVs may be considered in the model framework.

6.6 Conclusion

We investigated the role of perceived attributes related to EVs, perceived accidental risk, self-environmental identity, and general environmental beliefs on VKT by conducting an empirical analysis using survey results. The findings of this study indicate that perceived operating barriers and perceived economic aspects influence the post-purchase use of EVs. However, the influence of these perceptions varies among EV owners. In this regard, the perceived economic aspects are statistically significantly influential for sole BEV owners, whereas perceived barriers related to EVs are statistically significant for drivers owning both BEVs and ICEVs. It is possible that perceived barriers related to EVs are more strong for those who prefer to have EVs in addition to ICEVs that in a way they prefer to use the conventional cars in situations where they think using an EV is not so beneficial. In addition, marital status and the average number of children suggest that larger families tend to own both BEVs and ICEVs. These findings suggest the necessity for improvement in the functionality of EVs and charging infrastructure to convince those consumers that have negative perceptions related to EVs to drive their BEVs. In addition, the effect of perceived economic aspects on EV use is something that policymakers need to consider when prioritizing policy measures.

Post-purchase use is important to evaluate the ultimate success of introducing EVs in the mass market. Hence, the results of this study suggest the inclusion of car owners' perceptions related to EVs in predicting a more precise model of EV owners' travel demand, which is, in turn, necessary to estimate the energy demand accurately and to take the necessary steps in establishing the necessary infrastructure. Policymakers should be aware of the possible rebound effect of EV use and, consequently, establish balanced policy incentives to promote EVs on the road.

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7. Article 3: Electric vehicles: An assessment of consumer perceptions using importance –performance analysis

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Abstract

The electrification of vehicles represents a promising measure for decarbonizing the transport sector. Several countries worldwide have created incentives to promote the mass adoption of electric vehicles (EVs) to mitigate the environmental and energy effects caused by the increased road transport demand; however, many consumers remain skeptical about EVs.

Consumer perceptions and concerns are critical for evaluating a product's market position, identifying opportunities for improvement, and guiding strategic planning. The importance-performance analysis (IPA) represents a simple and effective technique for assessing consumer acceptance of product attributes that have been used in diverse fields.

This study aimed at revealing the key EV attributes that require more attention from policymakers and manufacturers to improve consumer satisfaction. It analyzed survey data of 278 Norwegian EV owners and identified that instrumental aspects (i.e. driving range, battery recharging time, safety function, energy efficiency), winter driving quality, and environmental effects of EVs, are the most decisive factors when considering what car to buy. The results showed that EVs perform best with respect to environmental aspects, winter driving quality, and interior and exterior design. Third, based on the IPA results, policymakers and car manufacturers should focus on the instrumental aspects, cost aspects, and winter driving quality of EVs to make EVs more attractive to consumers.

Our findings provide policymakers and EV manufacturers with a deeper understanding of the needs and perceptions of EV owners with respect to EV attributes, thus helping them develop and implement better strategies for improving the attractiveness and performance of EVs.

Keywords: Electric vehicles, importance-performance analysis, gap analysis, EV users' satisfaction, EV adoption

7.1 Introduction

The global transport demand has been increasing due to factors such as the growing populations, urbanization, and economic development, which has improved the purchasing power of millions of people worldwide. Therefore, transportation has accounted for an increasing proportion of total global oil consumption in recent decades (International Energy Agency (IEA), 2011), making it one of the main contributors to global CO_2 emissions, and consequently, global warming (Travesset-Baro et al., 2015; Zhao and Heywood, 2017). In this regard, electric vehicles (EVs) are considered to have the potential to reduce tailpipe emissions, traffic noise, and fossil fuel consumption caused by road transport (Asamer et al., 2016; Mersky et al., 2016; Zhang and Yao, 2015). Policymakers in many countries have implemented policies to promote the widespread adoption of EVs (IEA, 2016; IEA, 2018a; IEA, 2018b). These policies have contributed to an increased interest in EVs, the introduction of new EV models, and an increase in the EV share of the global market for passenger cars by 1000% from 2011 to 2016 (IEA, 2017). Nevertheless, by 2018, the number of EVs globally reached only 5.1 million (IEA, 2019).

EVs are powered entirely or partially by electricity (Egbue and Long, 2012; Rezvani et al., 2015). In general, EVs are categorized into three types: battery EVs (BEVs), plug-in hybrid EVs (PHEVs), and hybrid EVs (HEVs), depending on the powering system. BEVs are pure EVs or all-EVs in which an onboard electric battery pack solely stores energy and powers the electric drivetrain (Campanari et al., 2009). HEVs combine an internal combustion engine (ICE) and an electric motor for better fuel efficiency, compared to similar-sized vehicles solely powered by ICE; however, all of their energy is originally generated by liquid fuel (Egbue and Long, 2012; Schuitema et al., 2013). In comparison, PHEVs have a more robust onboard electric battery pack than HEVs, which can be recharged by the electrical supply through the ICE and regenerative braking (Schuitema et al., 2013).

Research suggests that to increase EV adoption, the following major factors have to be considered: instrumental attributes (e.g. Egbue and Long, 2012; Noppers et al., 2015), cost aspects (e.g. Qian and Soopramanien, 2011; Ziegler, 2012), environmental aspects (Hackbarth and Madlener, 2013; Ziegler, 2012), availability of different EV models (Hoen and Koetse, 2014; Chorus et al., 2013), winter driving functions (Solvoll et al., 2010), and generous policy incentives (Qian and Soopramanien, 2011; Fearnley et al., 2015). However, to the best of our knowledge, few studies have examined the satisfaction of EV owners with these attributes and aspects. Besides, there appears to be a gap in the knowledge related to the disparities between the importance assigned to the above-mentioned factors by consumers purchasing a car and the EV owners' satisfaction with the same elements. Such knowledge can be used to identify improvement areas for EVs to be more attractive, thus contributing to establishing a greener road transport system.

The primary objective of this study is to obtain detailed insights that policymakers and car manufacturers can implement to make EVs more attractive for car buyers. To achieve this objective, a tailor-made web-based questionnaire was developed and distributed to a sample comprised mainly of current EV owners, including BEVs, PHEVs, and HEVs, in the Norwegian market, which is one of the most saturated EV car markets worldwide. The data gathered were used to answer three related questions. First, what are the most important factors when considering what car to buy? Second, how well do EVs perform concerning these factors? Third, which of these factors should policymakers and car manufacturers focus on improving to make EVs more attractive to consumers? The third research question is answered using the importance-performance analysis (IPA) and gap analysis techniques. These techniques have been used to assess service quality and provide recommendations related to various transport modes (e.g. Epstein and Givoni, 2016; Ha et al., 2019; Hernandez et al., 2016; Prasad and Maitra, 2019; Solvoll et al., 2010).

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature on factors influencing EV adoption. Section 3 describes the methodology used to conduct the empirical analysis. Section 4 presents and discusses the results. Section 5 provides some concluding remarks.

7.2 Factors influencing EV adoption

7.2.1 Instrumental aspects

Car use has predominately been explained through behavioral models focusing on the instrumental factors related to car use (Steg, 2005). EVs represent one type of alternative fuel vehicle in which the propulsion system is powered by electricity partially or entirely (Egbue and Long, 2012; Rezvani et al., 2015). Previous studies show that the prospects of widespread EV adoption rely on the improvement of instrumental factors related to car use such as driving range, battery recharging time, safety function, energy economy, convenience, and performance (Chéron and Zins, 1997; Danielis et al., 2020; Graham-Rowea et al., 2012; Hoen and Koetse, 2014). Unsurprisingly, there are uncertainties and anxieties about the performance and safety of EVs, which is reasonable considering that EVs only became common in recent years. Studies suggest that consumers are less willing to adopt new products with high perceived risk related to performance and financial aspects (Aggarwal et al., 1998; Shimp and Bearden, 1982).

Battery performance is a crucial parameter influencing the driving behaviour of BEV drivers (Azadfar et al., 2015; Neubauer and Wood, 2014), with range anxiety being a common psychological barrier to EV adoption. Range anxiety is a specific form of mental stress which occurs when the driver of a BEV fears that the remaining battery power is insufficient to reach her or his destination (Franke et al., 2016). However, studies indicate that car owners overestimate their range needs (Franke and Krems, 2013; Rauh et al., 2017). Moreover, the concern about the cost of driving EVs and perceived technological risks negatively affects the probability of EV adoption (Kim et al., 2014).

7.2.2 Policy measures

Policymakers have implemented various incentives to facilitate EV adoption and lower the marginal costs of using such vehicles. Purchase incentives (e.g. rebate upon registration, sales tax exemptions, value-added tax (VAT) exemptions, and tax credit) reduce the cost of purchasing an EV, whereas use-based incentives (e.g. exemptions from road tolls, parking fees, and ferry fares, and allowing access to bus lanes) reduce the marginal cost of driving an EV (Langbroek et al., 2016; Lévay et al., 2017). In line with the notion of generalized costs (Button, 2010; Wilson et al., 1969), the purchase incentives, use-based incentives, and lower fuel costs contribute to reducing the generalized cost of driving EVs. In Norway, BEVs are exempted from registration tax, VAT and are entitled to reduced annual vehicle licence fees (Figenbaum, 2017; Figenbaum et al., 2015). Besides, BEV owners were exempted from road tolls, ferry fees, and municipality parking fees until 2017. Recently, local authorities are given authority to decide the policy incentives regarding access to bus lanes, exemption of fees for municipal parking facilities, and ferry services. However, local authorities need to follow the 50% rule, which means that counties and municipalities can not charge more than 50% of the price for fossil fuel cars on ferries, public parking, and toll roads (Haugneland et al., 2017). BEV owners still benefit from having access to bus lanes, although new rules passed in 2016 allow local authorities to limit access to only BEVs carrying one or more passengers (Norsk Elbilforening, 2018).

7.2.3 Cost aspects

In this study, the cost aspects correspond to the car owners' perceptions of the economic value of car use. The economic value indicates the purchase cost and the perceived refueling, depreciation, and maintenance costs. In particular, monetary costs strongly influence travel mode use (Verplanken et al., 2008). In addition to purchasing and use-based policy measures (e.g. exemption from road tolls, ferry fares, and parking fees), technological differences make EVs require less maintenance compared to ICE vehicles (Palmer et al., 2018). Moreover, the refueling (for ICE owners) or recharging costs (for EV owners) represent also a decisive factor in evaluating the marginal cost of driving any car type. In this regard, increased energy efficiency (Helmers and Marx, 2012; Larminie and Lowry, 2003), combined with a lower tax rate on electricity (Palmer et al., 2018), reduces operating costs of driving EVs. In Norway, electricity is subject to a much lower tax than fossil fuel (Fridstrøm, 2020). Although fast charging is more expensive than charging at home, it is an alternative when going on a trip or needing to recharge during the day. However, as most people in Norway charge at home daily, the monthly operating expense is considerably lower than for petrol and diesel cars as a whole (Haugneland, 2020).

7.2.4 Environmental aspects

Normative theories such as the value-belief-norm theory (Stern, 2000) and the theory of planned behaviour (Ajzen, 1991) are often used as theoretical frameworks to describe consumer behaviour related to protecting the environment. The most successful transformation policies, such as the German Energiewende and Norwegian policy instruments, were first implemented due to the momentum created by green and environmental movements (Fagerberg et al., 2016). EVs are functional innovations with better fuel efficiency than conventional cars with ICEs, have less or zero local carbon emissions, and generate little engine noise, thus improving the overall driving experience (Axsen and Kurani, 2012; Degirmenci and Breitner, 2017; Zhao and Heywood, 2017). A study by Kim et al. (2014) posits that the intention to purchase an EV is encouraged by environmental concerns and technological acceptance. Other studies find that environmental beliefs and consumer awareness of environmental issues influence EV acceptance (Egbue and Long, 2012; Lane and Potter, 2007; Rezvani et al., 2015; Simsekoglu and Klöckner, 2018; Skippon and Garwood, 2011). However, concern for the environment does not necessarily result in pro-environmental behaviour (Kollmuss and Agyeman, 2002; Oliver and Rosen, 2010; Stern, 2000).

7.2.5 Symbolic attributes

EVs are much more than just a means of transport; they symbolize ideas that have significance beyond the individual level. However, few studies have investigated the potential of EV adoption through symbolic-affective motives (e.g. personal status, and feelings of sensation, independence, and superiority), although in practice, automobile advertisements, TV commercials, and specific automobile magazines demonstrate symbolic-affective appeals either explicitly or implicitly (Heffner et al., 2007; Rezvani et al., 2015; Schuitema et al., 2013; Steg, 2005; Steg et al., 2001). Symbolic attributes were important to early consumers of BEVs in Norway and Austria as well as to first buyers of HEVs in California (Gjøen and Hård, 2002; Turrentine and Kurani, 2007). Multiple symbolic meanings are associated with owning EVs, including being pro-environment, being opposed to conflicts over resources, having an inclination to reduce support to oil producers, and desire for new mobility experiences (Gjøen and Hård, 2002; Heffner et al., 2007). Heffner et al. (2007) added that these denotations are linked to further personal connotations, such as ethics, maturity, concern for others, and individuality.

7.2.6 Winter driving

Studies have found that wind speed, temperature, and precipitation (rain and snow) are important weather indicators affecting all road transport types (Agarwal et al., 2005; Bardal and Mathisen, 2015). However, EVs are comparatively more vulnerable to low temperature than ICE vehicles as it adversely impacts EV's battery range and battery performance. In line with this, Bullis (2013) and Motoaki et al. (2018) reckon that low temperature tends to degrade the battery charging rate and, as such, extend the charging duration. Moreover, in low temperatures, additional energy is needed for the heating system, further reducing the range (Bullis, 2013; Engström et al., 2019; Zhang et al., 2018). In a study, Noel et al. (2020) reveal that winter weather is one of the barriers to EV adoption and is discussed in the context of its impact on range. In another study, EV owners expressed being least satisfied with the functionality of EVs during winter (Solvoll et al., 2010). Besides, EVs require special tires for a variety of reasons. EVs should have tires with increased load-bearing capacity to handle a battery pack's extra weight and ought to have lower rolling resistance than standard tires to maximize their driving range (Edelstein, 2020; Vossler, 2015).

7.2.7 Interior and exterior design

While reviewing the importance of consumer emotions for EV adoption, Rezvani et al. (2015) posit that consumers' perceptions of attributes, such as style, design, and size, construct their visceral emotions (Moons and Pelsmacker, 2012; Norman, 2004). A deep understanding of consumer emotions is vital for the design of communication, education, and policies to overcome existing barriers to EV adoption (Schuitema et al., 2013). Oliver and Rosen (2010) and Egbue and Long (2012) mention the size and style of EVs as barriers to the mass adoption of EVs. Technological developments have continued to influence consumers' expectations and improve their experience. However, acquiring knowledge about the consumers' perceptions of these factors remains essential for understanding the behaviour of car owners.

7.2.8 Availability of car models in the local market

Previous experiments suggest that a car is a highly positional good (Carlsson et al., 2007) and car buyers usually tend to have a strong predisposition to choose a car type that has similar attributes as their current car (Hoen and Geurs, 2011). Additionally, Chorus et al. (2013) and Hoen and Koetse (2014) suggest that having more alternative-fuel models available in the market increases the probability of choosing such vehicles. Moreover, the availability of a variety of EVs in the local market nudges the consumers' availability heuristics, which are useful mental shortcuts for people to make decisions relying on immediate examples when evaluating possible actions or behaviors (Thaler and Sunstein, 2008; Tversky and Kahneman, 1973). Arguably, brand image, perception, and loyalty influence car buyers' purchase decisions (Devaraj et al., 2001; Helveston et al., 2015; Hirsh et al., 2016). Morris (2013) finds that the car purchase path changes over time in the current digital era. However, the influence of car brands on purchase decision-making remains constant through the cycle of the pre-market, in-market, and post-market phases, with 63% of new car buyers initiating their search with a specific brand in mind. Nevertheless, the influence of brand values is somewhat lower in Norway (Jørgensen et al., 2016).

7.3 Method

7.3.1 Framework for IPA

Quadrant approach

The IPA is a technique developed by Martilla and James (1977) to identify which attributes to focus on when trying to improve customer satisfaction. The method implies using a two-dimensional grid with the attribute importance on one axis and the attribute performance on the other. Based on their perceived importance and performance, each attribute is positioned within one of four quadrants. The grid with its four quadrants is shown in Figure 7.1. The labels attached to the quadrants suggest how decision-makers should handle the factors in that quadrant:

1. High importance and high performance – "Keep up the good work": Attributes situated in this category are performing well and indicate opportunities for achieving or maintaining potential competitive advantages of a product or service (Deng, 2007; Sever, 2015). Consumers are satisfied with these attributes and also consider them important. Thus these attributes represent major strength and need continued investment (Esmailpour et al., 2020; Sever, 2015).

2. Low importance and high performance – "Possible overkill": Attributes falling in this category are performing strongly but have low importance to consumers. These attributes have less potential to attract consumers, and resources committed to these attributes should be deployed elsewhere – the best possible reallocation of resources could be to attributes situated in the category 'concentrate here' (Deng, 2007; Dwyer et al., 2012; Esmailpour et al., 2020).

3. Low importance and low performance – "Low priority": Attributes situated in this category require limited attention from the decision-makers (Padlee et al., 2020). These attributes are performing low and have relatively low importance to consumers. They represent minor weaknesses of a product or service, and therefore investing resources in improving these attributes poses less priority if they do not generate reliable outcomes (Esmailpour et al., 2020; Phadermrod, Crowder, and Wills, 2019).

4. High importance and low performance – "Concentrate here": This is the most crucial category, and attributes located in this category represent major weakness (Sever, 2015). These attributes require immediate attention for improvement from decision-makers, and if left underperformed, they threaten the competitiveness of a product or service (Esmailpour et al., 2020). Attributes in this category require the highest priority in allocating resources and effort (Azzopardi and Nash, 2013).

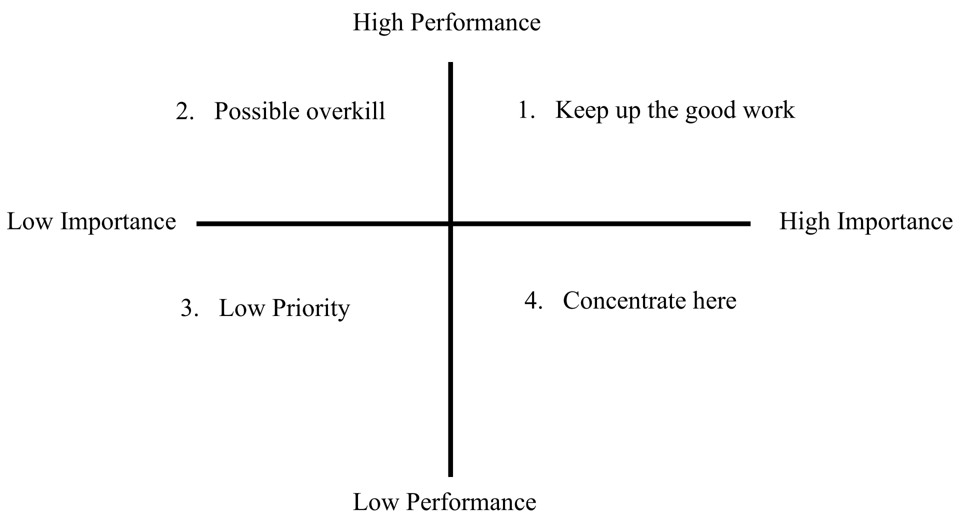

Figure 7.1: Typical IPA with quadrant model (based on Martilla and James, 1977; Mikulic and Prebezac, 2008)

IPA provides insights by identifying critical attributes to focus on improving the performance a product or service (Abalo et al., 2007; Chu and Choi, 2000). IPA helps the decision-makers prioritize actions to recommend the optimal allocation of limited resources to improve the consumer experience, enhance the loyalty of existing consumers, and attract new consumers (Cao, 2017; Sever, 2015). Intuitively, as indicated by the labels, managers should give low priority to factors of little importance to customers. Instead, the limited resources of an organization should be allocated to factors of high importance, particularly those with low perceived performance.

Since the IPA-technique is considered to be both simple and effective (Hansen and Bush, 1999), it is used to make resource allocation recommendations in several industries and services, including tourism (Newsome et al., 2019; Bi et al., 2019; Coghlan, 2012; Dwyer et al., 2012), higher education (Hanssen and Mathisen, 2018; O'Neill and Palmer, 2004), trade shows (Tafesse et al., 2010), healthcare (Abalo et al., 2007; Kinnaer et al., 2020), banking (Joseph et al., 2005), technology (Chen and Ann, 2016) and transportation (Das et al., 2013; Esmailpour et al., 2020; Freitas, 2013; Sum et al., 2019). However, Zhang et al., (2019) find that the application of IPA in transportation is scarce. Besides, no previous studies, to our best knowledge, used IPA to investigate consumers' perception about EV performance. Thus, considering the effectiveness and usefulness of the IPA method, our study offer a novel approach to evaluate EV attributes to improve and sustain consumer satisfaction and ultimately increase EV sales.

Diagonal approach and gap analysis

The traditional IPA (Figure 7.1) has a weakness in that a minor change in the positioning of a factor can lead to considerable changes in recommendations (Bacon, 2003). To overcome this weakness, gap analysis and the introduction of an iso-rating line or a diagonal line in the IPA analysis are used.

In the gap analysis, the mean performance score of a factor is subtracted from its mean importance score (Hanssen and Mathisen, 2018). Elements with the highest deviation between importance and performance should be prioritized when allocating resources. Previously, gap analysis has been used to predict consumers' buying attitudes and intentions (Ford et al., 1999; Sethna, 1982). However, the mathematical differences between the mean of two different constructs (importance and performance) simply explain an intuitive rather than a precise meaning (Bacon, 2003; Azzopardi and Nash, 2013). Additionally, the weakness of the traditional IPA can also be addressed by drawing an iso-rating line, which is a 45-degree upward slope line along which importance equals performance (see Figure 7.2). Consequently, there is a zero performance gap for all combinations of importance and performance along the iso-line (Magal et al., 2009). All factors below the iso-line have greater importance than performance, and thus, represent an opportunity for improvement (Skok et al., 2001) and should be prioritized. Previously several studies used the extension of the quadrant method to separate regions of different priorities in an importance-performance space (Bacon, 2003; Hawes and Rao, 1985; Levenburg and Magal, 2005; Sampson and Showalter, 1999).

Sever (2015) argued that IPA with the diagonal model is a more suitable method for identifying potential areas where the decision-makers need to focus more to improve the condition as this method directly interprets the differences between performance and importance rating. However, IPA analysis with diagonal approach has relatively limited interpretability and discriminative power than the quadrants approach because it has less information to offer with attributes located in only two categories (Sever, 2015). Therefore, Esmailpour et al. (2020) suggested combining these two approaches for in-depth understanding. Previously, Abalo et al. (2007), Hanssen and Mathisen (2018), Rial et al., (2008) and Dwyer et al. (2012) combined a diagonal approach with the quadrant approach in their studies. This study applies the IPA analysis with both quadrants approach and diagonal approach to generate knowledge that policymakers and car manufacturers can use to make EVs more attractive to consumers.

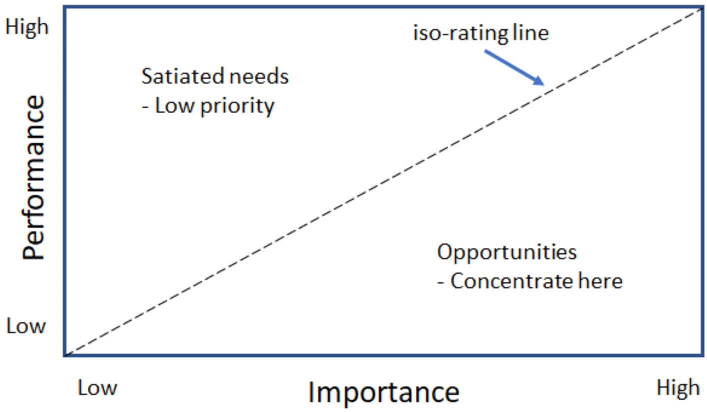

Figure 7.2 IPA with diagonal model

7.3.2 Survey

Sampling

A web survey was developed using a survey platform used internally at Nord University Business School, and used to collect data from electric car owners in Norway. The data were collected between March and May, 2019. The invitation to participate in the survey was distributed by traditional mail to 4330 car owners who were randomly drawn from a dataset provided by the Norwegian Public Roads Administration. The invitation letter included a web address where they could find the survey. A total of 451 respondents filled out the questionnaire, yielding a response rate of 10.42%. Among them, only 278 (62%) owned electric cars. In this study, we employ the responses provided by the 278 electric car owners to assess the importance and performance of EVs based on consumer perceptions.

Measures

As previously mentioned, the data used in this study were collected using an online questionnaire. The first section of the survey included questions about the respondents' most recently purchased car. The respondents were asked what type of car (i.e. BEV, PHEV, HEV, and ICEV) they bought most recently, the model of that particular car, how long they have owned it, the total number of vehicles in the household, and their driving habits. In the present study, to evaluate the performance of EVs, we included the responses from owners of BEVs, PHEVs, and HEVs.

In the demographic section of the survey, respondents stated their gender and marital status. Additionally, using multiple given options, respondents were asked about items such as income before tax, academic qualification, and population density of the municipalities where they lived.

In the next section, the respondents were asked to state the importance of different factors when purchasing a car on a 5-point Likert scale ranging from 1 (not important) to 5 (extremely important). Subsequently, the respondents were asked about their satisfaction levels with their latest purchased EVs for the same factors using a 5-point Likert scale ranging from 1 (not satisfied) to 5 (extremely satisfied).

The respondents were asked about the economic, instrumental, and environmental aspects; interior and exterior design; winter driving quality; and the symbolic elements of owning a car, and respondents' perception about the availability of the desired car, and use-based policy incentives. The factors were selected based on the literature review presented in Section 2, and comprised various items in our study constructs. The items of the attributes were developed based on previous studies that investigated multiple characteristics of cars, including EVs (Bullis, 2013; Button, 2010; Chorus et al., 2013; Egbue and Long, 2012; Hoen and T.Geurs, 2011; Langbroek et al., 2016; Schuitema et al., 2013; Sherman, 1967; Simsekoglu, 2018; Simsekoglu and Nayum, 2019; Solvoll et al., 2010; and Verplanken et al., 2008). The items related to each construct are shown in Table 7.2.

7.4 Results

7.4.1 Sample description

The sample included 197 males (71%) and 80 females (29%). Most of the respondents were married (86%) and aged between 41 and 60 years (59%). Table 7.1 shows that the majority of the sample (78%) earn more than 500,000 kroner ($54,000) per year. Regarding education, 72% of the respondents attended university. Moreover, about a quarter of the respondents (26%) drove more than 40 kilometers on an average day, while 59% of the respondents drove at least 30 kilometers on an average day. Finally, the average number of cars owned by the respondents' households was less than 2. Considering that a large survey among Norwegian BEV owners, based on the entire population, Fevang et al. (2020) finds that the male share of the respondents was 72%, that their average age was 51 and that 88% had higher education from a college or university, indicates that our sample broadly resembles that of Norwegian owners of BEV.

Table 7.1: Socio-demographic characteristics of the sample (n=278)

	Sample	
	Count	Percentage
Gender:		
Male	197	71%
Female	80	29%
Age:		
18-30	4	1%
31-40	50	18%
41-50	75	27%
51-60	88	32%
61-70	46	17%
> 71	15	5%
Income before tax:		
< 250 000 kr	3	1%
250 000 – 350 000 kr	13	5%
350 000 – 500 000 kr	46	17%
500 000 – 650 000 kr	80	29%
650 000 – 800 000 kr	48	17%
> 800 000 kr	88	32%
Education:		
Primary	7	3%
High School, vocational	35	13%
High School, general education	36	13%
≤ 3 years of college / university	77	28%
> 3 years of college/ university	123	44%
Kilometers driven per day:		
< 10km	24	9%
10- 20 km	47	17%
20-30km	42	15%
30-40km	43	15%
40-50km	49	18%
> 50 km	73	26%

Figure 7.3 shows that 26% of the respondents owned an EV manufactured by Nissan, while Tesla was the second most owned EV brand with 18% of the respondents. This is relatable to official statistics showing that Nissan sold most electric cars in Norway in 2018 (Kane, 2019). More precisely, the most popular EV model in the Norwegian market in 2018 was the Nissan Leaf, followed by Volkswagen e-Golf, whereas in 2017, Volkswagen e-Golf was most popular, followed by BMW i3 (Ayre, 2018; Pontes, 2019). At the beginning of 2019, Tesla started delivering pre-ordered Model 3 in the Norwegian market and ended the year as the best-selling EV model (Lambert, 2019; Pontes, 2020).

With respect to how long the respondents owned their latest electric car, Figure 7.4 shows that more than one-third of the respondents (37%) owned their latest electric car for less than a year and that slightly more than a quarter of them (28%) owned it for less than two years, but for more than a year. Only 9% of the respondents kept their latest electric car for 4 years or more.

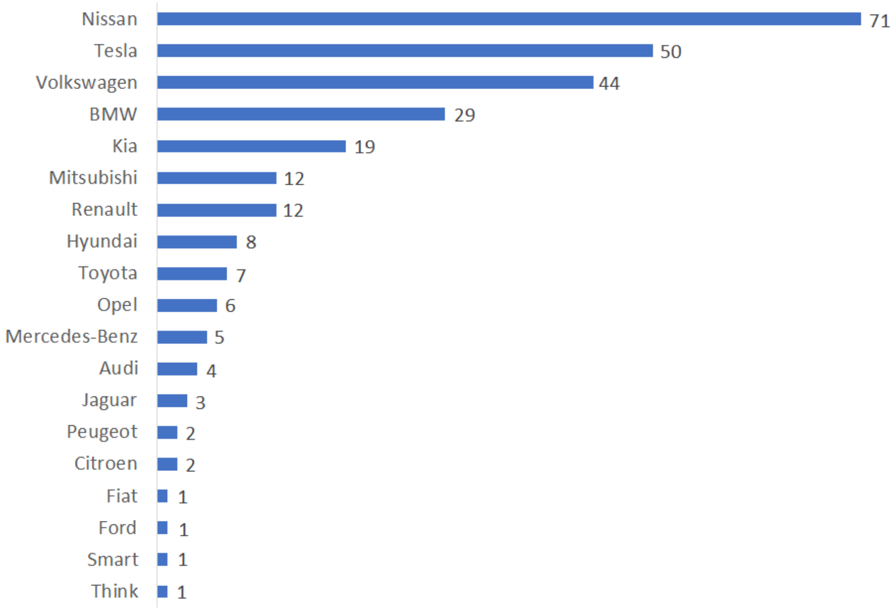

Figure 7.3: Number of respondents owning an EV by manufacturer

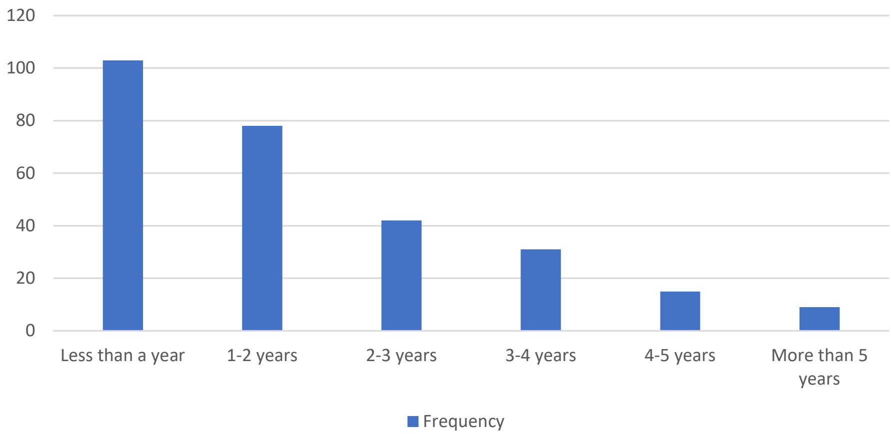

Figure 7.4: Number of respondents by length of ownership of their latest EV

7.4.2 Scale characteristics

To verify the reliability and validity of each set of measures, we conducted the principal component analysis (PCA). At first, we utilized the iteration and Varimax rotation, which identifies the dimensional structure of the scale measuring the attributes of interest. We used Kaiser's ‘‘eigenvalue>1″ criterion to decide the number of the dimension. As the next step, the correctness and reliability of the constructs were tested using Cronbach’s alpha (Panayides, 2013; Peterson, 1994).

Table 7.2: Principal component analysis (PCA) and confirmatory factor analysis (CFA)

	PCA		CFA
	Cronbach`s Alpha	inter-item correlations	Factor loadings
Cost aspects	0.65	0.32	
Purchase cost			0.55
Maintenance cost			0.56
Refueling (charging) cost			0.63
Depreciation cost			0.59
Instrumental aspects	0.71	0.38	
Driving range (battery range)			0.62
Safety features			0.44
Fuel (energy) efficiency			0.78
Refueling (charging) duration			0.64
Interior and exterior design	0.80	0.57	
Interior style/design/look			0.85
Exterior style/design/look			0.87
Car size			0.56
Environmental aspects	0.83	0.56	
Tailpipe emission			0.90
Traffic noise			0.74
Type of energy usage			0.64
Other environmental consequences			0.79
Availability	0.77	0.45	
Availability of dealers nearby			0.70
Availability of different models			0.51
Country of manufacturer			0.77
Manufacturer’s reputation			0.79
Use-based policy measurements	0.76	0.45	
Road toll			0.70
Ferry fare			0.72
Parking fee			0.67
Saving time (e.g. access to bus lanes)			0.71
Winter driving	0.80	0.57	
Tyre grip during winter			0.96
Driving performance during winter			0.95

Warmness inside the car in winter			0.42
Symbolic aspects	0.94	0.75	
A car that shows who I am			0.95
A car that says something about me			0.95
A car that says something about my status			0.91
A car that distinguishes me from others			0.89
A car that makes me feel good			0.62

The thresholds for Cronbach's alpha are up for debate, with different authors suggesting different limits. Nunnally (1978) recommends a reliability coefficient value of 0.7 or more. Later, however, values in the 0.60s and 0.70s have been considered good or adequate (Deković et al., 1991; Holden et al., 1991). All the constructs in our study had a reliability coefficient close to (or above) 0.70. Besides, for inter-item correlations, which represent a measure of internal consistency reliability, a coefficient around 0.30 is considered satisfactory (Hair et al., 1998; Lund et al., 2012). Table 7.2 shows that all inter-item correlations in our dataset are above 0.3.

In addition, we also conducted confirmatory factor analysis (CFA) considering the limitations of PCA (Raykov and Marcoulides, 2011). To ensure unidimensionality and discriminate validity, we conducted CFA using the maximum likelihood method. In addition to evaluating the factor loadings, we assessed the output mark of the root mean square error (RMSE), comparative fit index (CFI), and standardized root mean square residual (SRMR) to establish the fitted factor model, finding all of them to be satisfactory.

7.4.3 Assessment of the importance and performance of different factors

In Table 7.3, the mean importance (M_i) and mean performance (M_p) of the constructs and items were calculated and ranked in descending order. The ranking of the constructs such as instrumental aspects, cost aspects, environmental aspects, winter driving, interior-exterior style, symbolic aspects, percieved use-based policy measures and availablity of EV models, which we generated and confirmed in previous steps by conducting PCA, were calculated based on the mean values of the construct themselves. In addition, we presented the mean values of each item that made up the constructs (Table 7.3). According to the respondents, the least important item was "A car that says something about my status" (M_i = 1.92), while the most important item was "driving range" (M_i = 4.65).

Regarding the constructs, their descending order based on the importance perceived by the respondents was as follows: instrumental aspects, winter driving, environmental aspects, cost aspects, interior and exterior design, use-based policy measures, and symbolic aspects. Unsurprisingly, instrumental attributes (M_i = 4.41), such as driving range, energy efficiency, refueling (recharging) duration, and safety features are, according to the respondents, most important in the car purchase decision-making process, followed by driving functionality during winter periods (M_i = 4.36). The importance of winter driving quality was expected, since the survey was conducted in Norway, where winters tend to be long and cold. Conversely, use-based policy incentives and symbolic aspects were not critical when purchasing a car.

With respect to satisfaction, respondents were most satisfied with the environmental aspects (M_p = 4.44) of their latest purchased electric car, particularly with the type of energy it uses (M_p = 4.64), as both the electricity usage advantages and its production source in Norway satisfy their environmental concerns.

Table 7.3: The importance and performance of factors influencing EV adoption

	Mean (ranking)	
	Importance	**Performance**
Instrumental aspects	**4.41 (1)**	**3.97 (4)**
Driving range (battery range)	4.65 (1)	3.54 (26)
Safety features	4.59 (2)	4.31 (4)
Fuel (energy) efficiency	4.29 (7)	4.12 (10)
Refueling (charging) duration	4.14 (8)	3.91 (18)
Winter Driving	**4.36 (2)**	**4.11 (2)**
Tyre grip during winter	4.36 (5)	4.07 (14)
Driving performance during winter	4.38 (3)	4.09 (12)
Warmness inside the car during winter	4.31 (6)	4.18 (8)
Environmental aspects	**3.89 (3)**	**4.44 (1)**
Tailpipe emission	3.92 (14)	4.59 (2)
Traffic noise	3.57 (18)	4.30 (5)
Type of energy usage	4.38 (4)	4.64 (1)
Other environmental consequences	3.67 (15)	4.24 (6)
Cost aspects	**3.84 (4)**	**3.81 (5)**
Purchase cost	4.14 (9)	3.83 (19)
Maintenance cost	4.13 (10)	3.95 (17)
Refueling (charging) cost	4.02 (11)	4.22 (7)
Depreciation cost	3.06 (22)	3.40 (27)
Interior and exterior design	**3.69 (5)**	**4.11 (3)**
Interior style/design/look	3.48 (19)	4.13 (9)
Exterior style/design/look	3.61 (17)	4.08 (13)
Car size (spaciousness /seating capacity)	4.01 (12)	4.11 (11)
Availability	**3.26 (6)**	**3.82 (7)**
Availability of dealers nearby	3.43 (21)	3.98 (16)
Availability of different models	3.44 (20)	3.62 (25)
Country of manufacturer	2.24 (27)	3.70 (21)
Manufacturer's reputation	3.93 (13)	3.99 (15)
Use-based policy measures	**2.70 (7)**	**3.67 (6)**
Road toll	3.64 (16)	4.40 (3)
Ferry fare	2.29 (26)	3.62 (24)
Parking fee	2.92 (24)	3.65 (23)
Saving time (e.g. by access to bus lanes)	2.67 (25)	3.71 (20)
Symbolic aspects	**2.23 (8)**	**2.99 (8)**
A car that shows who I am	2.16 (29)	3.01 (28)
A car that says something about me	2.21 (28)	3.00 (29)
A car that says something about my status	1.92 (31)	2.84 (30)
A car that distinguishes me from others	1.93 (30)	2.81 (31)
A car that makes me feel good	2.96 (23)	1.69 (22)

7.4.4 Quadrant model

The mean scores for the constructs reported in Table 7.3 were used to generate the quadrant model shown in Figure 7.5, which visualizes our findings and functions as a basis for strategy formulation. The horizontal line passing through the matrix represents the grand mean of the perceived performance (M_p = 3.87), whereas the vertical line is the grand mean of the perceived importance (M_i = 3.55). These two lines produce four quadrants, with strategies formulated based on the quadrant in which each construct is placed. In the following, the importance-performance matrix is applied to evaluate the performance of EVs in the Norwegian market.

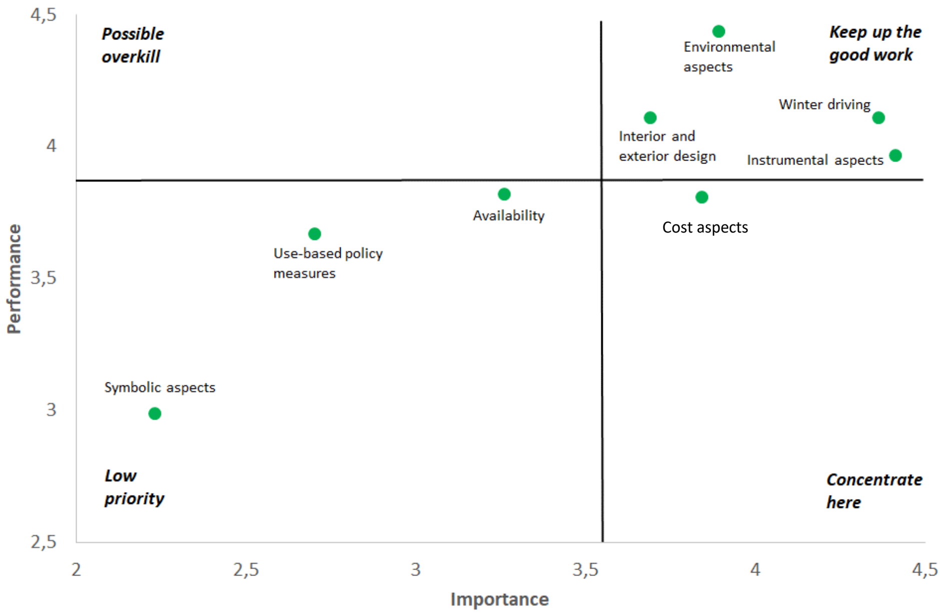

Figure 7.5: IPA - quadrant model.

Quadrant 1 (Keep up the good work)

The constructs in this quadrant have high importance and high perceived performance. Four of the constructs are located in this quadrant: environmental aspects, instrumental aspects, winter driving, and interior and exterior design. Unsurprisingly, Norwegian owners of EVs appear to be very satisfied with the environmental aspects of their EVs, particularly BEVs which produce zero tailpipe emissions and generate very little engine noise. Moreover, the electricity that drives EV powertrains in Norway is generated primarily from renewable energy sources (hydropower). Since the performances of these factors are of high importance when consumers purchase the EVs they prefer, the current high performance should be upheld to maintain the competitive advantages in the market.

Quadrant 2 (Possible overkill)
No constructs fell into this quadrant.

Quadrant 3 (Low priority)
The constructs in this quadrant have low importance and low perceived performance. This quadrant contains three constructs: policy measures, availability, and symbolic aspects. As these factors are of relatively low importance, manufacturers and policymakers should not prioritize them over other constructs, especially constructs in quadrant 4 (concentrate here). According to the IPA concept, these constructs represent minor weaknesses and do not pose any immediate competitive threats. Surprisingly, EV use-based policy measures such as exemption of road tolls, ferry fees, parking fees, and access to bus lanes fell into this quadrant, although Norway is quite well-known for it generous policy measures. One reason for the low importance of use-based policy measures might be that the Norwegian EV market is still in the development phase. In line with Rogers' (1983) innovation diffusion theory, the Norwegian EV market is currently in the late majority phase passing the innovator and early adopter phases. This theory suggests that governmental investment, such as policy measures, is a potentially useful tool to attract consumers when the products are in their early phases. Therefore, it could be argued that in the current development phase of the Norwegian EV market, consumers are perhaps not much concerned about the use-based policy measures compared to other factors. The low satisfaction level could be the result of recent changes in use-based policy measures at municipality level (see section 2.2). However, this finding is based on the responses of EV owners only. Therefore, it is plausible that respondents prioritized other factors (see Table 7.3) over use-based policy measures when making a decision about purchasing cars. Moreover, according to the 'low priority' category concept, it implies that the necessity of further improvement or allocation of resources depends on the yield and efficacy of use-based policy measures – which suggest further empirical investigation.

Quadrant 4 (Concentrate here)
The constructs in this quadrant have high importance but low perceived performance. This quadrant contains only one construct, namely, cost aspects. In line with this, cost aspects are of importance for attention and allocation of resources to improve performance. These findings suggest that both car manufacturers and policymakers should concentrate on reducing the cost related to purchasing, maintaining, and recharging EVs. Therefore, a lower monetary cost could, arguably, make EVs more attractive to potential buyers and make EV users more satisfied. Technological advancement (e.g. cheaper batteries) and generous policy incentives to manufacturers to encourage technological advancements and to consumers by providing access to more affordable charging options can play an essential role in lowering the economic cost of purchasing and driving EVs.

7.4.5 Diagonal model and gap analysis
In Figure 7.6, the points below the iso-line refer to an improvement area of high priority, while the points above the diagonal line refer to low priorities. This implies that constructs below the iso-line demand more focus than those above the iso-line. It should be noted that the iso-lines drawn in Figure 7.6 and Figure 7.7 are normalized to take into account that the two scales (i.e.

importance and performance) are not necessarily used equally by the respondents. The normalization is done by letting the iso-lines begin at the point where both importance and performance equals and continue through the "intersection" between the average value of the importance of the constructs and the average value of their performance. Consequently, the iso-lines take into account that there is a tendency in our dataset that the respondents state a higher level of performance than importance. We have also normalized the values for both performance and importance using a normalization method utilized in a study by Bia, Liua, Fana, and Zhanga (2019). Assuming $\overline{IM}$ and $\overline{PF}$ denoting the normalized values of importance and performance respectively, where

$$\overline{IM_i} = \frac{IM_i}{\sum_{i=1}^{n} IM_i}$$

$$\overline{PF_i} = \frac{PF_i}{\sum_{i=1}^{n} PF_i}$$

$i = 1, 2, 3, \ldots .n$

The main reason for using the iso-line in an IPA space is, as mentioned in subsection 3.1, that in the traditional quadrant model strategy recommendations might change considerably due to small changes in positioning. In Fig. 7.5, for example, a slight change in the performance of instrumental aspects could change the strategy recommendations for this construct considerably. In Fig. 7.6, where the iso-line is drawn, this factor is not as sensitive to changes in perceived performance. The diagonal model reveals that with regard to most constructs, performance is perceived as being higher than importance, whereas performance is lower than importance for three constructs only.

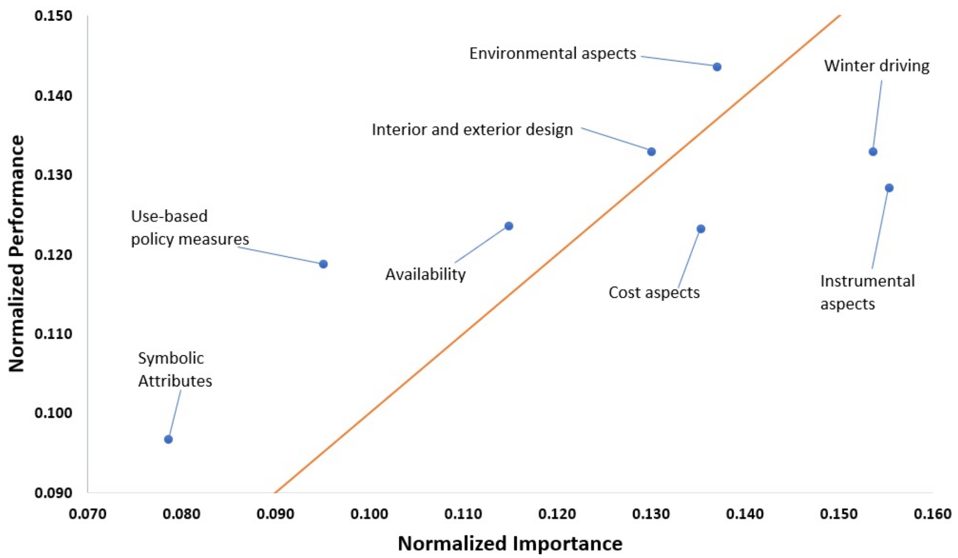

Figure 7.6: IPA – diagonal-model

The gap between the normalized importance and normalized performance for each construct is listed in Table 7.4. It can be seen that the three constructs in Table 7.4 with a positive gap between normalized importance and normalized performance also fall below the normalized iso-line in Figure 7.6. Two of these, namely instrumental aspects and winter driving quality, are primarily car manufacturers responsible for improving, whereas cost aspects can be improved by both car manufacturers and policymakers.

Table 7.4: Gaps between average importance and performance scores

	Normalized importance ($\overline{IM}$)	Normalized performance ($\overline{PF}$)	Gap ($\overline{IM}$ - $\overline{PF}$)
Instrumental aspects	0.155	0.128	0.027 *
Winter driving	0.154	0.133	0.021 *
Cost aspects	0.135	0.123	0.012 *
Interior and exterior design	0.130	0.133	-0.003 *
Environmental aspects	0.137	0.144	-0.007 *
Availability	0.115	0.124	-0.009 *
Use-based policy measures	0.095	0.119	-0.024 *
Symbolic aspects	0.079	0.097	-0.018

* *Statistically significant difference between normalized importance and normalized performance (p<0.01.)*

7.4.6 Implications for car manufacturers and policymakers

The mean importance and mean performance of the items comprising the concepts instrumental aspects, winter driving, and cost aspects are presented in Table 7.3. By incorporating these items into an IPA with an iso-line, as shown in Figure 7.7, it can be seen what car manufacturers and policymakers should focus on improving to make EVs more attractive. It should be noted that the iso-line in Figure 7.7 is similar to the one drawn in Figure 7.6.

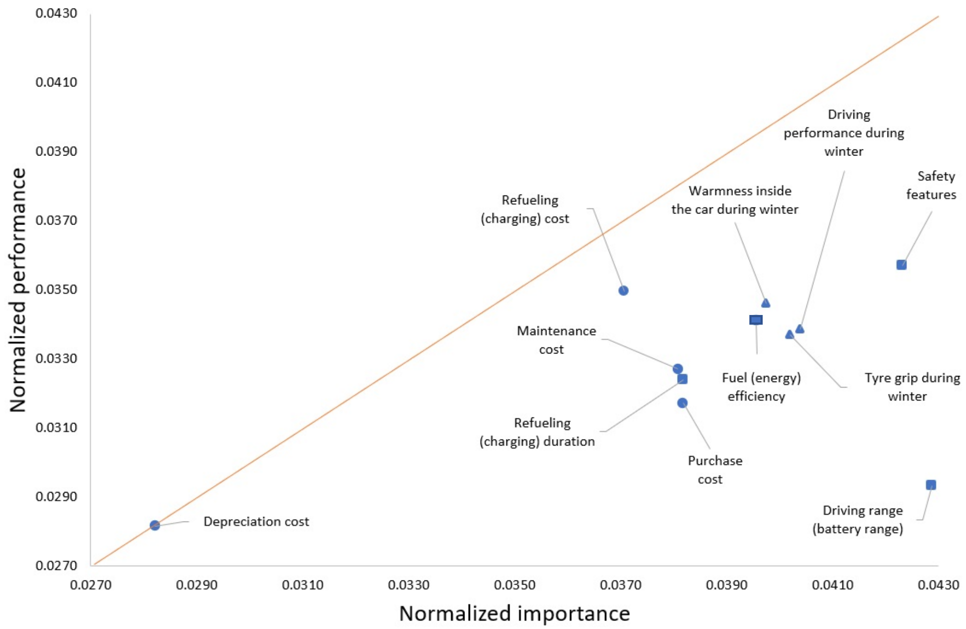

Figure 7.7: IPA with diagonal approach for items related to cost attributes, winter driving and instrumental aspects of EVs.

Note: Winter driving, instrumental attributes and cost aspects were labels by △, ◯, □ respectively.

The item standing out with the greatest deviation between importance and performance is the driving range. Consequently, despite recent years of significant improvement in the driving range of EVs, our data indicate that it is still the most important factor to improve. This finding is in line with previous research indicating that the driving range of EVs is a significant barrier to the acceptance of EVs (e.g. Franke et al., 2012). However, notably, car owners frequently overestimate their range needs (Franke and Krems, 2013; Rauh et al., 2017). The challenge related to driving range can, therefore, at least partially, be solved if car buyers have a realistic perception of their range needs. This can be achieved, for instance, by extracting data from providers such as Google Maps that can help potential car buyers obtain a more precise perception of their driving habits, and consequently, their range needs.

The remaining items related to winter driving and instrumental aspects have a deviation between importance and performance in the range of 0.005 and 0.007. Thus, it is much less important to improve these factors compared to improving the driving range of EVs. In addition, three of these factors, namely driving performance, tire grip, and warmness inside the car during winter, are probably of less importance in most countries, compared to Norway with its relatively harsh winters. Concerning safety features, previous studies suggest that the crashworthiness of EVs is affected by the change in their center of gravity because of having the traditional engine replaced by an electric motor (Sakurai and Suzuki, 2010). Moreover, fire incidents involving EVs have attracted considerable media attention, with the car manufacturers' pursuit of a greater driving range making them employ more lithium-ion batteries, thus increasing the potential heat release in the case of an EV fire (Sun et al., 2020). Consequently, both the crashworthiness and fire risk of EVs are examples of safety-related factors that should be considered and improved by car manufacturers to make EVs more attractive. It should also be noted that there is a potential conflict of objectives between increasing the driving range and reducing the fire hazard related to using EVs. Finally, with a deviation of 0.31 between importance and performance, the purchase cost is the cost aspect item with the greatest deviation between importance and performance. This indicates that it might be premature for Norwegian authorities to eliminate their policies that contributes to lower purchasing costs of EVs, such as their exemption from registration tax and VAT.

7.5 Concluding remarks

As car manufacturers and policymakers worldwide emphasize the mass EV adoption, a deep understanding of the factors influencing people's choice of cars and how EVs measure on these same factors is critical. Therefore, this study aims at generating knowledge that policymakers and car manufacturers can apply to make EVs more attractive to car buyers.

To achieve this objective, we conducted the importance-performance analysis with the quadrant approach, diagonal approach, and the gap analysis. The data used in our study were obtained from 287 Norwegian EV owners. The respondents were asked to state the importance of 31 items with respect to decision making when buying a new car and their satisfaction levels with the same items with regard to their recently purchased EVs. The items were grouped into eight constructs.

Three research questions were answered using the collected data. First, most important when considering what car to buy are: (1) instrumental aspects of the vehicle; (2) winter driving quality; and (3) the environmental aspects of the car. Second, EVs perform best with respect to their: (1) environmental aspects; (2) winter driving quality; and (3) interior and exterior design. Third, based on the IPA, policymakers and car manufacturers should focus on improving the following to make EVs more attractive to consumers: (1) instrumental aspects; (2) winter driving performance, and (3) cost aspects related to purchasing and driving EVs.

The constructs mentioned in the paragraph above are all comprised of several items. To produce more robust recommendations, the importance and performance of the items making up the concepts most essential to improve, namely instrumental aspects, cost aspects and winter driving, were plotted in an important-performance with a normalised iso-line running through it. This exercise suggests that the item most important to improve is the driving range of EVs. Additionally, improving the tire grip and driving performance during winter and the safety features of EVs will, according to our data, also make EVs more attractive.

Finally, it should be noted that our study, in line with all empirical studies, has some limitations. First, it can be argued that both the validity and reliability of the study are debatable, as all data analyzed are from the Norwegian car market, which has a higher EV penetration rate than most other car markets, and where a high number of policy measures are implemented to make EVs more attractive. In markets where car owners and purchasers have different preferences or where some factors are considered less important (e.g. winter driving functions), the results from this study might be less valid. Second, some respondents might have answered tactically, which might be, for instance, the case concerning the cost of purchasing EVs. Third, we studied only the responses from EV owners, making it difficult to generalize the findings to all car owners. Further research focusing on both EV and ICEV owners with a larger dataset will therefore be useful.

Despite the aforementioned limitations, this paper represents the first attempt to employ the importance-performance framework for understanding the EV market to offer car manufacturers and policymakers robust recommendations on how to make EVs more attractive, and consequently, contribute to establishing a greener road transport system.

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8. Article 4 : Electric vehicle re-purchase intention: An assessment using an extended theory of planned behaviour

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Abstract

Electrification of vehicles is one of the most promising measures for decarbonising the transport system. Several countries worldwide have implemented policy incentives to promote mass electric vehicle (EV) adoption to mitigate the environmental and energy-related challenges caused by the increased demand for road transportation. As a result, the number of EVs on the road is growing in several countries. However, despite the growing demand, many consumers are still sceptical about EVs. The aim of this study is to evaluate consumers' EV repurchase intention by using an extended theory of planned behaviour (TPB). Studies on EV adoption have found TPB determinants of intention to be relevant. Additionally, this study argues that the effects of satisfaction should be considered in addition to the TPB elements to better understand repurchase intentions. Consequently, this study includes EV users' satisfaction with relevant aspects such as range-recharge, environmental attributes, cost, availability, symbolic attributes, and use-based policy measures. A structural equation model (SEM) was established to analyse a survey dataset consisting of 278 Norwegian EV owners. To assess satisfaction with EV use and the behavioural intention of EV repurchases, only the responses from actual EV users were studied. This is important because consumers with no prior experience with EVs tend to inaccurately portray their interest in a new product or service. The findings are of interest for both policymakers and EV manufacturers seeking to gain actionable insights into EV owners' needs and perceptions concerning EV attributes, thus developing and implementing better strategies to increase EV attractiveness and performance.

Keywords: Electric vehicle, planned behaviour theory, behaviour analysis, consumer satisfaction, structural equation model, repurchase intention

8.1 Introduction

Electric vehicles (EVs) have shown great potential in ensuring energy security and reducing tailpipe emissions and local pollution caused by increased road transportation (Hardman et al., 2017; Mersky et al., 2016; Wu et al., 2021). Therefore, policymakers worldwide are supporting EV adoption through monetary and nonmonetary policy measures, aimed at boosting both supply and demand. However, widespread EV adoption is still hindered by economic, institutional, and behavioural barriers (Contestabile et al., 2017; Sykes and Axsen, 2017). As of 2019, approximately 7.2 million EVs were on the road, which was a massive increase from approximately 17,000 in 2010 (IEA, 2020), but only 20 countries had EV market shares above 1% (IEA, 2020). Norway has been the leader for EV market share over the past several years. Almost 75% of all new cars sold in 2020 in Norway were EVs (Norsk Elbilforening, 2020).

Various types of EVs are available on the market—battery EVs (BEVs), hybrid EVs (HEVs), and plug-in HEVs (PHEVs). Among them, only BEVs (e.g. Tesla, Audi e-tron, Nissan LEAF) operate solely on electricity stored in an onboard battery pack. These vehicles are therefore frequently known as 'pure- or all-EVs' (Campanari et al., 2009). By contrast, HEVs (e.g. Toyota Camry Hybrid, Honda Civic Hybrid) combine an internal combustion engine (ICE) with an electric motor and are more fuel-efficient than similar-sized ICE vehicles (Egbue and Long, 2012; Schuitema et al., 2013). The battery on board an HEV is recharged through regenerating braking and by the ICE (Rezvani et al., 2015). PHEVs (e.g. Mitsubishi Outlander, Volkswagen Golf GTE) are equipped with more powerful electric batteries than HEVs and can be recharged via electricity grids (Schuitema et al., 2013). Consequently, only BEVs have zero tailpipe emissions and are therefore considered better at mitigating the environmental challenges caused by road transportation (Liu and Wang, 2017). Finally, it should be noted that BEVs and PHEVs are frequently called 'plug-in vehicles' because they can be plugged into the electricity grid to recharge the batteries.

Several countries have promised to sell only EVs in the near future. For instance, according to Wappelhorst (2020) and Wappelhorst and Cui (2020), Norway aims to phase out ICEVs by 2025; Iceland, Ireland, the Netherlands, and Sweden, by 2030; Scotland, by 2032; Denmark and the United Kingdom, by 2035; France and Spain, by 2040; and Costa Rica, by 2050. Hardman and Tal (2021) claimed that to achieve a large market share for any new product, consumers must make the initial purchase, continue to purchase it, and not purchase back the other product whenever they replace their initial purchase. Moreover, consumers are the key participants in the EV diffusion process because it is they who must ultimately accept this technological innovation (Hoeft, 2021; Daziano and Chiew, 2012). In line with this, it is necessary to encourage the non-EV owners to purchase EVs as their next car and existing EV owners to keep using their EVs and/or to choose EVs again when they replace their old ones. Further, automotive retail markets are among the most mature and developed markets (Jørgensen et al., 2016), and, therefore, repurchases and loyalty are also crucial from carmakers' economic perspective. Loyal customers are less price-sensitive and more likely to pay higher prices than other customers (Krishnamurthi and Raj, 1991). Mellens and Steenkamp (1996) posit that the marketing cost of attracting new customers is much lower than that of retaining existing customers. However, a few studies have endeavoured to investigate consumers' EV repurchase intention.

Several studies have used the theory of planned behaviour (TPB) to investigate EV purchase intentions (e.g. Abrahamse et al., 2009; Degirmenci and Breitner, 2017; Haustein and Jensen, 2018). The TPB framework explains behavioural intention and behaviour by means of social norms, perceived behaviour control, and attitudes (Ajzen, 1991). Consequently, these TPB constructs are also relevant for studies assessing EV repurchase intention. We argue that expanding this TPB framework by including consumers' overall satisfaction with EV use would produce in-depth insights. Consumer satisfaction is one of the main drivers of consumer loyalty and behaviour (Mittal and Kamakura, 2001; Szymanski and Henard, 2001). Nevertheless, the direct effect of satisfaction on repurchase and loyalty varies between industries (Olsen, 2007). The inconsistent relationship between satisfaction and repurchase loyalty varies depending on additional elements such as personal characteristics, social norms, and intention (Fournier and Mick, 1999; Homburg and Giering, 2001; Mittal and Kamakura, 2001).

For transport innovations such as EVs, actual EV users could plausibly have different attitudes towards EVs than consumers who do not have any real-life experience with EV use. Hoeffler (2003) posits that consumers have more significant uncertainty when they try to estimate the future utility of a truly new product. With that said, it seems promising to study the responses from actual EV users to obtain an in-depth understanding of consumer satisfaction with EVs, their behaviour, and intention to purchase EVs (Chu et al., 2019). Moreover, Okada et al. (2019) and Schmalfuß et al. (2017) identify differences in purchase intention and satisfaction with EV attributes between post-purchase EV users and non-EV users. However, most EV studies are on the data of intended EV users rather than the actual EV user. Therefore, we argue that more studies on actual EV users are necessary for obtaining insights about the behaviour of consumers in the market.

Subsequently, the overall objective of this study is to generate knowledge of EV owners' repurchase intention, a topic few studies have investigated. More specifically, the primary aim of this study is twofold. First, this study explains EV owners' repurchase intentions using a TPB model integrated with post-purchase consumer satisfaction. According to TPB, assessing behavioural intention is a practical way to predict ultimate actions. Huang and Ge (2019) noted that a stronger purchase intention is associated with a greater purchase likelihood by individuals. Second, this study identifies the attributes of EVs that most strongly influence overall consumer satisfaction with EVs. This study analysed Norwegian EV users' data collected by a survey questionnaire method. The exemplary growth of EV market share over the last several years in Norway provides an ideal environment for analysing EV users' repurchase intention. A structural equation model (SEM) was used to investigate the relationships among the factors.

This study contributes to the EV literature in multiple ways. First, this study anchors consumers' EV repurchase intention in a rigorous behavioural framework based on the TPB expanded by consumers' overall satisfaction with EV use. Thus, it produces in-depth knowledge about the factors playing critical roles in their behavioural intention around EV repurchase. Second, this study integrates multiple EV attributes such as cost aspects, range-recharge, policy measures, environmental attributes, symbolic attributes, and availability of EV models to measure their impacts on consumers' overall satisfaction with EV use. It is helpful to realise the strengths and weaknesses of the current EV market policies and advancements. In addition, this study uses SEM to learn how factors are interrelated so as to comprehend the complete pathways of their influences. Lastly, this study analyses survey responses of actual EV users from a country with the highest EV market share. Thus, insights from this study can inform the broader EV diffusion process. The findings are of interest for assisting both policymakers and manufacturers to realise what needs to be improved to retain and repeat consumers' purchases, which, in turn, helps improve resource allocation. Furthermore, we argue that insights derived from a study on consumers' repeated EV purchase intention would also be somewhat crucial to comprehending consumers' acceptance of autonomous vehicles. Alsalman et al. (2021) claimed that insights from current technological issues (e.g. charging time, charging type, and driving range) related to EVs are critical to reasonably comprehending the transition towards autonomous vehicles (AVs) as the fuel system of AVs is expected to be electrical. In line with this, factors playing a significant role in EV repurchase intention, attributes contributing to consumers' overall satisfaction with EV use, and understanding of the complete pathways of the effects among factors are relevant for analysing the market of AVs as well.

The remainder of this paper is organised as follows. Section 2 provides a comprehensive literature review of the TPB, consumer satisfaction, and the relevant factors influencing EV usage and purchase intention. Section 3 describes the methodology used to conduct the empirical analysis. Section 4 details the results of the empirical analysis. Section 5 includes the discussion and implications, and Section 6 provides some concluding remarks.

8.2 Literature Review

8.2.1 Theory of planned behaviour (TPB)

This study uses the TPB (Ajzen, 1991) to understand the repurchase intention of EV users. The TPB is a useful and robust framework to explain individual intention and behaviour. This can explain why it has been used in several studies to explore consumer intentions to purchase EVs (e.g. Abrahamse et al., 2009; Degirmenci and Breitner, 2017; Haustein and Jensen, 2018; Moons and Pelsmacker, 2015; Schmalfuß et al., 2017; Simsekoglu and Nayum, 2019; Wang et al., 2016). The TPB framework assumes that behavioural intention is determined by an individual's attitude (e.g. purchasing EVs, purchasing ICEVs, riding the bus), perceived social pressure to engage or not to engage in a behaviour (e.g. people who are important to me are considering buying electric cars), and perceived ability to engage or not to engage in a behaviour (e.g. it is difficult to reach my destination with EVs because of their low battery range) (Ajzen, 1991). Therefore, all TPB determinants of behavioural intention—attitude, subjective norms, and perceived behavioural control—are relevant in studies on EV purchase intention. However, studies have reached mixed findings about their effects on EV use intention. Simsekoglu and Nayum (2019) find that subjective norms and perceived behavioural control are significantly and positively related to EV purchase intention among ICEV users. In addition, Kaplan et al. (2016) established a model that finds the expected linkage between electric commercial vehicle procurement intention and TPB constructs. In contrast, Huang and Ge (2019) find no statistically significant effect of subjective norms on purchase intention in a study of EV development in Beijing, while Asadi et al. (2021) find no statistically significant effect of perceived behavioural control on behavioural intention of EV use after analysing EV development in Malaysia.

According to the TPB framework, individuals systematically consider, process, and use the information available to them to decide any behavioural acts, which is a rational process of a sequence leading from beliefs to behaviour (Donald et al., 2014). However, although widely used, this framework has faced criticism over the years for estimating low predictive efficacy to explain an individual's behavioural intention and behaviour, which is apparently the result of insufficient determinants (Tommasetti et al., 2018). Notably, scholars from different fields of study, including transportation, exploited an extended theory of planned behaviour to account for additional determinants, such as moral norms and anticipated regrets (Wang and Xu, 2021); descriptive norms, environmental concerns, and habits (Donald et al., 2014); and moral obligations, awareness of consequences, and sustainable usage behaviour (Si et al., 2020). Given this tendency, the TPB framework was previously extended to include emotions (Moons and Pelsmacker, 2015); perceived mobility necessity, personal norms, and BEV experiences (Haustein and Jensen, 2018); environmental concerns and personal moral norms (Wang et al., 2016); perceived EV attributes, perceived accidental risk, and knowledge about EVs (Simsekoglu and Nayum, 2019); user experience (Schmalfuß et al., 2017); and cognitive status, product perception, and monetary and nonmonetary policy incentives (Huang and Ge, 2019) to examine the willingness to purchase EVs.

EVs are a technological innovation, given their physical and functional differences from conventional vehicles (Axsen and Kurani, 2012). Consequently, the vast majority of consumers are still sceptical about the performance and use of EVs. Thus, they frequently associate EVs with negative functional perceptions related to having a lower battery range, long recharging time, and lower driving performance at low temperatures (Haustein and Jensen, 2018). However, Haustein and Jensen (2018) argued that the perceived difficulties in using EVs (e.g. BEVs have too low a driving range) are difficult to differentiate from the TPB construct of perceived behavioural control (e.g. it is difficult to reach my destination with BEVs). Because of conceptual similarities, studies have operationalised such negative functional perceptions as perceived functional barriers (Haustein and Jensen, 2018) and operational ease of EV use (Kaplan et al., 2016). In line with this, the present study operationalises consumers' negative attitudes or negative perceived perceptions of EV use as perceived functional barriers and refers to the positive attitudes towards EV use as 'attitudes'.

8.2.2 Consumers' overall satisfaction

The present study extended the framework of TPB by including consumers' overall satisfaction with EV use, presuming its importance in their next purchase decision. The role of customer satisfaction in repurchase intention is critical. Generally, satisfaction is referred to as the evaluation outcome of related experiences and exchanges realised after consumption behaviour (Fang et al., 2016; Holmes, 1991; D. J. Kim, 2012; Liang et al., 2018). Although satisfaction and attitude are commonly considered as synonymous, their conceptual definitions are different

(Fu and Juan, 2017). Hunt (1977) argues that attitude is an emotion and that satisfaction is the evaluation of that emotion. Customer satisfaction with a product or service is a strong determinant of repeated purchase intention and word-of-mouth recommendations, which, in turn, increase customer loyalty, profitability, and market share of that product or service (Anderson et al., 1994; Bernhardt et al., 2000; Nadiri et al., 2008; Su et al., 2016; Walsh and Bartikowski, 2013). Studies suggest that satisfaction positively influences intentions regarding both EV repurchases and EV recommendations to others (Gyesoo, 2016; Koklic et al., 2017; Kwon et al., 2020; Liang et al., 2018).

Fu and Juan (2017) found a statistically significant influence of satisfaction on attitude while investigating the motivations underlying transport mode choice using TPB and customer satisfaction theory. It has been argued that satisfaction increases the likelihood of a target product or service being included in the list evoked by consumers as well as the favourability of attitude towards it. It also increases the degree of repurchase intention (Fu and Juan, 2017; Oliver, 1980). In line with this, we argue that consumers' satisfaction with EV use should affect their attitudes and perceived functional barriers to EV use. Thus, we assume that it is relevant to also examine these connections in our study. However, Bakti et al. (2020) did not find a statistically significant influence of satisfaction with attitudes when studying survey responses from three Indonesian cities to research public transport passengers' word-of-mouth communication using TPB, consumer satisfaction theory, and personal norm theory. In addition, findings about the influence of subjective norms on overall satisfaction have been inconclusive. This was confirmed in Fu and Juan (2017), although Bakti et al. (2020) could not confirm the influence as statistically significant.

8.2.3 Potential factors influencing consumer satisfaction with EV use

The overall satisfaction with EV use depends on users' evaluation of different EV attributes. Studies (Caber et al., 2013; Matzler et al., 2003) have identified the critical relationship between the performance of product or service attributes and overall consumer satisfaction. Huang and Ge (2019) used consumers' satisfaction with different EV attributes to measure product perception in order to examine its influence on EV purchase intention. Kwon et al. (2020) found that range satisfaction, charging satisfaction, and cost-saving intention have a statistically significant influence on overall satisfaction with BEV use based on an analysis of survey responses from actual BEV owners in South Korea.

To assess consumer acceptance of EVs, researchers have investigated the role of several factors, such as higher front costs and lower operation costs (Caperello and Kurani, 2012; Egbue and Long, 2012; Graham-Rowea et al., 2012; Sovacool and Hirsh, 2009; Zhang et al., 2011), the importance of consumers' environmental values and perceptions (Egbue and Long, 2012; J. Kim et al., 2014; Lane and Potter, 2007; Simsekoglu, 2018; Skippon and Garwood, 2011), instrumental attributes (Azadfar et al., 2015; Neubauer and Wood, 2014), policy incentives (Langbroek et al., 2016; Lévay et al., 2017), symbolic attributes (Gjøen and Hård, 2002; Heffner et al., 2007), and the availability of EV models (Hasan & Mathisen, 2021; Hoen and Koetse, 2014) in widespread EV adoption. Thus, previous findings provide a clearer picture of the potential attributes that influence EV usage and, in turn, play a role in formulating overall satisfaction after usage.

Policymakers are introducing incentive packages to motivate consumers to buy and use EVs. In Norway, the first EV policy to make EVs more attractive (temporary exemption from import tax) was introduced in 1990, and then, gradually, more incentives were added to achieve mass EV adoption (Figenbaum et al., 2015; Norsk Elbilforening, 2018). In addition to purchase incentives, Norway implemented use-based policy measures to benefit BEV users, such as bus-lane access and exemption from road tolls, parking fees, and ferry fees. Studies have found that these perks influence EV adoption in Norway (Aasness and Odeck, 2015; Bjerkan et al., 2016; Fearnley et al., 2015; Figenbaum, 2017). In Norway, the market share of EVs increased from 5.7% in 2013 to almost 75% in 2020 (Statista, 2021). The effect of policy measures has been prominent in other countries as well. Huang and Ge (2019) find that monetary policy incentives have significantly influenced EV purchase intention among consumers in Beijing. However, they find that nonmonetary incentives (e.g. right to use bus lanes, separate allocation of EV license plates, and abolishment of restrictions on traffic of EVs) have no significant influence on EV purchase intention. Santos and Rembalski (2021) posit that purchase incentives that reduce EV purchase cost are effective in accelerating the mass-market penetration of BEVs in the UK.

In addition, technological differences mean that EVs require less maintenance than ICE vehicles (Palmer et al., 2018). Moreover, increased energy efficiency (Helmers and Marx, 2012; Larminie and Lowry, 2003), combined with a lower tax rate on electricity (Palmer et al., 2018), reduces the operating costs of driving EVs. Krishna (2021) noted that running costs of EVs are highly dependent on the local electricity costs.

Low battery range, lengthy recharging duration, and lack of charging infrastructures hinder the widespread adoption of EVs (Greene et al., 2020; Rommel and Sagebiel, 2021)—such limitations of EVs cause psychological stress known as ‘range anxiety’ (Melliger et Al., 2018). Franke et al. (2017) claim that consumers' psychological range or subjectively available ranges play a significant role in range satisfaction, which, in turn, influences EV purchase intention. Greene et al., (2020) indicate that the availability of charging infrastructures can reduce consumers’ range anxiety and thus offset a significant fraction of perceived cost penalty triggered by BEVs’ low range and long recharging time. Recently, in another study on California’s EV owners, Hardman and Tal (2021) reveal that dissatisfaction with the convenience of charging is one of the significant factors in discontinuation of EV use. Previously, Chu et al., (2019) found that battery charging and battery range are the two greatest causes of dissatisfaction among both Chinese and Korean EV users. However, Rauh et al., (2017) and Franke and Krems (2013) found that vehicle owners tend to overestimate their range needs for their day-to-day driving patterns. EV users’ attitudes change as a result of the practical driving experience. Study shows that BEV users gradually adopt the range through modifying their behaviour and view BEVs more positively after driving for a few weeks (Bühler et al., 2014; Bunce et al., 2014; Franke and Krems, 2013; Labeye et al., 2016). However, in a study on Canadian new vehicle buyers, Miele et al. (2020) find that charging and refuelling station availability plays a minimal role in stimulating new EV sales.

EVs are transport innovations with better fuel efficiency than conventional cars with ICEs, have fewer or zero local carbon emissions, and generate little engine noise, thus improving the overall driving experience (Axsen and Kurani, 2012; Degirmenci and Breitner, 2017; Zhao and Heywood, 2017). Kim et al. (2014) posit that the intention to purchase an EV is encouraged by environmental concerns and technological acceptance. Regarding environmental awareness, Okada et al. (2019) claimed that, despite posing a significant direct influence on satisfaction ratings for those who do not own or use EVs, environmental awareness does not have a significant direct influence on post-purchase satisfaction ratings for those who own and use EVs. However, environmental concerns and economic motives are the most important indicators for the overall satisfaction of Chinese and Korean EV users, respectively (Chu et al., 2019).

Symbolic attributes were important to early consumers of BEVs in Norway and Austria as well as to first-time buyers of HEVs in California (Gjøen and Hård, 2002; Turrentine and Kurani, 2007). Schuitema et al. (2013) posit that the likelihood of EV adoption is influenced by perceptions of instrumental, hedonic, and symbolic attributes. Moreover, in a study on Norwegian EV users, Ingeborgrud and Ryghaug (2019) argue that a successful penetration of BEVs in the market requires both material and symbolic dimensions of ownership and use.

The availability of multiple EV models is essential so that prospective buyers can choose the most desirable model. In a study on Dutch private car owners using choice experiments, Hoen and Koetse (2014) find that the availability of models in the market positively affects EV acceptance but to a significantly lesser extent. Moreover, among other factors, brand image, perception, and loyalty influence car buyers' purchasing process (Devaraj et al., 2001; Helveston et al., 2015; Hirsh et al., 2016). A consumer survey analysis on Chinese consumers' willingness to pay for a car brand based on its country of origin reckoned that Chinese people mostly prefer cars manufactured in Germany. Korean, Japanese, American, and Chinese brands rank second, third, fourth, and fifth, respectively (iCET, 2016).

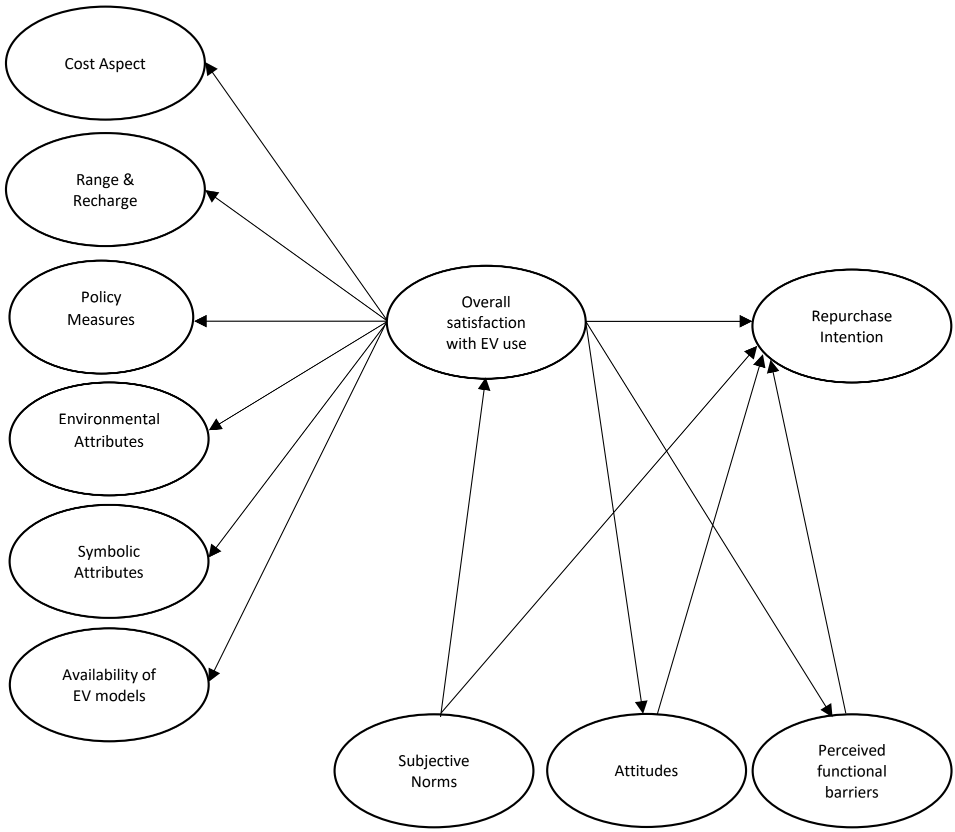

Figure 8.1: The hypothesised extended TPB model to assess EV repurchase intention

Based on the above reviewed literature, Figure 8.1 presents the hypothesised model to analyse the EV repurchase intention of EV users. This illustrates that EV users' satisfaction with EV attributes reflects their overall satisfaction, which is measured using second-order factor analysis. The model includes the following EV attributes: range-recharge, cost, environmental attributes, symbolic attributes, availability of EV models, and policy measures. Moreover, based on the reviewed literature, the model hypothesised that the direct influences from consumers' overall satisfaction, subjective norms, attitude, and perceived functional barriers manipulate their behavioural intention of EV repurchase. Furthermore, in line with previous studies, the model tested the effect of subjective norms on overall satisfaction and the effects of overall satisfaction on attitude and perceived functional barriers.

8.3 Method

8.3.1 Sampling

For the purpose of this study, a web-based questionnaire was developed. The data were collected between March and May 2019. The invitation to participate in the survey was mailed to 4,330 car owners who were drawn from a dataset of randomly selected registered owners of EVs and ICEVs provided by the Norwegian Public Roads Administration. The invitation letter included a web address where they could find the questionnaire. A total of 451 respondents filled out the questionnaire, yielding a response rate of 10.42%. Among them, 278 (62%) participants owned EVs. As this study focuses on satisfaction with EV use and EV repurchase intention, only the questionnaires completed by the 278 respondents owning EVs were used in the analysis. Among the EV owners, there were 256 (92%) BEV owners, 15 (5%) PHEV owners, and only 7 (3%) HEV owners. The statistical distribution of the sample is shown in section 4.1.

8.3.2 Measures

To investigate the intention to repurchase EVs, this study applied, as previously mentioned, a web-based questionnaire. At the beginning of the questionnaire, the respondents were asked what type of car (i.e. BEV, PHEV, HEV, or ICEV) they had bought most recently, the model of that particular car, how long they had owned it, the total number of vehicles in the household, and their driving habits. For the purpose of this study, only responses given by owners of BEVs, PHEVs, and HEVs were included in the analysis.

In the demographic section of the survey, the respondents were asked to reveal their gender and marital status, their annual income before tax and academic qualifications, and the number of inhabitants in the municipality where they lived.

The respondents were asked to state their satisfaction with relevant EV attributes using a 5-point Likert scale ranging from 1 (not satisfied) to 5 (extremely satisfied) based on their experience with their EV. Respondents stated their satisfaction with six EV attributes: range-recharge, symbolic attribute, use-based policy measures, cost aspects, environmental attribute, and availability. Each of these attributes comprised various items and was chosen based on studies that examined the relevant attributes for EVs (e.g. Bakker and Trip, 2013; Chorus et al., 2013; Egbue and Long, 2012; Langbroek et al., 2016; Schuitema et al., 2013; Simsekoglu, 2018; Solvoll et al., 2010). The range-recharge attributes were assessed using three items (e.g. battery range and battery range during winter). Both use-based policy measures and cost aspects encompass the economic elements of EV use. Use-based policy measures have focused only on the local incentives that benefit EV users. Thus, the items measuring this attribute were formulated as follows: exemption from road tolls, ferry fees, and parking fees, and access to bus lanes. Consumers' satisfaction with cost aspects was measured using three items (e.g. EV purchase cost and recharging cost). Environmental attributes were assessed using four items that address EVs' environmental benefits at local and national levels (e.g. tailpipe emissions and traffic noise). Four items focusing on the availability of EV models, brands, and nearby local EV dealers were used to measure consumers' satisfaction with EV availability. Symbolic attributes were assessed employing five items (e.g. 'EV is a car that shows who I am').

In the third section of the survey, participants graded their degree of approval for 12 items using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) to measure their subjective norms, perceived functional barriers, and attitudes towards EV use. To assess subjective norms, respondents answered questions about five items (e.g. ‘people who are important to me recommended that I buy EVs’). Perceived behavioural barriers were measured by addressing the functional difficulties of EV use using four items (e.g. ‘I am worried about running out of charge while driving EVs’). Participants answered questions about three items (e.g. ‘I believe my EV saves me money in the long run’), which were formulated to measure their attitudes towards EV use. Repurchase intention was measured using three items (e.g. ‘I am planning to buy EVs’ and ‘I am determined that my next car will be an EV’). These constructs were developed based on studies (Degirmenci and Breitner, 2017; Haustein and Jensen, 2018; Kaplan et al., 2016; Schmalfuß et al., 2017) that investigated the role of TPB in EV acceptance. The measurement items for all the constructs are presented in Table 8.3 in the Results section.

8.3.3 Statistical analysis

After the descriptive analysis was performed on the sample demographic characteristics, as a second step, Cronbach's alpha coefficient, Kaiser–Meyer−Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity were calculated to examine the reliability and validity of the scales. Finally, the EV users’ behavioural framework was investigated by formulating an SEM considering its beneficial feature of assessing the relationships between multiple factors. SEM combines both confirmatory factor analysis (CFA) and path analysis with simultaneous inclusion of both observed and hidden variables (Kiraz et al., 2020).

In the process of formulating the SEM approach, initially, measurement models for the latent constructs were tested. The latent constructs are ‘range-recharge satisfaction’ (RRS), ‘symbolic-attribute satisfaction’ (SAS), ‘policy-measures satisfaction’ (PMS), ‘environmental-attribute satisfaction’ (EAS), ‘cost satisfaction’ (CS), ‘availability satisfaction’ (AS), ‘subjective norms’ (SN), ‘perceived functional barriers’ (FB), ‘attitudes’ (ATT) and ‘repurchase intention’ (RI). After well-fitting measurement models were established, in line with the reviewed literature in Section 2, the structural model was specified as in Figure 1. Based on the six components RRS, SAS, PMS, EAS, CS, and AS, a second-order construct, ‘overall satisfaction with EV’ (OSE), was established to capture the shared variance of the six separate facets of satisfaction related to EV use. In other words, the latent variable ‘overall satisfaction with EVs’ represents the overarching satisfaction with EVs across all six components. Finally, the construct RI was expected to be predicted by the constructs of OSE, SN, ATT, and FB. In addition, on the basis of the reviewed literature, we also tested the relationship of OSE with SN, ATT, and PFC in the same model.

8.4 Results

8.4.1 Descriptive statistics

Table 8.1 shows that there were more males than females in our sample. Of 278 respondents, the majority (71%) were male; 29% were female; and only one respondent preferred not to mention gender. Eighty-one percent of the respondents were over 40 years old, and a majority

(32%) were between 51 and 60. More than three-quarters (78%) of respondents earned more than 500,000 kroner (≈ $54,000), while a majority of them (32%) earned more than 800,000 kroner. Regarding educational qualifications, nearly half (44%) of the respondents had completed more than three years of university study. Eighty-six percent of the respondents were married or living with cohabitants, and 41% of the respondents' households consisted of two people. Four respondents preferred not to mention their marital status.

On the basis of an extensive survey among Norwegian BEV owners, Fevang et al. (2020) reported that men made up 72% of the respondents, that their average age was 51, that the majority of them earned more than one million kroner, and that 88% a college or university education. These findings indicate that our sample broadly resembles that of Norwegian owners of BEVs.

According to the data, 9% of respondents stated that they travelled on average less than 10 kilometres a day, and 56% of respondents did not travel on average more than 40 kilometres a day. This indicates that, on average, they travel within the battery range of a fully charged EV. Statistics Norway (2017) reports that a Norwegian drives, on average, 34 kilometres (21 miles) a day.

Furthermore, for 29% of respondents, an EV is the only car in the household, and 56% of respondents claimed to have two cars in their household. This suggests that most EV owners have more than one car in their household. This is consistent with the findings of Holtsmark and Skonhoft (2014), which indicates that the policy measures in Norway are motivating high-income families to purchase an EV as a second car.

Table 8.1: Descriptive statistics of the sample (n=278)

	Count	Percentage
Gender:		
Male	197	71%
Female	80	29%
Age:		
18–30	4	1%
31–40	50	18%
41–50	75	27%
51–60	88	32%
61–70	46	17%
> 71	15	5%
Annual Income before tax:		
< 250 000 kroner	3	1%
250 000 – 350 000 kroner	13	5%
350 000 – 500 000 kroner	46	17%
500 000 – 650 000 kroner	80	29%

650 000 – 800 000 kroner	48	17%
> 800 000 kroner	88	32%
Education:		
Primary	7	3%
High School, vocational	35	13%
High School, general education	36	13%
≤ 3 years of college/university	77	28%
> 3 years of college/university	123	44%
Household numbers:		
1 member	23	8%
2 members	114	41%
3 members	57	21%
4 members	54	19%
5 members	2	9%
6 members	4	1%
7 members	2	1%
Marital Status:		
Married/Cohabiting	238	86%
Single	36	13%
Kilometres travelled on average day		
Less than 10 km	24	9%
10–20 km	47	17%
21–30 km	42	15%
31–40 km	43	15%
41–50 km	49	18%
More than 50 km	73	26%
Number of cars in households		
1	82	29%
2	157	56%
3	32	12%
4	5	2%
More than 4	3	1%

Table 8.2 presents the mean and median values for EV users' stated satisfaction with each of the EV attributes, and Table 8.3 presents the mean and median scores for each item of the TPB constructs and repurchase intention. The results show that, on average, the respondents are most satisfied with items related to environmental attributes and less satisfied with symbolic attributes, which could be because they are less concerned about the symbolic attributes of EV use. Relatively high mean values for attitude and lower perceived functional barriers suggest that the respondents have more positive impressions and attitudes about EV use. The median scores represent the satisfaction level of 50% of respondents for respective attributes. For instance, the scores for battery range indicate that 50% of the respondents are satisfied (we coded 4 as 'satisfied' on a 5-point Likert scale, while 5 was coded as 'very satisfied') with their cars' battery range. The median score for ferry fee exemption (0) indicates that for 50% of

respondents, this policy is irrelevant, meaning that they do not use ferries, or their cities/municipalities do not have the ferry facilities.

Table 8.2: Mean values of stated satisfaction with EV attributes

EV attributes	Satisfaction Mean	50th percentile (Median)
Range-Recharge satisfaction (RRS)		
Battery range	3.54	4
Battery range during winter	3.90	3
Recharging duration	3.29	4
Cost satisfaction (CS)		
Purchase cost	3.83	4
Maintenance cost	3.95	4
Recharging cost	4.22	4
Policy measures satisfaction (PMS)		
Road toll exemption/reduction	4.40	5
Ferry fee exemption/reduction	3.62	0
Parking fee exemption/reduction	3.65	3
Access to bus lane (time-saving)	3.71	1
Environmental-attributes satisfaction (EAS)		
Tailpipe emission	4.59	5
Traffic noise	4.30	4
Type of energy usage	4.64	5
Other environmental consequences	4.24	4
Availability satisfaction (AS)		
Availability of dealers nearby	3.98	4
Availability of different EV models	3.62	3
Country of manufacturer	3.70	3
Manufacturer’s reputation	3.99	4
Symbolic-attribute satisfaction (SAS)		
A car that shows who I am	3.01	2
A car that says something about me	3.00	2
A car that says something about my status	2.84	1
A car that distinguishes me from others	2.81	1.5
A car that makes me feel good	3.69	3

Table 8.3: Mean values for each item of TPB constructs

TPB Constructs	Mean	50th percentile (Median)
Subjective Norms (SN)		
People who are important to me are considering buying electric cars.	3.39	3
People who are important to me already own electric cars.	3.53	4
People who are important to me recommended that I buy an electric car.	3.28	3
People who are important to me support my interest in buying an electric car.	3.68	4
People who are important to me think electric cars promote a sustainable transportation system.	3.43	3
Perceived Functional Barriers (FB)		
I think that the driving performance of an electric car is inferior to that of conventional cars.	1.82	2
I think that an electric car has a lower maximum speed than conventional cars.	1.81	2
I consider conventional cars to be safer to drive than electric cars.	2.00	2
I am worried about running out of a charge while driving an electric car.	2.74	3
Attitude (ATT)		
I believe driving an electric car reduces (would reduce) the local air pollution in my residential area.	4.12	4
I believe driving an electric car saves (would save) money in the long term.	4.18	4
I believe driving an electric car reduces (would reduce) traffic noise.	3.91	4
Repurchase Intention (RI)		
I am interested in battery-electric car/s.	4.48	5
I am planning to buy a battery-electric car.	3.56	4
I am determined that my next car will be a battery-electric car.	4.08	5

8.4.2 Assessment of scale reliability and validity

This study used Cronbach's alpha to examine the reliability and internal consistency of previously validated measurement scales (Table 8.4). In addition, KMO was calculated to measure sampling adequacy, and Bartlett's sphericity test was used to examine the scale's validity (Mooi et al., 2018; Tommasetti et al., 2018). KMO and Bartlett's sphericity tests were used to indicate whether conducting factor analysis was feasible. In our study, a higher value of KMO (> 0.65) and small values of Bartlett's sphericity test's significance level (1%) indicate factor analysis feasibility. Cronbach's coefficient alpha is widely used in studies to assess the psychometric scale's rightness and reliability for independent variables (Panayides, 2013; Peterson, 1994). Thresholds for Cronbach's coefficient alpha are debated, with different authors suggesting different thresholds. Nunnally (1978) recommends a reliability coefficient value of 0.7 or more. However, other researchers suggest that Cronbach's alpha coefficients in the range of 0.60 to 0.70 are good or adequate (Deković et al., 1991; Holden et al., 1991; Mooi et al., 2018). In our study, the Cronbach's alpha for all the constructs was above 0.65.

Table 8.4: Validity and reliability of the measurement scales for the components of consumer satisfaction with EV use and TPB

Latent Variables	Cronbach's Alpha	KMO test	Bartlett Sphericity (sign)
RRS	0.66	0.66	0.00
SAS	0.94	0.89	0.00
EAS	0.82	0.79	0.00
PMS	0.66	0.68	0.00
CS	0.70	0.66	0.00
AS	0.71	0.71	0.00
SN	0.90	0.88	0.00
FB	0.79	0.78	0.00
ATT	0.82	0.72	0.00
RI	0.86	0.72	0.00

4.3 SEM analysis

The model (Figure 8.2) analysis used the maximum likelihood estimation method and included 10 latent variables: PMS, RRS, EAS, AS, CS, SAS, ATT, FB, SUB, OSE, and RI. Table 5 presents the standardised coefficient of the paths of the model.

Table 8.5: Standardised model estimates

	Coefficient	SE	p	R^2
PMS				**0.18**
PMS → pms1	0.57	0.07	0.00	
PMS → pms2	0.39	0.07	0.00	
PMS → pms3	0.67	0.07	0.00	
PMS → pms4	0.51	0.06	0.00	
EAS				**0.56**
EAS → eas1	0.61	0.05	0.00	
EAS → eas2	0.69	0.05	0.00	
EAS → eas3	0.67	0.05	0.00	
EAS → eas4	0.58	0.05	0.00	
RRS				**0.27**
RRS → rrs1	0.81	0.04	0.00	
RRS → rrs2	0.56	0.05	0.00	
RRS → rrs3	0.80	0.04	0.00	
SAS				**0.03**
SAS → sas1	0.93	0.01	0.00	
SAS → sas2	0.94	0.01	0.00	
SAS → sas3	0.92	0.01	0.00	
SAS → sas4	0.85	0.02	0.00	
SAS → sas5	0. 64	0.04	0.00	
CS				**0.67**
CS → cs1	0.37	0.07	0.00	
CS → cs2	0.28	0.07	0.00	
CS → cs3	0.80	0.07	0.00	
AS				**0.18**
AS → as1	0.54	0.06	0.00	
AS → as2	0.68	0.06	0.00	
AS → as3	0. 63	0.06	0.00	
AS → as4	0.56	0.06	0.00	
SN				
SN → sn1	0.75	0.03	0.00	
SN → sn2	0.80	0.03	0.00	
SN → sn3	0.81	0.03	0.00	
SN → sn4	0.81	0.03	0.00	
SN → sn5	0.67	0.04	0.00	
FB				**0.23**
FB → fb1	0.62	0.05	0.00	
FB → fb2	0.61	0.05	0.00	
FB → fb3	0.72	0.05	0.00	
FB → fb4	0.55	0.05	0.00	

ATT				**0.27**
ATT → att1	0.76	0.04	0.00	
ATT → att2	0.65	0.05	0.00	
ATT → att3	0.73	0.04	0.00	
RI				**0.50**
RI → ri1	0.65	0.05	0.00	
RI → ri2	0.49	0.06	0.00	
RI → ri3	0.77	0.05	0.00	
OSE				**0.10**
OSE → PMS	0.42	0.08	0.00	
OSE → EAS	0.75	0.06	0.00	
OSE → RRS	0.52	0.07	0.00	
OSE → SAS	0.18	0.07	0.01	
OSE → CS	0.82	0.07	0.00	
OSE → AS	0.42	0.08	0.00	
Structural Model				
SN → OSE	0.33	0.07	0.00	
SN → RI	0.22	0.07	0.00	
FB → RI	−0.24	0.09	0.00	
ATT → RI	0.49	0.09	0.00	
OSE → RI	0.04	0.11	0.75	
OSE → ATT	0.52	0.07	0.00	
OSE → FB	−0.48	0.07	0.00	

The path coefficients presented in Table 8.2 and Figure 8.2 are standardised solutions. Standardised coefficients are comparable for making inferences about the relative strength of relationships, particularly when the variables or constructs are originally measured using different scales. Further evaluated indices were root mean square error of approximation (RMSEA), normed chi-square, standardised root mean square residual (SRMR), and comparative fit index (CFI). STATA 15 was used for the data analysis.

The RMSEA is a goodness-of-fit measure, yielding lower values for a better fitting model. A model with an RMSEA value of 0.06 or less is considered acceptable, whereas 0.10 is suggested as the cut-off for a poorly fitting model (Browne and Cudeck, 1992; Hu and Bentler, 1999; Xia and Yang, 2019). In our study, the model reports an RMSEA of 0.053. The RMSEA is reported with the lower and upper bounds of its 90% confidence interval (CI). The model generates a lower bound of 0.48 and an upper bound of 0.58 of its 90% CI, confirming the hypothesis that the model fit is close. The P close value (0.129) also indicates that the model fit is close. SRMR is another goodness-of-fit statistic, and a value less than 0.80 is usually considered a good fit (Hu and Bentler, 1999). Our model generates an acceptable SRMR value of 0.079. In addition, the model generates a normed chi-square (chi-square/df) value of 1.75, which is also an indicator of good model fit (Kiraz et al., 2020; Tiglao et al., 2020). The CFI metric was used to evaluate the incremental fitness of the model. The value of this index ranges from 0 to 1, and a value above 0.90 (or even above 0.95) is desirable (Raykov and Marcoulides, 2011; Tiglao et al., 2020). The model generated a CFI value of 0.88. The model also generated a coefficient of determination (CD) of 0.89, which is represented as an R^2 for the whole model.

The satisfactory indices of the model suggest that the model fits well. This indicates that the TPB model, extended with overall satisfaction, is useful for examining EV repurchase intentions.

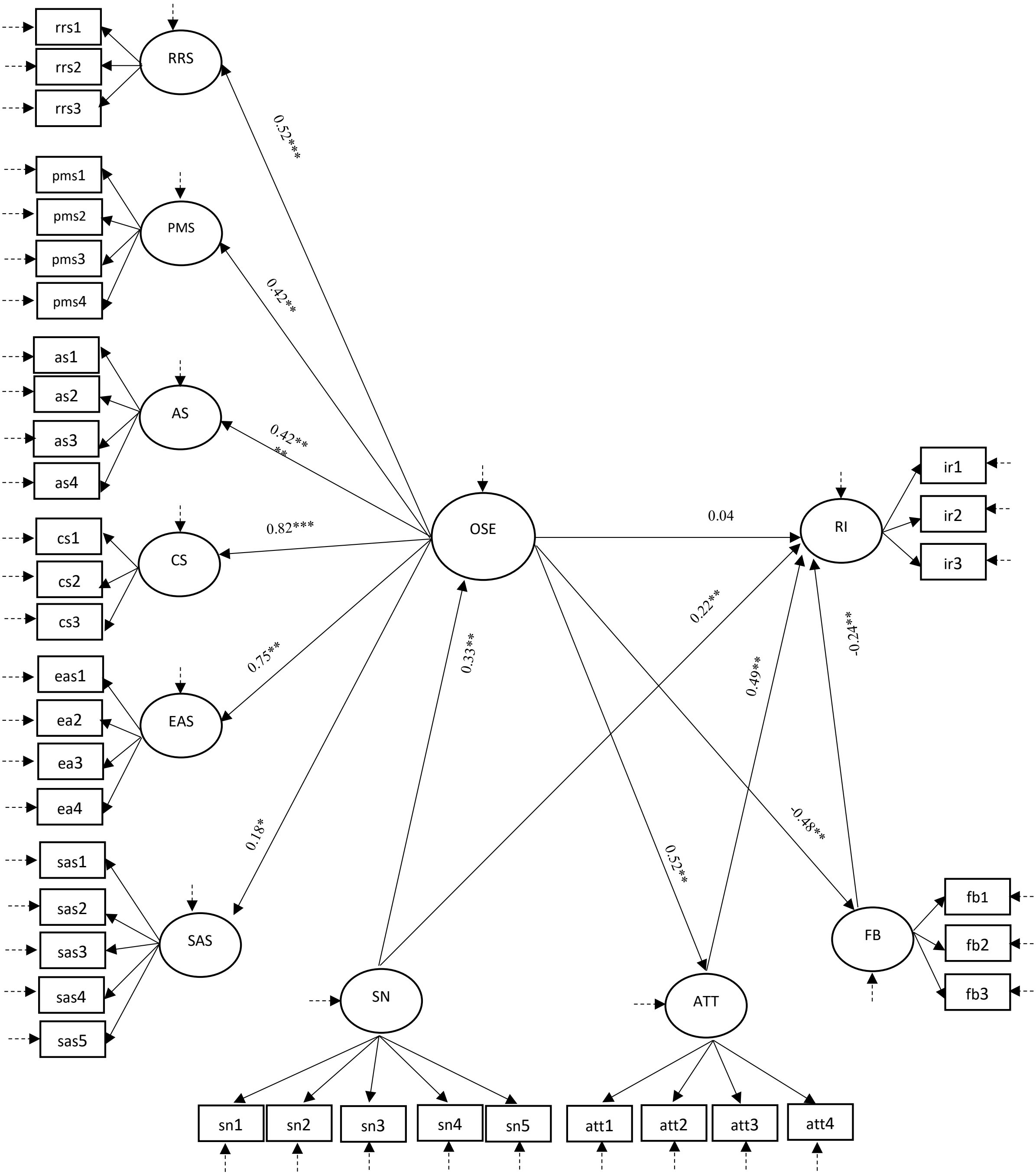

Figure 8.2: Results of the structural model with standardised estimates. Model fit (n = 278; Chi^2 /df = 1.75; RMSEA = 0.053 [0.048, 0.058]; CFI = 0.88, CD = 0.89); ***Note: Path:*** ***; Error:***

The model (see Figure 8.2) suggests that satisfaction, subjective norms, perceived functional barriers, and attitudes towards EVs play statistically significant roles in EV repurchase intention (RI). The result indicates that approximately 50% of the variance ($R^2 = 0.50$) in repurchase intention is explained by overall satisfaction (OSE), subjective norms (SNs), perceived functional barriers (FBs), and attitudes (ATTs) towards EV use. The model also suggests that EV users' satisfaction with range-recharge, use-based policy incentives, environmental attributes, cost aspects, availability of EV models, and symbolic attributes indicate their overall satisfaction with EV use at the 1% significance level. Unsurprisingly, the findings reveal that consumers' perceived functional barriers to EV use decrease repeated EV purchase intention. However, surprisingly, overall satisfaction does not have a statistically significant direct effect on repurchase intention; instead, it shows a significant effect on consumers' attitudes and perceived functional barriers to EV use. In addition, SEM output suggests that subjective norms have a positive impact on consumers' overall satisfaction with EV use at the 1% significance level. Furthermore, the second-order construct, 'overall satisfaction with EV' (OSE), is associated, at a statistically significant level, with the variance of the six separate facets (RRS, SAS, PMS, EAS, CS, and AS) of satisfaction related to EV use.

At the structural level, consumers' overall satisfaction (0.38) and subjective norms (0.82) have an indirect effect on repurchase intention. Both indirect effects were significant at the 1% significance level. Moreover, subjective norms have a statistically significant indirect effect on both attitude and perceived functional barriers (at the 1% level). In the absence of direct effects, the total effects (direct effect + indirect effect) of subjective norms on attitude and perceived functional barriers are the respective indirect effects.

This study further evaluated the mediation effect using approaches described by Gunzler et al. (2013) to examine whether overall satisfaction with EV use affects repurchase intention through mediators' attitude and perceived functional barriers. In the bivariate regression model, overall satisfaction has a statistically significant effect on repurchase intention ($\beta = 0.41$ at $p = 0.00$). However, in path analysis breakdown, the estimated paths for indirect effects were statistically significant, but the estimated direct path was not significant. These findings indicate that attitudes and perceived functional barriers fully mediate the path between overall satisfaction with EV use and EV repurchase intention.

8.5 Discussion

The estimated model reveals the role of an individual's satisfaction with EV use in their EV repurchase intention. In addition, the findings indicate the effects of various EV attributes on overall satisfaction. As expected, all TPB constructs (attitudes, perceived functional barriers, subjective norms) were found to be related to repurchase intention. This is consistent with studies (Haustein and Jensen, 2018; Kaplan et al., 2016) that determined the relevance of these constructs for EV acceptance.

Perhaps surprisingly, this study is unable to find a significant direct effect of overall satisfaction on repurchase intention. However, we cannot reject its impact on attitude and perceived functional barriers to EV use. It is plausible that overall satisfaction maintains an inverse relationship with consumers' negative attitudes and a positive relationship with consumers' attitudes towards EV use. This indicates that after consumers experience EV use, their satisfaction levels tend to have a positive influence on their emotions or perceptions about EV use. Highly satisfied consumers seem to have fewer negative attitudes and perceived functional barriers to EV use. Moreover, a higher satisfaction level boosts consumers' attitudes towards EV use.

Evidently, more favourable perceptions increase the likelihood of repurchase intention. In addition, the mediation effect analysis supports the full mediation of the overall satisfaction effect through mediators such as attitude and perceived functional barriers. The standardised coefficients demonstrate that attitudes towards EV use play the strongest role (0.49) of the three TPB constructs (0.22 for subjective norms and −0.24 for perceived functional barriers). This strongest impact implies that attitude dominates EV users' behavioural intention. In our study, the items of attitude construct includes the economic and environmental benefits of EV use such as its contribution to saving money in the long term and to mitigating air pollution and traffic noise. Thus, it emphasises the importance of economic and environmental benefits. These aspects could be used for promotional campaigns by trying to relate EV use benefits to environmental and economic values. To benefit the EV users financially in the long run, initially, policymakers need to implement incentives to purchase and use EVs. Previously, Munnukka and Järvi (2011) emphasised that consumers tend to be more influenced by their personal considerations.

Subsequently, individual beliefs about whether peers and people of importance approve or disapprove of EV purchases have been found to play a role in purchase decisions. Individuals' subjective norms influence not only repurchase intention but also satisfaction with EV use. This is consistent with previous studies. Habich-Sobiegalla et al., (2018)'s study based on a cross-national dataset from China, Brazil, and Russia found that online networks and personal relations, particularly knowing someone who already owns an EV, play a statistically significant role in EV purchase decisions. Moreover, the effects of subjective norms on satisfaction levels indicate that satisfaction with EV use increases if peers are expected to support EV use. The negative impact of perceived functional barriers is consistent with Haustein and Jensen's (2018) findings. This is expected because the items of this construct represent the adverse assessments of EV use and thus reasonably affect the repurchase intention adversely. EV users indicate adverse assessments regarding the performance, safety, speed, and low charging of EVs. Although EVs initially had several limitations, over the years their quality and performance have improved with the help of advanced technologies. However, to make EVs attractive, policymakers and carmakers need to maintain their consistency to improve the quality and performance of EVs as well as to promote them to consumers so as to improve their image.

As overall satisfaction plays a critical role in increasing the likelihood of repurchase intention via attitude and perceived functional barriers, it is important to understand which attributes of EVs actually influence overall satisfaction with EV use. Our model reveals that range-recharge, environmental attributes, cost aspects, symbolic attributes, availability of EVs, and use-based policy incentives all play a role in satisfying EV users. The standardised coefficients of the paths suggest that consumers' satisfaction with cost aspects, including purchase cost, maintenance cost, and refuelling cost, play a major role. It is well documented that the maintenance costs of EVs are lower than those of traditional vehicles. However, the purchase cost of EVs heavily depends on policy incentives, and the refuelling cost depends on both EV policy incentives and energy policies. In Norway, EV users benefit from generous purchase incentives and cheap electricity, which is generated mostly by renewable energy (Fridstrøm, 2020). However, for most other countries, the EV purchase price is still higher than that of conventional vehicles, and electricity prices are higher (Harvey, 2020). In a study comparing the total cost of ownership (TCO) between Norway and Italy, Scorrano et al. (2019) found that BEVs are more competitive in Norway than in Italy because their average value for annualised TCO/km is lower in Norway. Thus, countries need to invest heavily to lower the cost aspects of EV use to keep users satisfied and increase the likelihood of their repurchase intention. In addition to imposing various purchase incentives (such as exemption from registration tax, import tax, VAT), countries could subsidise the electricity price for EV users until it becomes competitive with the cost of fossil fuels.

Our findings also indicate that use-based policy incentives contribute to consumers' overall satisfaction with EV use. Use-based policy measures, such as bus-lane access and exemption from road tolls, parking fees, and ferry fees, reduce the operating cost of EV use. However, despite their potential benefits, financial incentives are sometimes criticised. It is argued that financial incentives drive financial pressure on local government and might have a rebound effect (Langbroek et al., 2016) as they reduce the operating cost of EV use—leading to an increased level of travel activities. Moreover, it is suggested that proposing different policy incentives for different types of EVs rather than providing homogeneous policy incentives is necessary to achieve substantial EV market growth (Hardman, Chandan, Tal, & Turrentine, 2017).

Potential buyers and existing users are satisfied if EVs are available in nearby EV dealers and various models are offered by their favourite carmakers. Introducing new EV models and making them available in the market is thus necessary to give consumers options to choose their desired EV. Supporting the carmakers by incentives and imposing market regulations is critical in making EVs widely available in the market.

The environmental construct, including items such as lower tailpipe emissions, traffic noise, and the energy EVs use to operate, satisfy the EV users. In Norway, hydropower is the source of most electricity production (Ministry of Petroleum and Energy, 2016). This could play a role in Norwegian EV users' stated satisfaction with EV energy and other environmental benefits. This is consistent with Table 8.2, which shows that participants' satisfaction with environmental attributes (average 4.44) was higher than satisfaction with other attributes, and the item 'type of energy usage' stood out with the greatest value (4.64). Moreover, the way that satisfaction influences EVs' environmental attributes indicates that consumers pay attention to both local- and national-level contributions of their EV use. This is an insight for those countries whose electricity generation still heavily depends on fossil fuels. Casals et al., (2016) noted that all European countries are already putting considerable efforts into decarbonising their electricity generation sectors. However, Felice et al. (2021) emphasise that the reduction of greenhouse gas emission depends on both decarbonisation of the electricity sector and individual driving behaviours.

According to the standardised coefficient of the EV attributes, the importance of EV range and recharge is followed by cost satisfaction and environmental attribute satisfaction. Although technological advancements have improved battery capacity and charging speed (IEA, 2020), improvements are still needed to compete with conventional vehicles, particularly at low temperatures. Respondents voice relatively low satisfaction (followed by symbolic attributes) with items related to range-recharge constructs (average 3.57), which supports a need for further improvements. Although the limited battery range at low temperatures is mostly relevant for cold regions in Norway, it could be relevant for other countries as well during the winter period. Countries need to install publicly accessible charging infrastructures and support installing charging facilities at home or workplaces where possible to mitigate consumers' range anxiety and overcome the low battery range issues. In addition to installing fast charging stations, recharging options at home or workplaces also offset challenges related to longer recharging duration as they facilitate recharging the car at night and/or during work hours when the cars usually stay idle.

Although our study focuses on behavioural intention, it also provides insights for predicting actual behaviour. Studies show the correlation between intention and behaviour. In a meta-analysis study, Sheeran (2002) showed that the correlation between behavioural intention and actual behaviour varies between 0.42 and 0.82, while the average correlation between intention and behaviour is 0.53, which is considered a strong covariation (Cohen, 1992).

8.6 Conclusions and implications

This study adds to the current literature on attitudes towards EVs in multiple ways: first, by extending the theory of planned behaviour through including satisfaction; second, by highlighting Norway's maturing EV market to study repurchase intentions rather than first purchase only; third, by establishing a model to comprehend interrelations among relevant factors and complete pathway of their influences; and, finally, by identifying the attributes of EVs that manipulate EV users' satisfaction with EV use.

This study finds that EV users' attitudes towards economic and environmental values of EV use have a stronger impact on their behavioural intention to repurchase EVs than subjective norms and perceived functional barriers. In line with this, our study argues that economic and environmental benefits of EVs are likely to dominate consumers' behavioural intention. Further, EV users' overall satisfaction significantly affects their perceptions about EV use. This implies that a higher satisfaction level is likely to produce positive impressions and lessen adverse impressions about EV use. However, although consumers' satisfaction with EV use influences their positive and negative attitudes towards EV use, their attitudes partly stem from their peers' influences. Interestingly, this study finds that the effects of EV users' overall satisfaction is mediated through their attitude and perceived functional barriers.

This study finds that cost aspects have the strongest effects on manipulating overall satisfaction. The construct items indicate that policymakers and carmakers need to focus more on reducing costs related to purchases, recharging, and maintenance when allocating their limited resources. Implementing generous financial incentives is likely to reduce the purchase cost and recharging cost until technological advancement make EVs competitive with conventional vehicles. Although cost aspects turn out to be the most influential attributes, policymakers and carmakers also need to prioritise other statistically significant attributes such as range-recharge, environmental attributes, use-based policy incentives, symbolic attributes, and availability of EV models.

Finally, it should be noted that our study, like all empirical studies, has some limitations. The survey data analysed in the present study are from the Norwegian EV market, which has a higher EV penetration rate than most other car markets and numerous policy measures to make EVs more attractive. In markets where the preferences of car owners and purchasers differ or where some EV functions are considered less important (e.g. winter-driving battery range), the effects of the factors could differ. However, in general, the insights from this study are of interest for other countries as well. Second, some respondents might have answered tactically, which might be, for instance, the case concerning the perceived functional barriers. Third, subgroups of EV owners (i.e. sole EV users, users who have both ICEVs and EVs) could be helpful for a more in-depth understanding of EV users' repeated purchase intentions and behaviour. Future research can include other relevant factors (e.g. sociodemographic factors, geographical locations, personality traits) in the model to expand our understanding even further.

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Electric Vehicle Adoption: Empirical Analyses

Policymakers worldwide are attempting to shift to the electrification of transportation to mitigate environmental and energy challenges caused by transportation. However, many consumers are still skeptical about this transport innovation. Consumers are some of the key participants in the transition process of electrified transportation because it is they who must ultimately accept this technological innovation. This thesis comprises four articles that aim to contribute to the knowledge base related to electric vehicle (EV) adoption.

A comprehensive review of existing EV literature suggests that there are still knowledge gaps that need to be filled to understand EV adoption in-depth. Consequently, this thesis investigates the impacts of policy measures and consumers' behavioral factors on the transition towards electric mobility. It explored four different assessments in four scientific articles. As Norway had the highest EV market share over the past several years, insights from this market should be helpful for other countries. Therefore, this thesis explores the Norwegian EV market in all four studies. This thesis uses multiple methods to conduct empirical analyses - ordinary least squares regression models, quadrant–diagonal importance-performance analysis models, and structural equation model. The data sets of the articles were collected from multiple sources, including both primary and secondary data sets.

The combined findings of four articles suggest that EVs' functional, environmental, and economic aspects are the most critical factors that dominate consumer behavior. In other words, these aspects are the main drivers of the demand for EVs and their use. Moreover, publicly accessible charging infrastructures, regional accessibility, and climate play a critical role in driving EV demand. The findings of this thesis are of interest to policymakers and makers of electric cars. The extracted insights are helpful in comprehending consumers' behavior and the effects of policy measures in-depth and in allocating limited resources in the promotion and production of EVs.

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