Scientia Moralitas International Journal of Multidisciplinary Research
ISSN 2472-5331 (Print) | ISSN 2472-5358 (Online) | Vol. 9, No. 2, 2024
DOI: 10.5281/zenodo.14526514

Acceptance of Electric Vehicles: Critical Review Towards a Unified Research Concept

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ABSTRACT: In many countries, electric mobility, especially electrified vehicles, is seen as essential for moving towards a more efficient, cleaner, and ideally CO2-neutral way of personal transportation. Despite the considerable technological progress in electric mobility over the last decade, the challenge of public acceptance remains unresolved, raising concerns for both manufacturers and policymakers. This article first outlines the registration situation in Germany and then explains the political framework surrounding it. Following that, it presents the number of publications related to electric vehicles, placing them within the larger context of research on acceptance. Additionally, existing meta-analyses on electric mobility are reviewed to identify potential factors influencing the adoption of electric vehicles, including purchasing decisions and future ownership. Finally, the research question is framed within the literature on customer preferences, and an overview of the theoretical implications is discussed.

KEYWORDS: technology acceptance, user acceptance, electric vehicle, electric mobility, consumer preferences

1. Introduction

The levels of pollutants and particulate matter in the air, primarily due to vehicle traffic, have been rising each year. The transportation sector accounts for about 20% of global carbon dioxide emissions annually, with nearly half of that coming from private motorized transport (Deutsches CleanTech Institut 2020; Europäisches Parlament 2023, 3; Martin et al. 2022; Rodrigue 2020, 132 f.). This indicates that passenger transport significantly affects both human health and the environment, contributing to local noise and air pollution as well as global climate change (Creutzig et al. 2015, 911 f.; Lelieveld et al. 2015, 1 f.). As a result, more people are becoming concerned about environmental issues (Attenborough & Lagarde 2019, 5; Continental AG 2020, 7; Finger 2015, 10). In this context, the traditional internal

combustion engine is at the center of discussions about drive technology. The goal of electrifying drives is to promote the use of environmentally friendly technologies. This offers a chance to decrease long-term oil dependence and lower emissions (Appel 2021; Delhaes 2021; Karle 2022, 2; Proff and Szybisty 2018, 2). To meet the targets outlined in the Paris Agreement[1], it is crucial to cut emissions from motorized private transport (Rockström et al. 2017, 1269 f.).

Electric Mobility (EMOB) is crucial for the energy transition and the quest for sustainable transportation in many countries. Specifically, battery electric vehicles (BEVs) are a key component in this effort (Kampker et al. 2018, 60 f.; Karle 2022, 29f.; Middelkoop and Koppelaar 2017, 45 f.). BEVs utilize electricity sourced from local, low-emission options whenever possible (Ajanovic and Haas 2016, 1452; Bradley and Frank 2009, 115 ff.; Chan 2007, 707 ff.). Electric vehicles have been commercially available for just over a decade (F. Dudenhöffer 2022b, 37; Karle 2022, 3). For a long time, electric vehicles made up only a small fraction of total vehicle sales in Germany, leading to significant skepticism about the market potential of this innovative drive technology (Kampker et al. 2018, 13; Kraftfahrt-Bundesamt 2024b).

2. Electromobility in Germany

The low number of registrations can be attributed to several factors. Key criticisms of electric vehicles include their significantly higher purchase price, limited range, inadequate charging infrastructure, lengthy charging times, and concerns regarding technical safety and reliability (Bennett and Vijaygopal 2018, 501; Proff et al. 2022, 7). It was not until the period from 2020 to 2022 that we saw a significant rise in electric vehicle sales. Given these changes, it is important to consider whether the increase in registered electric vehicles is solely due to political support measures or if other technical, socio-economic, or psychological factors have also influenced consumer buying decisions (Bandelow and Kundolf 2018, 172; CAM 2021; Kampker et al. 2018, 14; Kraftfahrt-Bundesamt 2022). Despite the growing number of registrations, the criticisms of current electric vehicles cannot be overlooked. Considering the technical limitations, it seems reasonable to suggest that consumer acceptance of electric vehicles may still be constrained (K. Dudenhöffer 2015, 321; Fazel 2014, 303–306; Sanguesa et al. 2021, 391).

The Federal Republic of Germany set an ambitious goal of having 1 million registered electric vehicles by 2020, but this target was not achieved (Bundesministerium für Wirtschaft und Klimaschutz der Bundesrepublik Deutschland 2016). However, electric vehicle sales saw a significant increase, with over 524,200 new registrations recorded in Germany in 2023. In December 2023, the government announced an early end to the environmental bonus, a subsidy for electric vehicles that was initially intended to last until the end of 2024. In light of

1 The Paris Agreement is an international treaty concluded by 195 parties to the United Nations Framework Convention on Climate Change with the aim of protecting the climate, following the Kyoto Protocol (United Nations 2015).

this, several manufacturers stated they would temporarily absorb the government funding portion to avoid a sharp drop in sales. The subsidy for plug-in hybrid vehicles had already lapsed at the end of 2022, and support for electric vehicles owned by commercial entities ceased in August 2023 (Kraftfahrt-Bundesamt 2024a; ntv, 2024). As a result, interest in electric cars in Germany has noticeably declined. In July 2024, the number of registered electric cars was 36.8 percent lower than in the same month the previous year, making up only 12.9 percent of all new registrations. Since the start of the year, around 215,000 electric cars have been sold, marking a significant drop compared to the same period in 2022. Contributing factors to this trend include high prices, a lack of affordable models, limited range, long charging times, and insufficient charging infrastructure. Despite advancements in technology, demand remains low. The government's goal of reaching 15 million electric vehicles by 2030 seems increasingly difficult, especially considering that only 1.4 million have been registered to date (Kraftfahrt-Bundesamt 2024b). Dudenhöffer, an expert in the automotive industry, has sharply criticized the SPD's plans to offer purchase premiums of €6,000 for new electric cars and €3,000 for used ones. He describes these initiatives as reactionary and lacking a systematic approach. Dudenhöffer points out that the lack of a clear strategy creates uncertainty for potential buyers, which ultimately stifles demand instead of encouraging it. The ongoing discussions about the car summit and the various, sometimes disjointed, political proposals are destabilizing the market. As a result, buyers are becoming more hesitant, worsening the situation (F. Dudenhöffer 2024). Given these considerations, it is important to explore the reasons behind the slow acceptance of electric vehicles and the strategies that could be implemented to promote the adoption of innovative drive technologies (Bundesministerium für Wirtschaft und Klimaschutz der Bundesrepublik Deutschland 2016, 2022, 2023; Dudenhöffer 2022a, 160 ff.). This leads to the following question: Which factors influence the acceptance of electric vehicles?

The research project aims to investigate this question to understand the elements influencing the acceptance of electric mobility and to find effective tools for boosting both acceptance and sales. The ultimate objective is to sustainably enhance the sales of electric vehicles.

3. Acceptance research and electric mobility

The goal of acceptance research is to explore the psychological and sociological factors that affect how individuals accept new technologies and to create models based on these factors (Dillon and Morris 1996, 8). User acceptance refers to the enthusiastic adoption of a product or idea through active engagement, rather than just passive acceptance (Dethloff 2004, 18). Developing positive attitudes and intentions is essential for achieving acceptance. Acceptance serves as a measure of how consumers view a product, like electric vehicles, as a legitimate alternative (K. Dudenhöffer 2015, 76; Wicki et al. 2022, 66). Research on the Technology

Acceptance Model (TAM) can be categorized into four distinct phases: introduction, validation, expansion, and refinement (Lee et al. 2003, 755). According to Lee et al. (2003), the technology acceptance research conducted so far can be segmented into four phases: model introduction, model validation, model expansion, and model refinement (Fazel 2014, 131; Lee et al. 2003, 755).

The accompanying Figure 1 illustrates how various technology acceptance models have evolved over time. TAM 1 (Technology Acceptance Model 1): This model was first introduced in the late 1980s and underwent several validation studies until the early 2000s. TAM 2: An extension of the original TAM, introduced in the mid-2000s, which became the focus of extensive research throughout the 2010s. The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed in the mid-2000s and builds upon earlier models, being developed alongside TAM 2. TAM 3 and UTAUT 2: Both models were introduced in the late 2000s and continue to be refined and developed to this day. UTAUT 2 showcases a progressive enhancement, contextualization, and exploration of technology acceptance.

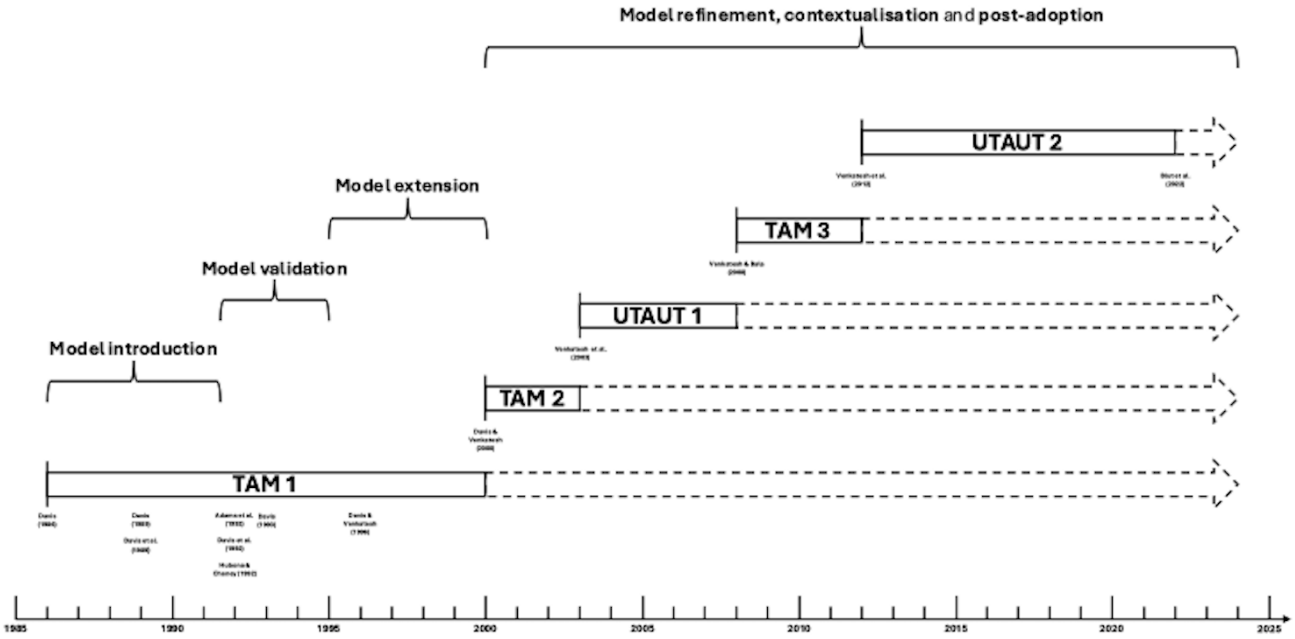

Figure 1. Phases of technology acceptance research to date and key publications[2]

To better understand the developmental stages of technology acceptance models, it is also helpful to provide a descriptive overview of the literature on acceptance research related to electric mobility. For this purpose, the multidisciplinary database Scopus was searched for peer-reviewed research literature that includes the term 'electric vehicle' in the title, abstract, or keywords. The results underwent a systematic relevance check (Holden and Karsh 2009, 162; Yarbrough and Smith, 2008, 652).

2 For completeness, the figure also includes Davis' 1986 dissertation, which is the first to mention the technology acceptance model. However, as the 1989 paper is referred to in the literature below as the "origin of TAM", this is also taken into account in this paper.

To align with the research context of this study, the following search terms were used: 'electric AND vehicle' along with 'intention OR acceptance OR TAM OR UTAUT OR technology acceptance OR technology acceptance model'. The following Figure 2 illustrates that this focused search resulted in a total of 1,843 publications (shown in orange) and 1,088 specialized articles (shown in blue).

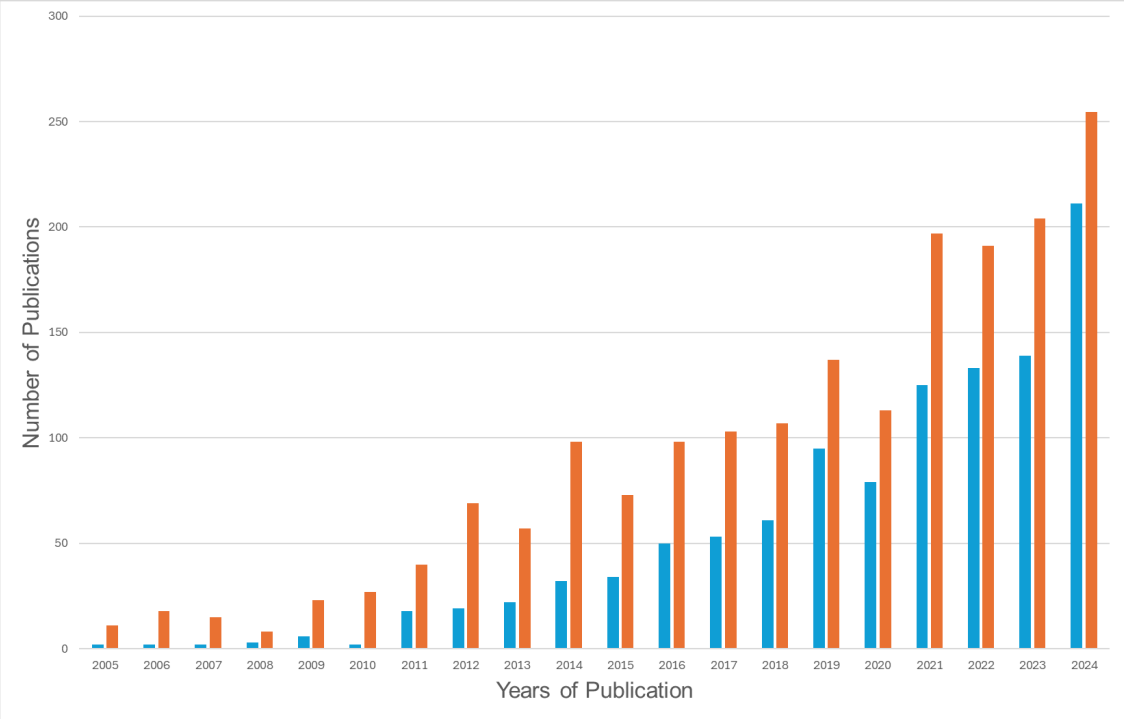

Figure 2. Number of Publications for electric vehicles from 2005 to 2024[3]

The publications were also examined based on scientific journals. It was discovered that there is a significant link between acceptance research and electric vehicles, especially in journals related to transport and sustainability. In total, articles were published across 160 journals, with around two-thirds of the publications found in 29 of the journals listed in the following table.

Table 1. Number of publications in the field of research context according to scientific journals

Journal	Publications
Sustainability Switzerland	69
Transportation Research Part A Policy and Practice	44
Transportation Research Part D Transport and Environment	39
Journal of Cleaner Production	33
World Electric Vehicle Journal	33
Energies	30
Energy Policy	30
Transport Policy	21
Energy	18
Transportation Research Part C Emerging Technologies	16

3 The figures for the year 2024 are extrapolated, the call-off date of the data is the 31st of May 2024.

Transportation Research Part F Traffic Psychology and Behaviour	16
Journal of Power Sources	13
Technological Forecasting and Social Change	13
Applied Energy	12
IEEE Access	12
Qiche Gonachenq Automotive Engineering	12
International Journal of Electric and Hybrid Vehicles	11
International Journal of Hydrogen Energy	11
International Journal of Sustainable Transportation	11
Journal of Energy Storage	11
Case Studies on Transport Policy	10
Environmental Science and Pollution Research	9
IEEE Transactions on Vehicular Technology	9
IEEE Transactions on Intelligent Transportation Systems	8
Dianli Xitong Baohu Yu Kongzhi Power System Protection and Control	7
Energy Reports	7
Energy Research and Social Science	7
International Journal of Automotive Technology	7
Research in Transportation Business and Management	7

The research clearly shows that many individual studies have been carried out in the area of 'electromobility and technology acceptance'. However, since this work focuses on the broader obstacles to accepting electric vehicles, it is important to look at not just the individual findings that fit the specific context, but also those that might overlook some key factors influencing acceptance. Meta-analyses are particularly relevant to summarize findings in their field of research (Moro and Lonza 2018).

The exploration of attitudes and preferences regarding electric vehicles began in 2007. Table 2 below summarizes the relevant studies. It shows that, alongside Davis' technology acceptance model, researchers also utilized the theory of planned behavior and Rogers' diffusion theory as their theoretical frameworks. It is also striking that only a small number of the studies scientifically examined, validated and qualified their results from the literature research in a second step.

Table 2. Overview of EMOB meta-analyses and reviews

Author/s	**Title**	**EV-type**	**Method of factor identification**	**Research focus & Main theory**	**Categories to bundle the research determinants**
Lane and Potter 2007	The adoption of cleaner vehicles in the UK: exploring the consumer attitude–action gap	BEV	>Literature review >Qualitative and quantitative interviews via questionnaire	>Adaption barriers of BEVs *via* >Theory of Planned Behavior (TBP) >Value-belief-norm theory >Habits >Diffusion of Innovation Theory (DOI)	>Situational factors >Psychological factors
Razvani et al. 2015	Advances in consumer electric vehicle adoption research: A	PHEV	>Literature review, Peer-reviewed journals only	>Consumer intentions and adoption behavior towards EVs *via* >Theory of Planned Behavior (TBP)	>Technical factors >Contextual factors >Cost factors >Individual and social factors

	review and research agenda				
Coffman et al. 2017	Electric vehicles revisited: a review of factors that affect adoption	EV	>Literature review, Peer-reviewed journals only	Adaption factors for EVs *via* >Gap analysis	>Internal factors >External factors
Li et al. 2017	A review of factors influencing consumer intentions to adopt battery electric vehicles	BEV	>Literature review, Peer-reviewed journals only	>Adaption intention of BEVs *via* >Theory of Planned Behavior (TBP) >Diffusion of Innovation Theory (DOI) >Technology Acceptance Model (TAM)	>Demographic factors >Situational factors >Psychological factors
Liao et al. 2017	Consumer preferences for electric vehicles: a literature review	BEV. PHEV	>Literature review	Consumer preferences *via* > Identification of the variables for further research	>Financial attributes >Technical attributes >Infrastrucure attributes >Policy attributes >Individual-specific attributes
Hardman et al. 2018	A review of consumer preferences of and interactions with electric vehicle charging infrastructure	BEV. PHEV	>Literature review	Recognize consumer preferences for charging infrastructure for market introduction via >Literature review	>Charge point activity and locations >Pricing and interoperability >Cost of charge >Number of public charging stations >Temporal distribution of charging and charge management >Infromation, education, and outreach
Daramy-Williams et al. 2019	A systematic review of the evidence on plug-in electric vehicle user experience	PHEV	>Literature review	User experience of PHEV via >Systematic Literature review	>Driving behavior >Travel behavior >Interactions with the vehicle >Subjective aspects of the user experience
Wicki et al. 2022	What do we really know about the acceptance of battery electric vehicles? – Turns out, not much	EV	>Literature review, Peer-reviewed journals only >Meta-analysis (PRISMA)	Identify determinants for BEV adoption and prospective ownership via >Technology Acceptance Model (TAM)	>Technical determinants > Contextual determinants > Cost-related determinants >Sociodemographic determinants >Attitudinal and behavioural determinants >BEV-specific experience >Social determinants

The multitude of results, both in terms of the identified determinants and their groupings in the individual studies, as well as their temporal difference, make it difficult to derive a unified research model. Therefore, in this article, the latest research of Wicki et al. (2022) is focused on and shortly presented below.

As shown by the meta-analysis 'What do we really know about the acceptance of battery electric vehicles? – Turns out, not much' by Wicki et al. (2022) shows that the discussion about the relevant factors that play a role in different socio-cultural and context-dependent decision-making situations is not yet complete. Table 2 lists the identified determinants and their classification into seven groups. In addition, the last column shows how these determinants influence the acceptance of electric vehicles when their influence is strengthened (Wicki et al. 2022).

Table 3. Identified determinants for acceptance of BEVs with concluded effect

Categorization of the determinant groups	Determinant	Concluded effect when the value of the determinant is strengthened
Technical determinants	Motor power	(+)
	Driving range	(+)
	Reliability	(+)
	Charging time	(-)
Contextual determinants	Market availability	(+)
	Charging availability	(+)
	Environmental impact	(+)
	Policy & incentives	(+)
Cost determinants	Purchase price	(-)
	Operational costs	(-)
	Fuel efficiency	(+)
	Resale value	(+)
Sociodemographic determinants	Income	(+)
	Education	(+)
	Gender	(+)4
	Age	(-)5
Determinants of individual attitudes and behavior	Travel demand	(-)
	Vehicles per household	(+)
	Technology affinity	(+)
	Environmental attitudes	(+)
Determinants of BEV-specific experience	Knowledge	(+)
	Familiarity	(+)
Social determinants	Norms	(+)
	Neighbourhood	(+)
	Word-of-mouth	(+)

4 (+) = male
5 (-) = older

Wicki et al. highlight six important limitations that future research should consider.

- Generalization without representativeness: Many studies rely on insufficient samples, and there is a lack of information regarding response rates.
- Limited cross-country comparability: The use of different survey methods complicates comparisons between countries.
- A significant drawback is the absence of causal analysis, as most studies focus on correlations instead of exploring causal relationships.
- Another limitation is the scarcity of replication data; only a handful of studies share their data for review, which restricts the potential for replication.
- The analysis is confined to English-language, peer-reviewed studies published from 2010 to 2019, which may create a bias towards English-language research.
- Additionally, grey literature and internal company data were not included in the analysis (Wicki et al. 2022, 80 ff.).

4. Consumer preferences and cultural impact

This chapter shows that consumers from different countries have varying preferences for the types of drive systems they choose for their vehicles. It also explores whether there are commonalities and differences in the main selection criteria and if these can be linked to cultural, social, or personal factors. The countries examined are China, the USA, and Germany, as they display the most significant differences in purchasing preferences, as noted in the literature (F. Dudenhöffer 2021, 2022b; K. Dudenhöffer 2015, 236) (K. Dudenhöffer 2015, 236 ff.). The figure[6] 3 below depicts consumer preferences for the types of drive systems used in passenger vehicles across three countries: the USA, China, and Germany. It compares the distribution of preferred drive systems, including internal combustion engines, hybrid drives (PHEV and HEV), and battery electric vehicles (BEV).

- The internal combustion engine remains the most common drive system in all three countries. In the USA, 64% of consumers prefer it, while in China, this figure drops to 33%. In Germany, the preference stands at 49%.
- Hybrid vehicles: The preference for hybrid drives (PHEV + HEV) is strongest in China, where they make up 31% of preferences. In Germany and the US, the respective shares are 21%.
- Battery electric vehicles (BEV): The preference for fully electric vehicles is lowest in the USA, with only 6% of consumers choosing BEVs. In Germany, this figure rises to 13%, and in China, it reaches as high as 33%.

The graphic shows that the preference for electric or electrified vehicles in China is significantly higher than in Germany and the United States, while the internal combustion engine continues to be the dominant mode of propulsion in the United States (Proff et al. 2024, 6).

6 Based on the Deloitte study "2024 Global Automotive Consumer Study Key Findings: Global Focus Countries".

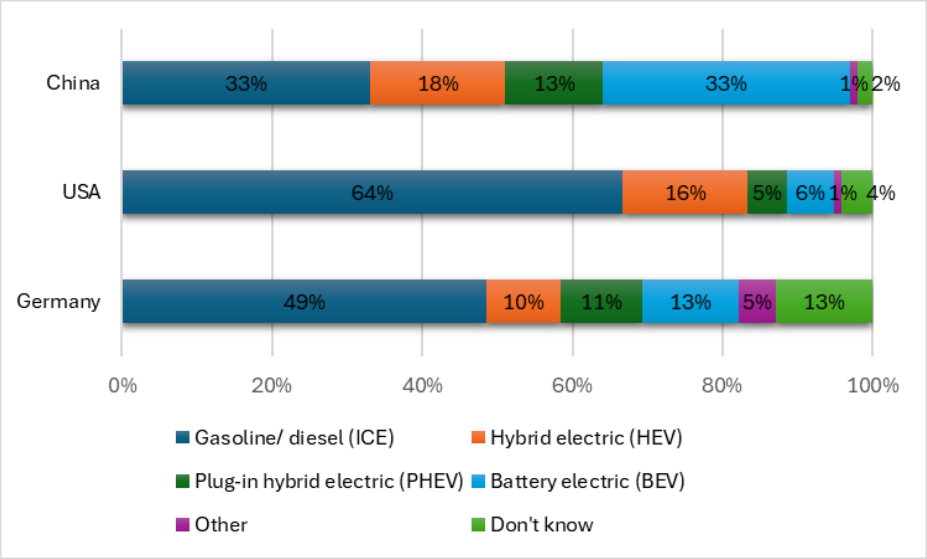

Figure 3. Consumers' powertrain preferences for their next vehicle

A comparison of consumer preferences today with those from 13 years ago shows significant changes. While electric mobility was relatively insignificant back then, it has gained importance in recent years and is now increasingly viewed as an eco-friendly alternative to traditional combustion engines (Bandelow and Kundolf 2018, 205 f.; Deutsches CleanTech Institut 2010, 17; F. Dudenhöffer 2022a). Over this time, consumer awareness of this innovative technology has grown. According to Rogers' diffusion theory, the first users of vehicles with (partially) electric drives can be classified as "early adopters," as they embraced the new technology early on (Karnowski 2017, 21; Rogers 2003, 281). The following Figure 4 presents findings from a 2011 Deloitte study that explored the acceptance and adoption of electric vehicles across various countries. The graphic illustrates how consumers in the US, Germany, and China reacted to this emerging technology in different ways (Giffi et al. 2011, 1–3).

- In the United States and Germany, both known for their automotive traditions, a rather skeptical view of electric vehicles was noted. The graph clearly indicates that consumers in these nations were less receptive to the introduction and use of electric drives. This skepticism may stem from established preferences for conventional drive technologies and a deep-rooted automotive culture.
- China: The chart shows that consumers in China are much more open to electric vehicles compared to those in other countries. One reason for this greater acceptance could be the lower number of private vehicles, which might lessen any bias against new technologies. Furthermore, many consumers have not yet developed strong preferences for specific types of vehicles, which likely makes them more receptive to innovative technologies like electric drives.

The graphic 4 highlights the cultural and geographical differences in how electric vehicles are perceived and accepted, particularly contrasting the established

automotive markets in the USA and Germany with the emerging market in China (K. Dudenhöffer 2015, 60–62, 296–298).

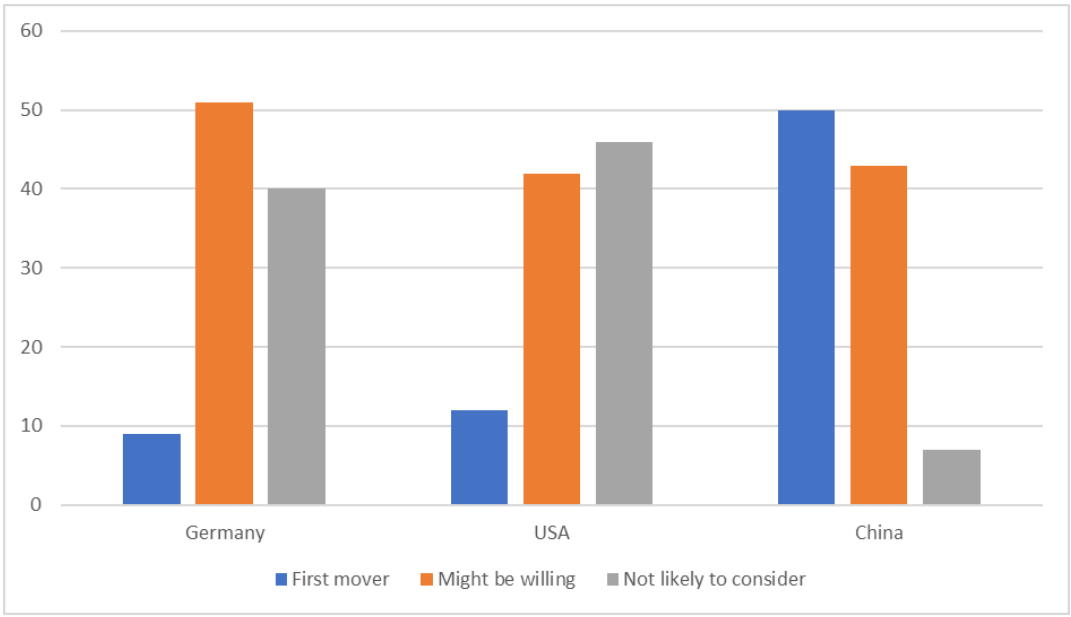

Figure 4. Comparison of consumer interest in purchasing EVs in selected countries in 2011

In addition to the consumer statements of intent regarding the acceptance of electric mobility from 2011 and 2024, further surveys conducted by various institutions have analyzed the key requirements for electric vehicles. It has become clear that factors such as reduced emissions, environmental friendliness, government subsidies or tax breaks, lower costs in terms of life cycle cost analysis (total cost of ownership, TCO), and the need to keep up with technological advancements could be crucial in influencing the decision to purchase an electric vehicle. However, since the underlying studies and surveys are distinct, a direct comparison of results among the three countries (USA, China, Germany) is not feasible (BDEW - Bundesverband der & Energie-und Wasserwirtschaft e.V, 2020; Deloitte Global 2018, 12; Proff et al. 2024, 6 f.; Rakuten Insight 2019).

Incorporating additional factors derived from cultural, social, and individual characteristics may provide a more comprehensive understanding of technology acceptance. Individual factors, in particular, are believed to play a significant role in consumers' acceptance and purchasing decisions (K. Dudenhöffer 2015, 321). Moreover, there is a correlation between research findings based on individual characteristics and the local context (e.g., Germany), which allows for insights into the social and cultural nuances of the respective research area and the segmentation of consumers. A country-specific comparison of purchase intentions between 2011 and 2024 shows that the conditions for electromobility have changed significantly, highlighting the need for new insights into the target group for TAM research (K. Dudenhöffer 2015, 322; Wicki et al. 2022, 82).

5. Research implications

The goal is to create a unified study design that can be tested across various countries with representative population samples at different times. It is suggested that surveys or field experiments be employed to assess the causal effects of specific factors on the acceptance of battery electric vehicles (BEVs). Additionally, it is advised that study designs and raw data be made publicly accessible to facilitate future research (Wicki et al. 2022, 80–82). A thorough theoretical model is necessary to effectively capture the complexity of a diverse product. Research has shown that technology acceptance models are not only useful for explaining the acceptance of information systems but can also be adapted to other technology domains (Davis 1986; Fazel 2014, 103; Kumar Jain et al. 2022, 3). The following approach is suggested to identify the most appropriate technology acceptance model, which can serve as a foundational model for the research. Initially, a comparison will be made between the findings of Wicki et al. and the definitions of existing technology acceptance models to determine which determinants from Wicki et al. can be linked to the constructs of these models. The aim is to assign and compare the determinants identified by Wicki et al. without altering or expanding the models themselves. After this assignment is completed, a decision will be made regarding which acceptance model aligns best with Wicki et al.'s research based on the highest level of agreement. The next step will involve assessing whether any model extension or adaptation is needed and to what degree. The number of determinants that can be linked to the target model will influence this decision. Hypotheses will also be formulated in this context. Finally, the research model will be developed, the hypotheses will be outlined, and the entire research project will be summarized.

The following figure provides a visual representation of the process outlined for developing the research model.

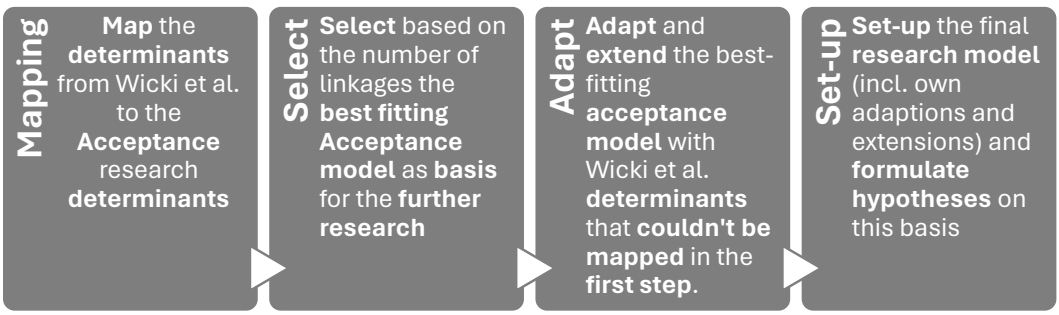

Figure 5. Procedure for deriving the research gap and setting up the research model

The research model should be broadened to include the cultural context as an indirect moderating variable (Hilale and Chakor 2024). Blut et al. (2022, 13) highlighted in their meta-analysis that cultural moderators can significantly affect the strength of relationships between variables across different contexts. It is essential to consider moderators whenever applying the UTAUT model, as certain

predictors, like social norms, are particularly influenced by the dimensions of individualism and collectivism. Consequently, the adapted technology acceptance model is utilized (Blut et al. 2022; Zhang et al. 2018). In collectivist cultures, individuals in high-status positions have a more substantial impact on behavior. However, the effect of social influence is stronger among vertical collectivists compared to horizontal collectivists and individualists, who tend to be more independent (Hofstede 1980; Triandis 2004).

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