

Review

Identifying Factors Associated with Consumers' Adoption of e-Mobility—A Systematic Literature Review

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Abstract: Electrification of road transport—replacing internal combustion engine vehicles with new energy vehicles such as electric vehicles (EVs)—seems to be a promising step towards achieving sustainable urban development, yet the diffusion of EVs is proceeding slowly. Investigating this phenomenon, researchers have provided numerous findings. However, these findings also created a fragmented and heterogeneous body of literature. This article applies a systematic literature review to establish a status quo of factors associated with the adoption of EVs. A total of 49 articles were identified and analyzed in detail for their contribution to EV adoption. The results from the systematic literature review were synthesized. The article ends with implications for policymakers and suggests fruitful research avenues for future investigations.



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Keywords: e-mobility; literature review; innovation adoption; electric vehicles

1. Introduction

The transport sector has been brought into sharp focus of western society due to the increasing necessity of climate protection. The problems caused by transport, such as excessive oil consumption, air pollution, and greenhouse gas emissions, contribute to the process of climate change, especially in urban areas [1]. Road transport accounts for almost one fifth of total emissions of CO₂, the main greenhouse gas, in the EU [2]. The electrification of road transport, i.e. replacing internal combustion engine vehicles with new energy vehicles such as electric vehicles (EVs), seems to be a promising step towards sustainable urban development [3]. Since the year 2000, the CO₂ emission has increased rapidly, which has greatly enhanced research into the technologies of e-mobility [4]. Governments and companies in various countries are making efforts to push the market introduction and market diffusion of electric cars. However, our understanding of the adoption of EVs is at an early stage.

So far, the literature on EV acceptance has shown that consumers' perception and individual characteristics play an important role in the acceptance of EVs [5–8]. Other studies focus on antecedents that can act as barriers or motivators for the consumer. For instance, Bunce et al. [9] and Hardman et al. [10] examined the influence of the charging infrastructure, whereas Sierzchula et al. [11] studied the impact of certain policies and incentives. Some studies combine several factors and rely on theoretical frameworks such as the theory of planned behavior [12,13]. Yet other studies focus on the impact of social influence [14,15] or sociodemographic factors [16,17]. Despite these efforts to investigate the phenomenon of the adoption of EVs, past studies have contributed to a fragmented and heterogeneous body of literature. To provide a comprehending and contextualizing overview of past findings, a systematic literature review seems necessary. More specifically, using a systematic procedure this paper aims to address the following questions:

(1) What are the associated factors that affect the consumer's intention to purchase EVs?

- (2) What is the impact of sociodemographic variables on the adoption of EVs?
- (3) What are the main obstacles to and motivators for introducing EVs and the expected recommendations for manufacturers, politicians, governments, and scientists?

This paper is organized as follows: First, an overview of the theoretical principles underlying the review is provided. After outlining the methodological approach, the results are presented and discussed. In the following, the importance for science and practice is presented. Next, today's limitations and possible future research avenues are presented and discussed. The paper ends with a summary of the findings and our conclusions.

2. Overview of Available Electric Vehicle Solutions

The main differences between electric vehicles and conventional vehicles with an internal combustion engine (ICE) are the energy storage onboard and the transfer of power to the vehicle [18]. In EVs, the electrical energy is stored in batteries (lithium-ion batteries), whereas ICE cars are powered by liquid fuel that is filled into the fuel tank [3]. Another difference is the charging of the vehicle. In the case of an ICE, the vehicle tank is filled with petrol at a filling station and the filling process takes only a few minutes [19]. The EV batteries are charged by connecting them to an external electricity supply. Since the charging time is significantly longer than for ICE vehicles, one conclusion is that the EV battery is recharged overnight at home [20].

At present, EVs are offered on the market not only as pure battery-powered electric vehicles (BEVs), but also as hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and range-extended electric vehicles (REEVs) [3]. BEVs have the highest potential for CO₂ reduction by using renewable energy. The REEVs have an electric motor with a battery that can be charged from the power supply. In addition, they are powered by a modified low-power combustion engine or a fuel cell. In contrast, PHEVs have an internal combustion engine in addition to the electric motor with a rechargeable battery [21]. The HEVs are equipped with an internal combustion engine, which is supplemented by an electric motor. The battery is charged by recovering the braking energy [22]. Since HEVs cannot be recharged at a power outlet, the use of an HEV is not different from a conventional vehicle with ICE. The range of PHEVs and REEVs is similar to that of an ICE vehicle, although they require recharging from an external power source when the battery is discharged. BEVs have the longest electric range, but the considerable amount of time needed for charging the vehicle's battery requires the greatest deviation from their current usage behavior and habits [23]. Currently, the complete charging time of a Tesla Model S (state of charge 15%) with a battery capacity of 120 kW is 32 minutes [24].

3. Methodological Approach

In this paper, a systematic literature review was conducted following recommendations from Tranfield et al. [25] and the general guidelines from Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Relevant studies were identified through an electronic search of the databases EBSCO Host and Science Direct. Various keyword combinations were selected in order to determine relevant studies for the research proposal. However, it was ensured that the delimitation was only made to the extent that all aspects of the research project were included. The following combination was selected as the final search term: "electric vehicle" AND "innovation" AND "consumer behavior" OR "consumer behavior" AND "adoption" AND "attitude" AND "environment". The search was temporarily restricted, as the field of e-mobility was first made popular for consumers at the beginning of 2010. Since 2009, Germany and many other countries have launched extensive research programs for the development of vehicles and batteries and have carried out field trials to test the technologies developed in the handling of mobility solutions. These include the pilot project "regions of electromobility" to determine the individual goals of the country [22]. Thus, the search covered articles from 2010 to 2019 and returned a considerable number of studies that dealt with one or more of the combined

search terms. Furthermore, the search was restricted to peer-reviewed scientific journals. At the end, the search resulted in a total of 2,193 papers (December 5th, 2019) (Figure 1).

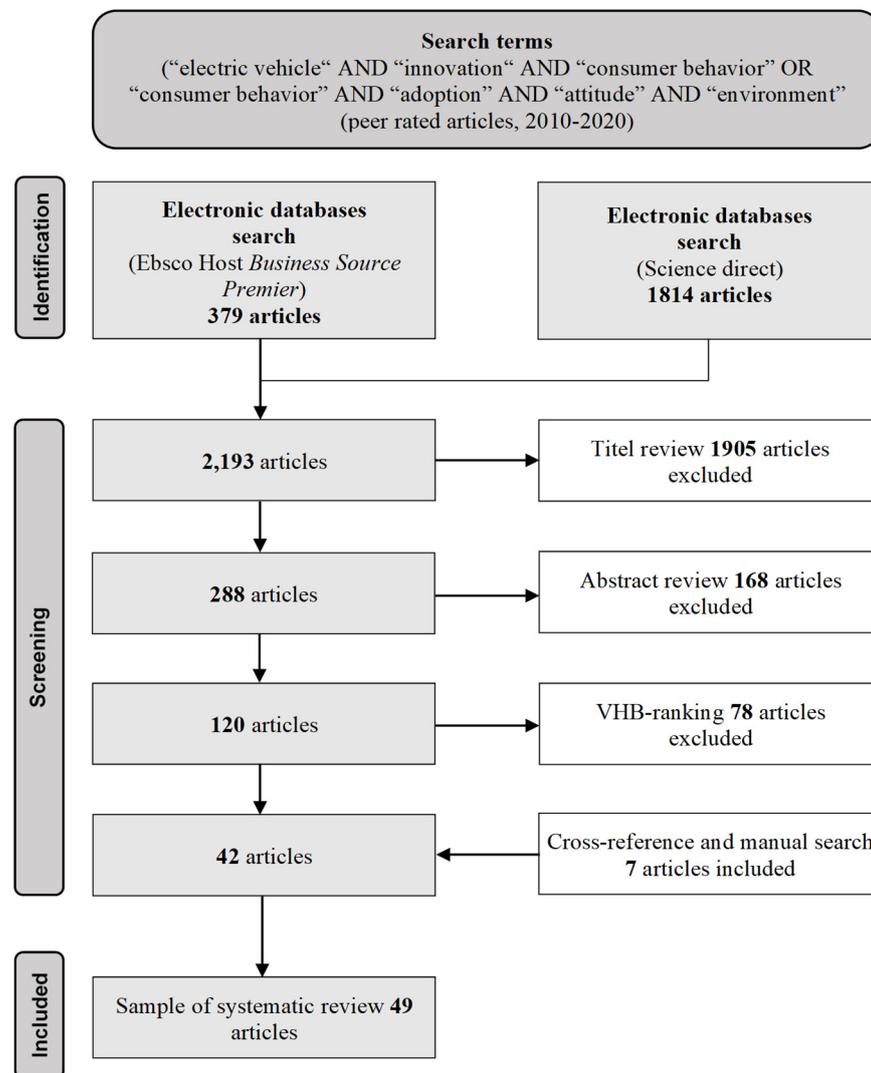


Figure 1. Mapping scientific literature search.

In the next step, 1905 papers were excluded due to missing references to the research hypotheses in the title. After deleting duplicate results, the abstracts of the papers were screened for fit with our research question. This procedure further limited the number of articles to 120. Finally, journals listed lower than “C” in the VHB ranking were eliminated to ensure a high standard of the peer-reviewed publications. By applying this threshold, we excluded research that is usually subject to less stringent peer review procedures (e.g., books and conference papers) [26]. This step generated a total of 42 papers. Additional studies were also identified by manual cross-reference screening in a later step of the process to ensure comprehensive coverage. After the final screening the review included 49 papers. In the next step, a full-text search was conducted. Each article was coded according to its associated factors, contextual factors, and methodological approach [27] (for a complete list of articles please contact the first author).

3.1. Methodological Approach

The relevant studies were examined regarding their methodological approach, which led to the insight that quantitative methods were predominant (31). In contrast, qualitative

methods were only used in 11 papers as a research design (Table 1). The quantitative methods include survey-based methods, secondary data analysis, simulations, and optimization techniques, whereas in articles with a qualitative research design the following methods were applied: case study, literature review, and interview. By far the most common method used in EV adoption research is the survey-based method, followed by secondary data analysis and literature review. A combination of qualitative and quantitative methods was used in one study.

Table 1. Methodological approach.

	Method	Total Amount of Articles	% of Final Set
Quantitative	Survey	25	60
	Secondary data analysis	4	10
	Simulation	1	4
	Optimization techniques	1	4
	Case study	3	7
	Interview	3	7
	Literature review	4	10
	Mixed Method	1	4

3.2. National Differences

The intensity of research into the adoption of EVs varies greatly between countries. It was found that Germany is the leader in the research on EV adoption, followed by the UK, USA, and China. Many of these studies (83%) refer to country-specific requirements and political circumstances in order to accelerate the spread of EVs in the country concerned [14]. Figure 2 illustrates the global distribution of related research. However, some studies (16%) were not conducted in any specific country. Other studies (5%) investigated several countries in order to find out and understand regional and cultural differences.

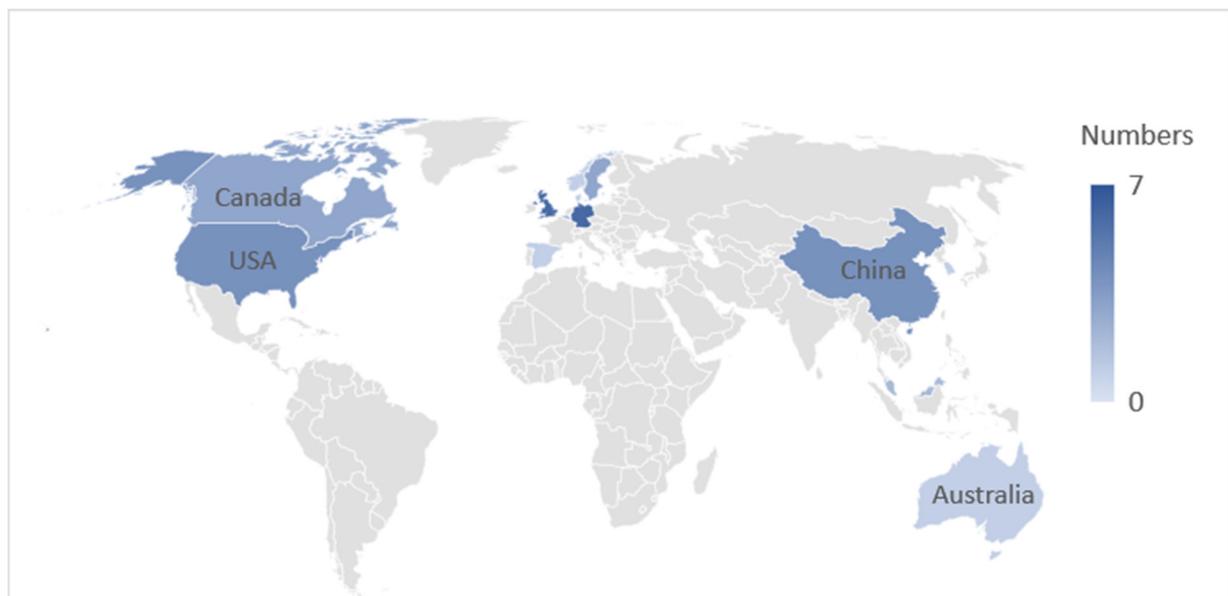


Figure 2. Number of studies in the countries.

3.3. Overview of Factors Associated with EV Adoption

A co-occurrence analysis using the VOSviewer Software package [28] was performed to derive a network of factors frequently used in investigating the adoption of EVs. The evolved keywords were labelled following recommendations by Heidenreich et al. [29], namely: consumer attitude, social influence, sociodemographic factors, government policy, technical and product features.

The categories themselves were prioritized according to the frequency of dealing with each category as a major issue. From the examined papers it can be concluded that technical and product features are the strongest factors influencing the adoption of EVs (cf. Figure 3). Government policy and consumer attitudes are likewise important factors. Contrary to Axsen et al. [14], social influence during the process of adoption is only considered relevant in 6 % of the analyzed papers.

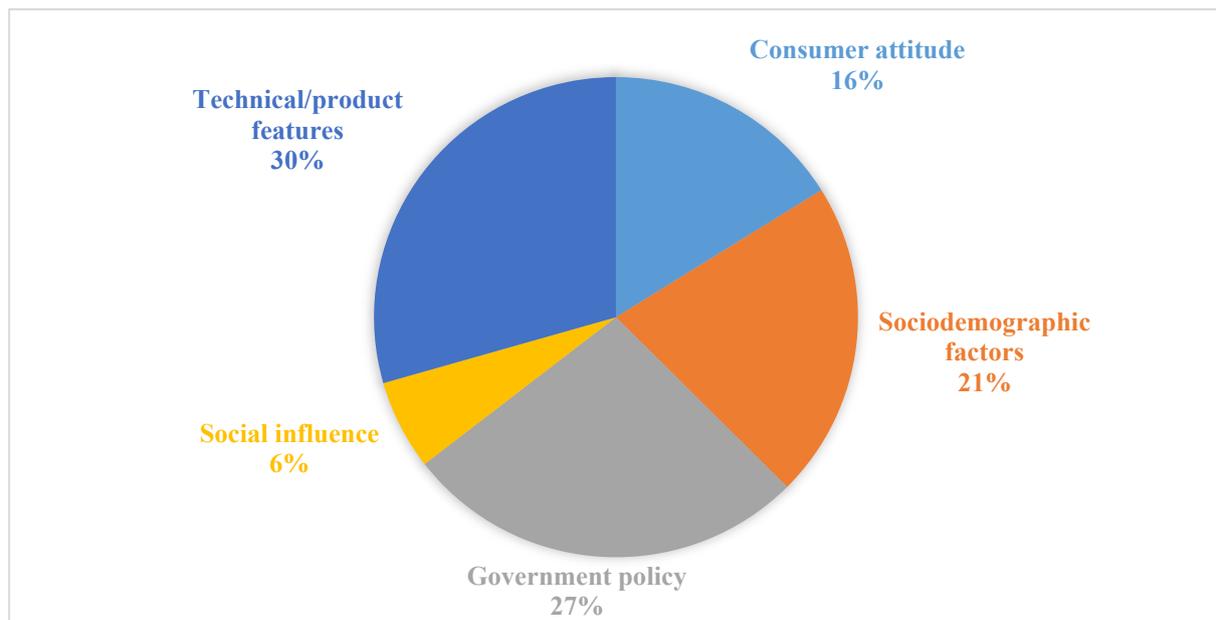


Figure 3. Frequency of articles dealing with the influential EV adoption factors.

3.4. Technical and Product Features

Essential differences between EVs and vehicles with ICE are performance-related aspects such as driving range and refueling time. Costs such as acquisition costs and running costs are also important factors in the adoption of EVs. In addition, technical factors such as battery life and acceleration have a major influence on the customer's willingness to buy EVs. The influence of these factors is reviewed in the next section.

3.4.1. The Total Cost of Ownership

In the analyzed studies, it became apparent that low operating costs increase the motivation to buy an EV. Multiple dimensions of the cost structure are covered, such as purchase price, maintenance costs, operating costs, and energy prices [30]. Compared to ICEs of similar vehicle configuration, the high acquisition costs of EVs are discussed in most studies as an obstacle to the introduction of EVs, while the lower operating costs are put forward in favour of the introduction of EVs [31,32]. However, some studies distinguish between different groups of adopters, to whom different types of vehicles are assigned. Hardman et al. [33] distinguish between “high-end adopters” and “low-end adopters”. High-end adopters would buy a model of a luxury brand (e.g., Tesla), whereas low-end adopters would choose cheap models (e.g., Nissan or Toyota). Lieven et al. [34] distinguish between adopters who use their EV as a “family car”, “micro cars”, “midi cars” or “luxury cars”. Studies also reveal that consumers willing to purchase EVs at a lower price pay only half as much for beneficial changes to other vehicle features compared to those who indicate that they would buy more expensive vehicles [6]. In addition to the acquisition costs, the charging costs are an important factor associated with the adoption of EVs. It has been shown that lower cost for charging can compensate for higher acquisition costs [35].

3.4.2. Vehicle Performance Factors

Most EVs have a shorter driving range than comparable vehicles with ICE. In this context, it was found that a limited range has a negative impact on the purchasing behavior of consumers [14]. The limited range of EVs limits the consumers' ability to participate in important activities, such as camping, mountain biking, or simply visiting friends or family living farther away [14]. However, the extent of the restriction depends on the respective lifestyle of the consumer. Adopters who use the car to commute or live in the city find the limited range less problematic than adopters who often have to cover long distances [34].

In this regard, it is possible to state that the extension of the range would increase the consumers' willingness to purchase such vehicles [35,36].

Similarly, the charging time of the battery is a barrier to adoption. In contrast to ICEs, where refueling only takes about five minutes, the charging time for EVs is considerably longer. Since the vehicle is in an undrivable condition while being charged, consumers perceive this time as a restriction of their flexibility and freedom of movement [37]. Furthermore, a study in which test persons could drive an EV for three weeks free of charge found that 50% of their planned trips could not be carried out due to the limited range in combination with long charging times (reported in Bunce et al. [9]). The cost of battery replacement is also higher for EVs than for vehicles with ICEs as power source [38]. All in all, it seems undoubted that a significant reduction of the charging time would lead to higher adoption of EVs [6].

3.4.3. Product Perception

In addition to technical factors, product-specific factors are associated with a consumer's willingness to buy. These include the size of the car and the product type (e.g., SUV, sports car, city car, or family car) [33,34,36,39]. Dumortier et al. [39] have found that the size of the car has a positive influence on the purchase of EVs. Furthermore, the possibility to experience the EV can influence the adoption of EVs [16]. Other relevant factors mentioned are quietness, smoothness, and fast initial acceleration [14]. As an additional aspect, car safety is mentioned in Huang and Ge [16] and Zhang et al. [17]. In the study by Zhang et al. [17], a positive correlation between willingness to purchase and car safety was stated. In addition, greater availability and variety of EV models at car dealerships, combined with the promotion of viewing and experiencing EVs, could help to promote the sale of EVs [40]. It can be concluded that the higher the rating of the product features of EVs, such as range, charging time, battery life, and safety, the stronger the consumer's buying intention.

3.4.4. Environmental Benefits

In many studies, environmental attributes are relevant factors for the adoption of EVs. A distinction is made between the identified environmental benefits of EVs and the impact of consumers' environmental awareness on the purchase of EVs. Essential benefits that make EVs attractive include the reduction of air pollution, the reduction in greenhouse gases (GHG), and the aspect of energy saving [5,6,14,33,38,41,42]. Hardman et al. [33] have found that an increase in environmental impact increases the intention to purchase EVs. In the study by Egbue and Long [38], EVs are described as environmentally friendly. This feature significantly influences early adopters [41]. However, there are also conflicting opinions on the environmental advantages. Thereby, the carbon intensity of the power source and the environmental impact of the production and disposal of advanced automotive batteries are mentioned as factors that can hinder the adoption of EVs [5,6,14].

3.5. Government Policy

The influence of government policy has gained extensive attention in recent years. With growing numbers of EVs on the roads, the infrastructure must be adapted to meet the new requirements. Support from the government and industry is a major contribution to the expansion of the system. For this reason, many studies have examined the relationship between the spread of EVs and the infrastructure.

3.5.1. Charging Infrastructure

Several studies have verified that the unavailability of adequate charging infrastructure is a major barrier to the diffusion of EVs [6,11,16,43], for the inadequate charging infrastructure reduces the flexibility and user comfort, thus making driving EVs less attractive [11].

The charging infrastructure includes different models with regard to the place and method of charging the battery. Several studies exhibit a positive relationship between home charging stations and EV adoption rate. The domestic charging infrastructure has the advantage that the charging process occurs overnight, making a filling station obsolete [14]. However, it has been found that there is a lack of charging infrastructure in cities for many individuals who live in small apartments without home-charging stations [40,44]. Thus, additionally to recharging at home, recharging at work or on the way to work are the most commonly used charging locations [10,45]. Moreover, there are public charging stations, which are usually located at shopping malls, supermarkets, and on travel corridors [10]. Many companies offer free loading stations at their stores, which has led to the problem of overcrowded parking spaces and a loss of customer satisfaction [46]. Another hurdle to the diffusion of EVs is the insufficient number of charging stations and the non-standardized cost system at charging stations [6,7,9].

3.5.2. Incentives

Many studies distinguish between monetary and non-monetary incentives. The current monetary incentives mainly include purchase subsidies, governmental tax relief, and free parking and charging. Several studies have determined that all these incentives have a positive effect on consumers' adoption intentions [6,9,11,16,36]. Non-monetary incentives are factors that provide convenience to consumers when buying and using EVs, such as the separate allocation of EV number plates and the right to drive in bus lanes [16]. Studies have found no significant positive correlation between non-monetary incentives and the adoption intention. Thus, non-monetary government incentives appear unable to accelerate EV adoption [6,16]. In addition to the governmental incentive systems, a positive influence of incentives provided by the automotive industry has also been identified. These include discounts and coupons for EV users [36]. Furthermore, the diffusion of EVs can be promoted through advertising measures that illustrate the benefits of EVs [7].

3.6. Sociodemographic Factors

In the literature examined, various sociodemographic characteristics are considered as distinguishing features to measure adoption behavior. Variables like gender, age, income, educational level, and family or life factors are particularly relevant in this context for the adoption of EVs.

3.6.1. Gender

Gender differences in the diffusion of EVs are mentioned in many studies. However, no consistent results have been found that one gender receives higher benefits from EVs. Based on several studies, it is assumed that more male consumers perceive the advantages of EVs [16,17,32,41,44]. Axsen [44] has cited as a potential explanation that in technical innovation, men usually make up the largest part of the group of pioneers. Some studies indicate that women are more interested in adopting EVs [7,12,43]. He et al., [7] have found that women are more likely to buy EVs because of environmental concerns. The vehicle type may also be a gender-related variable. For example, in the luxury and SUV segment, men are more willing to buy an EV, whereas no gender-specific effect could be observed in the mini and midi car segment [47].

3.6.2. Age

The influence of age on the adoption of EVs varies between studies. For instance, it has been found that middle-aged consumers show the greatest willingness to buy such vehicles [16,32,38,41]. According to the study by Huang and Ge (2019) [16], the interest in EV technology is highest within the age range of 25–30 years. In contrast, the studies of Axsen et al. indicate that the largest share of potential buyers is in the 40–50 years range [41,44]. Higgins et al. [47] found that older consumers feel more comfortable with

ICEs. In contrast, He et al. [7] did not find a significant influence of consumers' age on their purchasing behavior.

3.6.3. Income

The influence of income on the adoption of EVs is examined in many studies because the purchase price of EVs is higher than for ICEs [31,32]. Some studies have found that there is a positive correlation between a higher income and the willingness to pay for EVs [7,32,35,47]. In Zhang et al. [17] it is shown that the more the consumer earns, the higher the willingness to pay for EVs. Other authors have reported only marginal increases in EVs adoption for consumers with higher incomes [47]. However, this effect is considered less significant when compared to age, gender, and educational level [11,47]. In the study by Egbue et al. [38], no significant correlation between income and the adoption rate of EVs can be found.

3.6.4. Consumer Education

Another research issue has been the investigation of the adoption of EVs with regard to the consumers' educational levels. The studies distinguish between low, middle, and high educational levels [16,17,32]. A positive correlation between educational qualifications and the adoption of EVs is determined in several studies [8,14,16,17,35,38,44]. The study by Zhang et al. [17] shows that a high level of education increases the willingness to pay for EVs. In addition, a high level of education has a positive influence on the purchase of EVs in all vehicle segments [47]. He et al. [7] did not confirm an effect of educational level to purchase intentions regarding EVs.

3.6.5. Living and Family

Family factors are also variables that have an impact on the decision-making process regarding the purchase of EVs. In the studies examined, the number of cars, the number of children, and the number of persons with driving licenses in the respective household are the main concerns. As Zhang et al. [17] state, consumers in families with more vehicles have less intention of adopting EVs in the short term. In contrast, in Aksen et al. [44] it is shown that the intention of adopting EVs increases if there are more cars in the household. Regarding the number of driving licenses, it has been found that the more driving licenses in one household, the greater the interest in EVs [17]. Furthermore, the possession of a driving license has a positive effect on the willingness to pay the price of an EV [12]. In terms of household members, Plötz et al. [32] have stated that consumers who own EVs might live in multi-person households. This result is inconsistent with the study by Higgins et al. [47], who found that the more children in the household, the less interest there is in purchasing EVs.

3.7. Social Influence

Some of the studies suggest that the social network has an influence on the adoption rate of EVs. It could be found that the opinion of the peer group has a significant influence on the adoption of EVs [12,14,15,17,41,48]. The study by Moons et al. [12] shows that peer pressure has a greater influence than media pressure. It has also been shown that car buyers show off their adoption decision to others, such as other drivers and neighbors [12,48]. The studies by Aksen et al. [14] and Jansson et al. [15] classify social influence into three groups: family, neighbors, and co-workers. Studies have been undertaken on the differences between the individual groups regarding adoption behavior. The greatest influence on adoption behavior is exerted by neighbors, followed by colleagues and then by family members [15]. The results also show that co-workers influence the consumer opinion in the environmental awareness and evaluation of EVs, whereas the aspects of lifestyle are mainly affected by family members [14]. However, the effect of social influence on the acceptance of EVs is affected, for example, by sociodemographic variables [15].

3.8. Consumer Behavior

Many studies point out that psychological aspects such as consumer attitudes, behavior, and moral values have a significant influence on the purchasing behavior of EVs. Some studies focus on the effects of attitudes based on the theory of planned behavior (TPB), which states that the emergence of human behavior is the result of careful consideration and that behavioral change is a complex mental process. Thus, attitudes cannot influence human behavior directly, but only indirectly by influencing individual intention. The measurement of attitudes can only be accurately assessed and predicted if the analysis focuses on the relationship between attitudes and intentions [13].

3.8.1. Environmental Awareness

The influence of environmental awareness on the adoption of EVs is examined in many studies. In this respect, studies have mainly examined the role of environmental attitudes, values, and beliefs in relation to the intention of adopting EVs. A high level of environmental awareness and "green" political consciousness are important factors regarding the adoption of EVs [16,49]. People with a high sustainability awareness are more likely to adopt EVs than people with low sustainability awareness [38]. Furthermore, it has been stated that pioneers have a more pronounced environmental awareness [44]. Smith et al. [50] also note that consumers who are aware of the environmental situation are more inclined to purchase EVs. In addition, a positive correlation between age, length of time in possession of a driving license, and the degree of "greenness" has been found [12].

3.8.2. Innovativeness

He et al. [7] have shown that personal innovativeness can be a predictor of perceived monetary benefits and reduced risk perception when adoption EVs. Some studies have also shown that consumers with a high degree of innovativeness are significantly more likely to be concerned about the environmental impacts of EVs [44].

3.8.3. Emotions and Consumer Intention

In a study conducted by Huang and Ge [16], attitude and emotions towards the car itself were the most important determinants of the decision to purchase an EV. With regard to the influence of emotions, it is shown that the anticipation of positive emotions from environmentally-conscious behavior is an important motivation for consumers to purchase EVs [51]. Besides the emotions, an influence of the factors of TPB could be found. A positive attitude towards the vehicle plays an important role in the adoption of EVs [12,16]. A positive connection has been found between emotions and attitude. Consumers who have positive emotions have a greater interest in adopting EVs [13]. Furthermore, Rezvani et al. [51] demonstrated that personal moral standards are important predictors of strongly environmentally-friendly behavior. In this context, they have found that, when adopting EVs, personal moral standards significantly and positively influence the expected positive emotions [51]. Considering the perceived behavioral control mentioned by Ajzen [52], an influence in favor of the adoption of EVs could be found. Therefore, it is shown that the more substantial the PBC, the higher the probability that a consumer will buy an EV [12,16]. In contrast, aspects of the social norm have less influence on the purchasing behavior of EVs [12,16].

4. Discussion

As shown in this study, consumer acceptance of EVs has been investigated using several theoretical frameworks. To answer the first research question, a systematic literature review was carried out to determine the factors associated with the adoption of EVs. Based on the published literature, five factors have been identified regarding the consumer's adoption of EVs. Figure 4 illustrates the relationships between the factors associated with the adoption of EVs. "Government policy", "Technical and product features" and "Social influence" are antecedent variables preceding the introduction of EVs and acting as barriers

or motivators. "Sociodemographic variables" are used as control variables in many studies. They can also be utilized to determine demographic, geographical, and cultural differences.

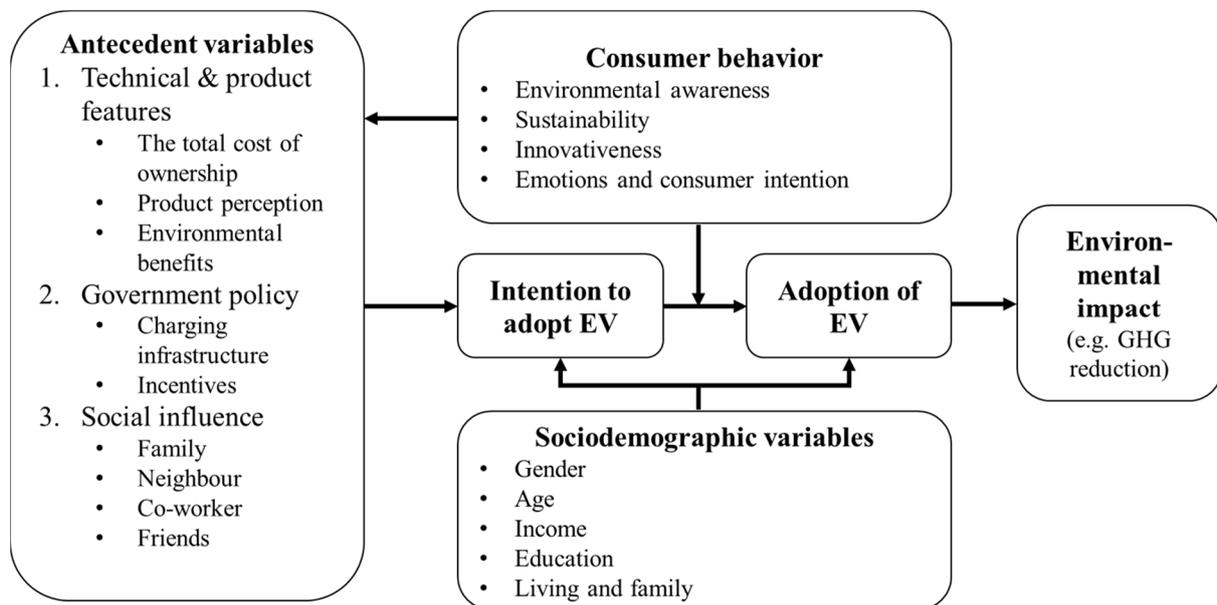


Figure 4. Overview of the context of adoption of EVs adapted and modified from Kumar and Alok (2020).

In the available literature, few studies do not focus their research exclusively on a single issue but rather include the interaction of the various factors. The results suggest that all five issues have an impact on the adoption of EVs. Hardly any of the studies measure the actual adoption (behavior) of EVs, but rather an intentional variable. This can be attributed to the fact that the adoption of EVs has only increased in the last five years (cf. Figure 2). Thus, the current adoption rate can only be determined in part due to a lack of scientific significance caused by a too limited sample. It was also shown that research is carried out almost exclusively in countries like Germany, the UK, the USA, and China, which are major economic powers and have a large influence in the manufacturing of automobiles [53,54].

With regard to the influence of sociodemographic variables, various factors could be identified. A middle-aged consumer with a high income could be identified as an optimal adopter. Yong Zhang et al. [17] stated that the probability of being able to afford a more expensive car increases with age. Junquera et al. [35] found out that car-sharing programs could also give young people the opportunity to experience and use EVs. Furthermore, most adopters have a higher level of education. In this context it was found that education and environmental awareness are positively correlated, so it is more likely that a consumer with a higher level of education has the intention to buy an EV [17]. Different intentions for the purchase of EVs were found for the gender. For example, He et al. [7] could determine women's intention to buy EVs stems from environmental awareness, whereas men have a higher affinity for technical innovations [44]. No conclusive results could be determined with regard to the influence life circumstances might have on adoption intention. However, this might be due to a low presence of studies.

The importance of stakeholders like manufacturers, politicians, governments, and scientists for the diffusion of EVs was also highlighted. The most significant influence is exerted by factors that are technical or product specific to EVs (cf. Figure 3). The acquisition costs represent a major barrier to the adoption of EV for consumers. In Junquera et al. [35] it is shown that reducing costs through incentives can increase the intention to purchase EVs. Axsen and Sovacool [41] and Rezvani et al. [13] also cite car-sharing programs and leasing as ways to reduce acquisition costs. In Germany, many car manufacturers offer incentives for switching from ICE vehicles to EVs. Moreover, German EV owners receive

tax advantages. Yet, lowering the costs of ownership alone might not increase the adoption of EVs. Dumontier et al. [39] argue that consumers must be informed more extensively about potential cost advantages, for instance with calculations over 3, 5, and 10 years, where all costs of ownership (initial, energy, repair, etc.) should be considered, as many consumers are deterred by the acquisition costs and have no information about the reduced maintenance costs.

In addition to the acquisition costs, the limited range of the vehicles and the long charging process are also barriers that limit the diffusion of EVs [13]. When considering the range, however, it must be acknowledged that there is a variety of models and brands of EVs with different ranges. With regard to the power supply, it has been shown that the PHEV is the most popular variant of the EVs, as they do not require a charging station [6,33]. Furthermore, range and charging time are directly related. Adopters who live in the city more often use EVs, because their habits rarely need to be changed: They drive rather short distances and are not disturbed by a longer charging time. Since many car manufacturers concentrate on the business with EVs, the question arises how these barriers can be circumvented. Different approaches can be found in the investigated studies: Battery research needs to be intensified and research should also focus on the installation of a comprehensive fast-charging infrastructure and the improvement of its user-friendliness to mitigate the inadequacy of the limited driving range of BEVs. One way to improve the user-friendliness is to introduce battery exchange and battery leasing programs [36]. These programs could be subsidized by the government. Besides, the expansion of charging stations at public places such as supermarkets and restaurants could enhance convenience especially for urban consumers. Furthermore, the legislative requirements for recharging must be clarified. In Guo et al. [55], overcrowded parking places and obstruction by fully charged vehicles represent a major limitation to the use of EVs. For this reason, a uniform system for the use of public charging stations must be implemented by the government. Companies might benefit from charging stations in company parking places as they enhance the image of the company. The most attractive location for a charging station is at home because it is easy and convenient to use. Bunce et al. [9] suggest that advertising campaigns should focus more on the benefits and ease of charging EVs. Toll-free charging stations or car-sharing programs can increase the acceptance of EVs because they significantly reduce the GHG emissions of the cities and the costs for the consumer [14]. Many large companies such as Volkswagen and BMW offer car-sharing or ride-sharing programs, thus reducing the burden on urban traffic. "MOIA" is an example for a consumer-friendly ride-sharing program with which the trip can be conveniently booked and paid for by using the app [56].

Most perceived benefits that contribute positively to an individual's attitude are the EV's potential for saving fuel, the convenience of recharging at home, and the feeling of a smooth, quiet ride. In addition to cost reduction through fuel saving, the associated environmental impact is another major factor that positively influences the adoption of EVs [14]. However, the impact of the benefits of an EV varies and is additionally influenced by social environment and advertising. Furthermore, a potential buyer's individual characteristics, as well as behavior, values, and norms, are factors that tend to influence the adoption of EVs. Innovativeness as a factor is only explicitly investigated in a few studies. It has been found that a high degree of innovativeness has a positive influence on the adoption of EVs [7,44]. The comparatively intense involvement and commitment, such as the financial risks accompanying innovation, can be seen as reasons for the positive correlation between innovativeness and the adoption of EVs [29].

Social influence has the least influence on the adoption of EVs (cf. Figure 3). Partly, this might be due to the fact that few studies have been conducted on the influence of social interaction. Furthermore, social influence is an overarching concept that includes peer pressure as well as subjective social norms, neighborhood effects, collective effectiveness, and social culture. In many studies, the subjective norm is described as a factor associated with the adoption of EVs. It is, to a certain extent, determined by external factors and

individually expressed by the consumer. The influence of external factors cannot be defined by measurements and rules [57]. Social influence is most strongly exerted by neighbors and colleagues. The results suggest that in particular, employees exchange product-related information and evaluations, whereas attitudes are more likely to be discussed within the family [14].

Environmental benefits act both as a motivator and as a consequence of the adoption of EVs. It has been found that an environmentally-friendly character of a vehicle increases the consumer's intention to purchase it, providing the positive self-image of being environmentally responsible [38,51]. His decision can also be influenced by social norms and influential people. In contrast, He et al. [7] state that no impact of the environment on consumers' purchasing intentions can be perceived. They suggest that, on the one hand, consumers are aware of the environmental attributes of electric vehicles but, on the other hand, believe that their purchasing behavior of electric vehicles has no significant environmental effect. The reduction of GHG by using EVs has a positive impact on the environment [22]. Thus, the reduction of GHG is a positive consequence of adoption.

5. Implications

5.1. Techno-Marketing Implications

The study reveals several implications regarding the adoption of EVs. First, the review revealed that manufactures need to pay more attention to the improvement of the technical and product-specific characteristics of EVs. This includes, for instance, extending the range and battery life of EVs. Another important finding that emerged from reviewing past studies is that the infrastructure surrounding EVs is crucial for adoption. This being said, particularly the diffusion of charging stations remains an inhibiting factor for EV adoption across studies. Currently, there are about 18,400 charging stations in Germany (2020). The majority of them are located at public parking lots or in the streets [58]. To put the number of charging stations in context, in 2019, approximately 83,200 electric vehicles were registered. In addition to the fragmented charging infrastructure, consumers are confronted with varying pricing models for charging their vehicle. Results of the present review suggest that the slow diffusion of EVs is indicative for how a technological sub-system (in this case, battery life and charging station network) limits the performance of the technological system. When viewing EVs not as a single product but as a technological system comprised of hierarchically structured and interconnected sub-systems, it becomes apparent that certain sub-systems are still insufficiently developed [59]. Due to their interconnection within the system, however, the performance of sub-systems affects the performance of the entire system. Scholars refer to this circumstance as a reverse salient (for a detailed review on past and current developments on reverse salients, readers should consult Dedehayir [59]; the authors are grateful to the anonymous reviewer for suggesting this idea). Hence, following the reverse salient logic, a diffusion of rapid charging systems is necessary to increase the adoption of EVs. The company Qualcomm, for example, offers technology for inductive charging systems and has already licensed a dynamic charging system called Halo. This system overcomes prior technological obstacles that led to long charging intervals by burying inductive charging plates in the road [60].

Second, governments and companies need to take action to improve the consumers' perception of EVs and related incentive policies. The government could provide financial incentives (e.g., subsidies, tax exemptions) and the industry could offer discounts and coupons to EV consumers to improve the perceived financial benefits. The analysis of Ahlswede [61] shows that since 2016, the sales figures for EVs have increased by 61% in Germany (current value in January 2020: 136,600 EVs). In addition, electric cars could be exempt from motor vehicle tax for up to ten years. For instance, Romania offers consumers an environmental bonus of up to 10,000 Euros [62]. Similarly, China offers non-monetary incentives by exempting EVs from driving bans and giving them preferential registration (ibid.). These findings signal that financial aspects are a key factor for the consumer contemplating the purchase of an EV.

Third, from an environmental perspective, the reduction of GHG emissions remains the underlying goal of adopting EVs. As it has been shown, the use of EVs can reduce GHG emissions compared to vehicles with combustion engines. However, when considering the entire life cycle of EVs, these advantages might vanish. Industrialized countries such as China and India use coal as their main energy source for electricity production [63]. The emitted GHG emissions for using EVs might thus vary between countries, depending on the prevailing energy production to power EVs [64]. An increase in adoption of EVs might thus not necessarily lead to the desired effect in GHG emission reduction. Therefore, it is important that countries whose main energy source is coal-fired power plants decarbonize their power generation source in order to reap the real benefits of EVs.

5.2. Theoretical Implications

The results of the systematic literature review provide several theoretical implications. First, the present manuscript connects and realigns findings from various sources that span across disciplines (i.e., management, environmental science, engineering). This is particularly important for researchers interested in studying sustainability. Sustainability in general needs to be seen as an interdisciplinary area connecting and valuing interrelations between economic, ecologic and sociologic disciplines. Here the present manuscript offers a summary of past findings and synthesizes them into one framework.

Second, the socio-demographic variables are usually considered control variables. However, in this paper, it was shown that they may significantly influence the adoption of EVs [47], too. Thus, socio-demographic factors should be taken into consideration for future investigations on EV adoption.

Third, the reviewed articles consider the adoption of EVs in specific regions and countries. Yet, it has been shown that there are a strong country and region-specific discrepancies. In particular, the extent of the charging infrastructure shows large differences [58]. For this reason, more academic research on the differences between regions and countries needs to be undertaken in order to become aware of the needs of each region and country.

6. Limitations and Future Research

One limitation is the lack of access to all studies. Furthermore, only two reference databases were searched and evaluated. Therefore, the study should be extended to other databases in order to provide a more comprehensive overview of the factors associated with EVs. Many studies used the survey method, with participants who have no direct experience of EVs to base their answers on. Thus, they are far removed from the actual use of EVs, which limits the validity of the conclusions regarding adoption drawn from their responses. Among the studies in which participants actually have previous experience with EVs, sample bias may occur, as the studies often interviewed early adopters who are particularly motivated to own such EVs. Therefore, the samples cannot be considered representative of the majority of consumers.

Likewise, the studies carried out are mostly cross-sectional studies so that the dynamic development of consumer attitudes cannot be depicted. Thus, the development of the economy, the social culture, changes in the legal framework, or the further development of technology are not included. For this reason, more longitudinal studies should be carried out in order to be able to map the dynamics of the adoption of EVs. Furthermore, the studies are country-specific or do not consistently reflect the differences between the individual countries. There are cultural and social differences in the countries that can influence the purchasing of EVs. Furthermore, most of the studies are conducted in countries with strong economic power or a strong gross domestic product [53]. The study also considers only private consumers, but recent studies also point to a relevant EV market potential for commercial vehicles [41,65]. The study does not strictly differentiate between the various types of EVs. For this reason, not all advantages of each type can be illustrated. Likewise, the different climate targets of the individual countries are not explicitly considered in the

study, which means that consumer attitudes may differ in the individual countries. The different climate targets should be included as a variable in following studies [22].

A further limitation can be identified in terms of charging infrastructure and range, which are presented in different ways by the authors and are perceived by countries and regions as different, but distinct barriers to the introduction of EVs. Furthermore, the economic benefits of EVs vary according to country-specific policies and incentives [62]. It might be impossible for the consumer to estimate the total cost of ownership for his EVs, since the cost of recharging at public stations is determined by the provider and the replacement cost of the batteries cannot be estimated. The lack of battery recycling models is also a point of criticism in the available studies [36]. Moreover, future studies should include technological advances such as inductive charging, as well as battery leasing and car-sharing programs to comprehensively map the possibilities of EV adoption.

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