Research in Transportation Economics 82 (2020) 100880

Contents lists available at ScienceDirect

Research in Transportation Economics

journal homepage: http://www.elsevier.com/locate/retrec

The role of psychological factors on vehicle kilometer travelled (VKT) for battery electric vehicle (BEV) users

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ARTICLE INFO

JEL classification:
Q28
R41

Keywords:
Battery electric cars
Travel demand
Perceived attributes
Electric vehicles
Psychological factors
Vehicle kilometres travelled
Mobility pattern

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. Drivers who own only BEVs and those who own both internal combustion engine vehicles and BEVs were compared 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.

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, Sprei, Samaras, & Qian, 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 1).

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, Tate, Wadud, & Nellthorp, 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, Kurani, & Turrentine, 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, Harpster, & Savagian, 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

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https://doi.org/10.1016/j.retrec.2020.100880
Received 15 June 2019; Received in revised form 2 December 2019; Accepted 3 December 2019
Available online 4 August 2020

Table 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.

insufficient available driving range for the remaining travel distance (Franke, Rauh, Günther, Trantow, & Krems, 2016). Franke and Krems (2013); Rauh, Günther, Franke, and Krems (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, Sreeram, & Harries, 2015; Neubauer & Wood, 2014). Moreover, concern for values related to driving EVs and technological risks contribute negatively to the probability of accepting EVs (Kim, Rasouli, & Timmermans, 2014).

Evidently, in existing literature, substantial numbers of studies have endeavoured to investigate the influence of psychological factors in EV purchase (Liao, Molin, & Wee, 2017; Noppers, Keizer, Bockarjova, & Steg, 2015; Rezvani, Jansson, & Bodin, 2015; Schuitema, Anable, Skippon, & Kinnear, 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, Mokhtarian, & Laidet, 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, Wang, & Ouyang, 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, Pfaffenbichler, Figenbaum, & Jellinek, 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.

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, Nayum, & Mehmetoglu, 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.

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, Vlek, & Slotegraaf, 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).

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.

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, Nordfjærn, Jørgensen, & Rundmo, 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).

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, Carley, Lane, & Graham, 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, Cha, & Wilemon, 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, Nordfjærn, & Rundmo, 2012; Nordfjærn & Rundmo, 2010).

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, Walker, Davis, & Jurasekb, 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, Nørbech, & Nordtømme, 2016; Figenbaum, Assum, & Kolbenstvedt, 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.

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, Park, & Jang, 2017; Hymel, Small, & Dender, 2010; Plötz, Schneider, Globisch, & Dütschke, 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, Offer, Slade, Jaegerc, and Thoennesc (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, Inderbitzin, & Bening, 2015). Consequently, in order to compensate for the higher purchase price compared with ICEVs, EVs need to be driven many vehicle kilometres.

3. Method

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.

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, Kempton, Guensler, & Elango, 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, Pelsmacker, & Moons, 2017; Graham-Rowea et al., 2012; Haustein & Jensen, 2018; Kaplan, Gruber, Reinthaler, & Klauenberg, 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?").

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:

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

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, Annema, & Banister, 2013).

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

where $i = 1,2,3\ldots n$; $i \neq 0$.

Assuming a non-linear relationship between dependent and independent variables and to achieve normal distribution of dependent variable values, e*VKT* was log-transformed.

4. Results

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 0.60s and 0.70s as good or adequate (Deković, Janssens, & Gerris, 1991; Holden, Fekken, & Cotton, 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 2). In respect of the average inter-item correlation, the prevalent correlation range between items is 0.15–0.50 (Briggs & Cheek, 1986; Clark & Watson, 1995). All constructs met the recommended threshold with the exception of self-symbolic attributes (0.56) and environmental identity (0.65).

4.2. Comparison of demographic characteristics between BEV driver groups

The comparative socio-demographic characteristics of BEV-owner groups are shown in Table 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

Table 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.* driving 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.

Table 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 deviation)				
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.

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.

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 4). The travel purposes for both types of BEV owners are almost similar.

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

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 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, 36%. 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 2, which shows that owners with both BEVs and ICEVs have less annual VKT than sole owners of BEVs.

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.

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

Table 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.

Table 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.

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, Bagozzi, & Warshaw, 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, Mathisen, & Jørgensen, 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 km daily, whereas the drivers owning both BEVs and ICEVs drive their BEVs, on average, 41 km 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. 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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