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Which Electric Car Disadvantages Are Most Significant from the Users' Perspective? An Analysis of Key Factors

Abstract

This article aims to identify the disadvantages of electric cars, resulting from their current technological development and the state of supporting infrastructure, which users perceive as particularly problematic. The severity of each factor was assessed in two dimensions: firstly, by considering the likelihood of each issue occurring according to users' opinions; secondly, by evaluating the significance of its potential impact on the respondents. Both assessments are grounded in the perceptions of actual electric car users. The methods employed in this research include a literature review, opinion surveys with non-random sampling techniques, descriptive statistics and the Pearson correlation coefficient. The study was conducted on a sample of 59 electric car users in Poland. The originality of this article lies in its dual-dimensional approach to evaluating the disadvantages of electric cars, combining the likelihood of occurrence with the perceived significance of their impact from the perspective of actual users. This approach provides a comprehensive insight into the user-experience-driven challenges in electric vehicle adoption.

Keywords: EV, electric vehicle, electric car, customer, disadvantage
JEL Classification: Q55

Introduction

Electromobility, especially in the form of electric cars, is becoming increasingly popular as an alternative to traditional internal combustion engine vehicles [Chinoracky et al., 2022; Weber, 2020], with the literature describing diverse combinations focused on a green mindset using electromobility. Studies describe different proposals for the use of electric cars and their combination with other modes of transport within the public ecosystem. The analyses include both individual options of users with different modes of transport and sharing models [Campisi et al., 2020; Hu et al., 2021; Sobiech-Grabka et al., 2022].

The choice of the electric car as the main mode of transport contributes to the reduction of harmful emissions, especially in countries with a low carbon footprint of electricity production [Petrović et al., 2020]. Electric cars provide numerous advantages, including zero direct emissions, significantly reduced operational costs, and a notably quieter driving experience, making them an attractive alternative to traditional internal combustion engine vehicles from both the environmental and economic perspective. However, due to the current level of technological development of electric vehicles and market conditions, the purchase and operation of these vehicles still present challenges in the form of higher purchase costs, shorter range, and longer charging times compared to conventional vehicles. Additionally, in many countries and regions, the charging infrastructure is still not sufficiently developed to provide reliable and convenient charging for electric vehicles.

Given the rapid pace of the ongoing electrification of vehicles in urban transportation systems, current research and analysis focus not only on the effects of electrifying electric cars but also on other modes of transport, as well as the shared use of multiple electric vehicles by individual users. This includes electric cars in combination with electric bicycles [Wang et al., 2022], electric scooters [Brezovec, Hampl, 2021], public transport [Bell et al., 2022] and zero-emission travel methods [Ortar, Ryghaug, 2019]. Incorporating these modes of transport into daily mobility habits has numerous benefits for both users and the environment.

The main research problem addressed in this paper is identifying which disadvantages of using electric cars are perceived as most significant by users, considering their current, early stage of development as a product. The main objective was therefore defined as the identification of the perceived risks of electric cars by their users in relation to their purchase and use. The identification was carried out on two levels: an assessment of the likelihood of a given problem occurring, and an evaluation of the magnitude of the consequences of a particular threat associated with the ownership and operation of electric vehicles, including financial impacts.

The theoretical background section describes the sales structure of electric cars in Europe and Poland, presents electric propulsion as an alternative to combustion solutions, and reviews user evaluation studies of electric vehicles, including disadvantages. Compared to the European Union, the Polish market is much less developed, with the share of electric cars statistically 10 times lower than the EU average, while the ratio of the average salary to the price of EVs

among Polish consumers is not favourable. The Polish energy mix is also controversial on environmental issues (e.g. according to the Polish Power Grid, in December 2023 only 20% of energy was from renewable sources). At the same time, Poland will have to meet, among other things, the requirements for the development of charging infrastructure resulting from EU directives, which is why the example of Poland was used in the study relating to barriers to the use of electric mobility.

Theoretical background: the structure of the electric vehicle market as a factor influencing its popularity

The structure of the electric vehicle market and the development of charging infrastructure play a fundamental role in shaping consumer purchasing decisions regarding these vehicles [He, 2022; Ivanova, Moreira, 2023; Samarasinghe, Kuruppu, Dissanayake, 2024]. The availability of various EV models offered by manufacturers positioning their products in a differentiated manner, as well as the spatial distribution of charging stations, directly influence the perceived convenience and cost-effectiveness of using electric cars as a primary mode of transportation. The more developed the EV market and the more accessible the charging infrastructure, the greater the consumer propensity to choose electric vehicles as an alternative to internal combustion engine vehicles [He, 2022; Ivanova, Moreira, 2023; Samarasinghe et al., 2024].

In 2024, battery electric vehicles (BEVs) accounted for 13.6% of the European market, while cars with combustion engines (petrol and diesel) made up a total of 45.2%. In comparison, on the Polish market, petrol and diesel cars represented 46.3%, while BEVs had a significantly lower share of just 3.0% [ACEA, 2025]. Among European countries, Norway (88.9%), Denmark (51.5%) and Sweden (35.0%) have the highest share of BEVs among newly registered cars [ACEA, 2025]. Although the share of electric cars should be assessed as small, it should be pointed out that on the European market, the volume of sales is characterised by a moderate level, with no apparent upward trend. In 2023, 1,538,106 BEVs were purchased in the EU, whereas in 2024, this number decreased by 3% to 1,447,934. In Poland, these figures are as follows: 17 070(2023), 16 564(2024) [ACEA, 2025]. In 2023, on the European market, the leading electric car manufacturers were Tesla (25.3%), Volkswagen (24.6%), MG (7.2%), Fiat (6.6%) and Dacia (5.5%). It is important to note that about one-third of the European electric cars market was occupied by manufacturers that do not include combustion-powered cars in their product portfolios [Battery Electric Vehicles, Europe, 2024].

From the perspective of the advantages and disadvantages of purchasing and using electric vehicles, the state of development of the BEV charging infrastructure in a given market is extremely important. At the end of 2024, there were 8,659 publicly available electric vehicle charging points in Poland, of which 31% were fast DC charging points, while 69% were slow AC charging points with a power output of 22 kW or less [Rynekelektryczny.pl, 2025], which

means that there were 9.32 fully electric passenger and commercial vehicles per charging point [Rynekelektryczny.pl, 2025]. Considering the potential to support the purchase and use of electric vehicles, in addition to the increasing number of AC and DC charging points it is also necessary to indicate the number of operators present in Poland. The largest operators in Poland in terms of the number of publicly available charging stations at the end of 2024 were: GreenWay (726), Orlen (478), Power Dot Poland (295), Eleport (227), Noxo Energy (220) and Tauron Nowe Technologie (211) [Cleanerenergy.pl, 2024]. The current, still relatively low share of battery electric vehicles (BEVs) in Poland makes research on the perception of electric vehicle disadvantages compared to conventional vehicles particularly important from the perspective of transport policy. These studies are crucial for advancing the implementation of sustainable development goals, including increasing the share of zero-emission vehicles.

Electric propulsion as an alternative to combustion solutions

The implementation of electric propulsion technology as an alternative to traditional combustion solutions in the transport sector is key to reducing emissions and improving air quality. There is a wide spectrum of scientific research on the impact of electric propulsion on emissions reduction and air quality [Cherubini et al., 2015; Helmers et al., 2017; Li et al., 2016; Oman, 2002; Pan et al., 2023; Petrović et al., 2020; Soret et al., 2014], all of which highlight that electric vehicles can eliminate local emissions of CO2 and harmful substances, such as particulate matter (PM) and nitrogen oxides (NOx).

The advantage of electric propulsion is its zero emissions, which contributes to the fight against global warming and the negative effects of air pollution [Liu et al., 2022]. Additionally, electric cars are quieter compared to internal combustion vehicles, which contributes to noise reduction in urban environments [Nyeste, Wogalter, 2008]. However, the introduction of electric propulsion requires further development of charging infrastructure [Ryu et al., 2014; Zhang et al., 2017], with chargers necessary in strategic locations such as public car parks, shopping centres and workplaces. Planning and modelling the distribution of charging points in cities are important aspects [Cavadas et al., 2015; Zhou et al., 2022]. In addition, the development of battery technology and increasing battery capacity and efficiency are essential to increase the range of electric vehicles [Ucer et al., 2019], while in line with the principles of sustainable development and the circular economy, ensuring the sustainability and proper management of used batteries is also crucial [Aziz, Ravi, 2022]. Effective recycling and recovery of battery materials are key to a sustainable electromobility model [Chen et al., 2019].

In conclusion, the introduction of electric propulsion as an alternative to combustion solutions has numerous benefits, such as reduced emissions, improved air quality and reduced noise. However, further investment in charging infrastructure, development of battery technology and political support for electromobility is needed to fully realise its potential.

Determinants of electric car choice in the context of users' disadvantages

Electromobility, including the development of electric cars, is currently one of several major trends in transportation [Chinoracky et al., 2022]. Global initiatives to reduce air and greenhouse gas emissions are being observed, particularly in the automotive sector [Moćko et al., 2011], and are specifically relevant in road transport, which in the European Union accounted for nearly 72% of total transport GHG emissions in 2019 [European Environment Agency, 2022]. Many countries are showing a growing interest in electric cars as an alternative to internal combustion vehicles [Adhikari et al., 2020; Nour et al., 2020; Singh et al., 2020], leading to an increase in the number of electric cars [Borge-Dies et al., 2021]. The growing popularity of electric cars [Tundys, Wiśniewski, 2023] makes it worthwhile to examine the factors influencing consumers' choice of such vehicles. This section aims to present key determinants of electric car choice, including economic factors, charging infrastructure, range and environmental awareness and the disadvantages associated with these areas. It is worth noting that although these problems were diagnosed more than 20 years ago, they are still relevant today [Gärling, Thøgersen, 2001].

Economic factors are among the main determinants of electric car choice [Adhikari et al., 2020; Chen et al., 2020; Fasiecka, Marek, 2018; Janczewski, 2017; Wang et al., 2019]. The upfront purchase cost, including the price of the vehicle itself, plays a crucial role in consumer decision-making [Krishna, 2021]. Additionally, the potential expenses related to installing a home charging station have a significant impact on the consumer decision [Chakraborty et al., 2019]. These financial considerations, such as long-term savings from lower operating costs versus the higher initial investment, have a significant impact on the adoption rate of electric cars.

The present cost of BEV is considerably higher than that of traditional combustion vehicles, and the authors determined that Poles are willing to spend between around EUR 18,600 and EUR 21,000 to purchase an electric car [Majchrzak et al., 2021]. This is lower than typical prices of EVs: according to the JATO report [2023], the average price of a BEV in the first half of 2023 was just under EUR 70,000 (about PLN 315,000), while according to Statistics Poland the average salary in the economy in Q2 2023 was around EUR 1,560. The list price of a new electric car is around 80% higher than a similar model offered with combustion engine – this is an average, since depending on the manufacturer, the price gap can vary from around 40% to as much as 140%. According to used car dealers, the average price of a second-hand vehicle in Poland in 2019 was around EUR 3,950, whilst the median price was EUR 4,400. Meanwhile, the prices of secondary market accident-free BEVs are around EUR 32,800 (average) / EUR 28,580 (median) [Sendek-Matysiak, Grysa, 2021]. The higher purchase price also increases other costs, including auto-casco insurance, among others [Witewska et al., 2017]. It is therefore

not surprising that the BEV market share was estimated at 4% [JATO, 2023], which generates a lack of tangible benefits of purchasing electric vehicles (economic viability, range issue, etc.) [Dróżdż et al., 2020]. For this reason, the availability of government subsidy programmes and tax incentives may be important for potential buyers, while operating costs, such as charging costs compared to traditional fuel, may influence the decision to purchase an electric car. However, in some circumstances, according to the total cost ownership (TCO) calculation, operating costs of an EV can be lower in comparison to conventional vehicles. The authors point to the daily distance as a one of the factors (urban vehicles – at least 41.6 km per day, vehicles from other segments – 77.9 km) [Wu et al., 2015].

Another factor that affects the viability of buying an electric car is government subsidies. Majchrzak et al. [2021] indicate that according to a report by the Polish Alternative Fuels Association-PSPA (Polish EV Outlook 2020), in the scenario of subsidising EV purchases (e.g. the possibility of a 100% VAT reduction), the overall number of electric cars in Poland in 2030 could reach over 280 thousand, while without such intervention, the number of users would be around 130 thousand. Poland introduced a subsidy programme for the purchase of an electric car called *My Electric Car*, under which, by October 2023, 54% of the amount earmarked for individuals had been allocated, as well as 32% for businesses and entities other than individuals, and 91% in the banking pathway. An additional advantage of buying an electric car is the exemption from excise duty and the higher amount of depreciation than in the case of cars with combustion engines (around EUR 50,000.00 vs. around EUR 33,333.33). These issues are regulated in Polish law in the PIT Act (Article 23(4)(a)), the CIT Act (Article 16(1)(a)) and the Excise Duty Act (Article 109a) since November 2023. Despite the proposed subsidies for purchasing an EV, it still has a higher cost than purchasing a combustion vehicle [Sendek-Matysiak, Rzędowski, 2021].

Charging infrastructure is an extremely important factor influencing the choice of buying an electric car [Chakraborty et al., 2019; Chen et al., 2020; Fasiecka, Marek, 2018; Globisch et al., 2019; Janczewski, 2017; Krishna, 2021; Neves et al., 2019; Łosiewicz, Sendek-Matysiak, 2018; Wang et al., 2019], as the availability of an adequate number of charging stations and their distribution are important, especially in the context of longer journeys, which can influence the decision of potential buyers [Krishna, 2021]. In Poland, there is a pressing need to expand the charging infrastructure both in cities and on intercity routes [Chmielewski et al., 2023]. The current lack of a sufficiently developed charging network presents a significant barrier to the widespread adoption of electric vehicles, as it not only limits the convenience of daily use but also raises concerns about long-distance travel, further discouraging potential buyers from considering electric cars as a viable option. As a result, inadequate infrastructure remains a key obstacle in promoting electric vehicles. From the perspective of climate goals, there is a need to expand the charging network to enable the integration of renewable energy sources with power supply for electric vehicles with appropriate energy performance [Dróżdż et al., 2020; Krupa et al., 2018].

At the same time, it is important to remember that charging EVs at home generates a risk of overloading the grid. The authors point to unaware users who start charging when they return home (around 05:30–06:00 pm), which coincides with the evening peak of household energy demand, resulting in increased energy consumption and a strain on the electricity grid. On the other hand, aware users charge their vehicles during off-peak hours (between 10:00 pm and 06:00 am). This "grid-sensitive" behaviour not only avoids an increase in peak demand but also reduces the load on the electrical grid and postpones any unnecessary upgrades to the existing infrastructure [Marmaras et al., 2017].

The range is another crucial factor when choosing an electric car [Adhikari et al, 2020; Capuder et al, 2020; Fasiecka, Marek, 2018; Janczewski, 2017; Krishna, 2021; Łosiewicz, Sendek-Matysiak, 2018], as customers are often concerned about the limited range of electric cars and fear that they will not be able to cover longer distances without having to charge frequently, and therefore increasing the range of electric cars and developing battery technology are key to convincing consumers to switch to electric solutions [Krishna, 2021]. The current range of electric vehicles is limited, and there are relatively few charging stations available. These factors need to be considered when using an electric vehicle, especially if users are accustomed to the widespread availability of fuel stations and the convenience of quick refuelling times [Canizes et al., 2019].

Users commonly experience 'range anxiety', which can be described as the feeling of never having sufficient battery power to reach a destination and being stranded. Consequently, as anxiety increases, the likelihood of resorting to coping strategies (such as driving economically or charging the car more frequently) increases [Franke, Krems, 2013]. Range anxiety decreases with access to supplementary charging infrastructure [Neubauer, Wood, 2014], interaction with other users and improved availability of information, such as live traffic data for estimating travel times [Franke, Krems, 2013; Marmaras et al., 2017] proposed the name user-battery interaction (UBI) to describe the process by which users manage the limited energy resources stored in the battery.

Environmental awareness is also an important factor influencing the choice of buying an electric car [Chen et al., 2020; Fasiecka, Marek, 2018; Singh et al., 2020], as customers who are more committed to the environment may be more inclined to purchase an electric car due to its low or zero emissions. In addition, the need for pro-environmental measures is generating a trend towards increasingly stringent emission standards, making the replacement of internal combustion cars with electric ones inevitable [Janczewski, 2017]. However, consumers are also increasingly taking into account the issue of environmental responsibility and, in line with the current trend, choosing 'green' models, although for them economic criteria are a priority [Hasiuk, Zagajewska, 2011]. However, it is worth noting that there is a different perspective on the environmental aspect, as shown in a study [Śliwka et al., 2015], where economic and safety factors were found to have a greater influence on users' choice of car than the environmental aspect. Similar conclusions can be drawn from the study described in [Więcław, 2022], where it was indicated that the main reasons for purchasing an electric

car are savings and convenience. At the same time, the results showed that there was no statistically significant correlation between the respondents' interest in environmental issues and owning an electric car.

Battery safety in electric vehicles is one of the most fundamental problems identified in the literature [Feng et al., 2018; Liao et al., 2020; Sun et al., 2020; Xu et al., 2020]. Electric vehicles are most often equipped with a lithium-ion battery with high energy density and extended life [Feng et al., 2018]. As an energy storage device, the lithium-ion battery (LIB) can be highly dangerous in circumstances of unreasonable misuse or abuse, with the authors pointing to consequences such as an internal short circuit resulting in a thermal discharge, which is a great risk to the safety of the whole vehicle. Internal short-circuiting is the most frequent trait of all dangers [Feng et al., 2018]. The most typical electric vehicle fires include spontaneous ignition (or self-ignition/auto-ignition) in parked vehicles due to arson or permanent misuse, fire during charging, spontaneous ignition while driving, and fire after a highspeed collision. EV fire is therefore unique and different from cars with traditional propulsions [Sun, 2020]. Incomplete statistics show that there were 40 fire accidents with BEV globally until August 2019, including Tesla models that suddenly caught fire when not in use, which raised serious user concerns about the safety of electric vehicles [Xu et al., 2020].

Battery recycling, which stands in opposition to the pro-environmental approach by consumers, is another EV issue addressed in the literature. Ahuja et al. [2020] found that the likelihood of a circular economy forming on its own in this area is low. Battery recycling poses certain challenges, as it is currently not fully economically viable and remains in the development stage. While existing technologies are still being refined, further research and innovation are needed to improve the efficiency and cost-effectiveness of large-scale recycling processes, with the aim of addressing both environmental and economic considerations [Yu et al., 2022]. The authors suggested that a circular economy of EVs will need to be driven by regulation, and ignoring the problem is a potentially high risk of environmental and health costs. Moreover, this question will rise in the future, as the technology is still new and most EV batteries have not yet reached the end of their first life. However, recycling is not the only option, as second life batteries may be reused, refabricated or resold to effectively improve their sustainability [Liu et al., 2022].

The key determinants influencing the choice of electric vehicle, as identified in the literature, encompass a range of factors, with economic considerations such as purchase price, operational costs and available incentives playing a significant role. Additionally, the availability and accessibility of charging infrastructure are critical in shaping consumer decisions. Vehicle performance factors, including driving range and energy efficiency, are also important considerations, while environmental awareness, particularly concerns about sustainability, and challenges related to battery technology and recycling further influence the adoption of electric vehicles. Research indicates that the various factors influencing the decision to purchase electric cars have highly diverse impacts, with the magnitude and direction of these effects not always clear or predictable [Mandys, 2021]. In order to increase the popularity of electric

cars in Poland, it is necessary to take these factors into account and take measures to remove obstacles and stimulate demand for electric cars. The development of environmental awareness, charging infrastructure and battery technology is crucial for the further development of electromobility.

Methodological assumption

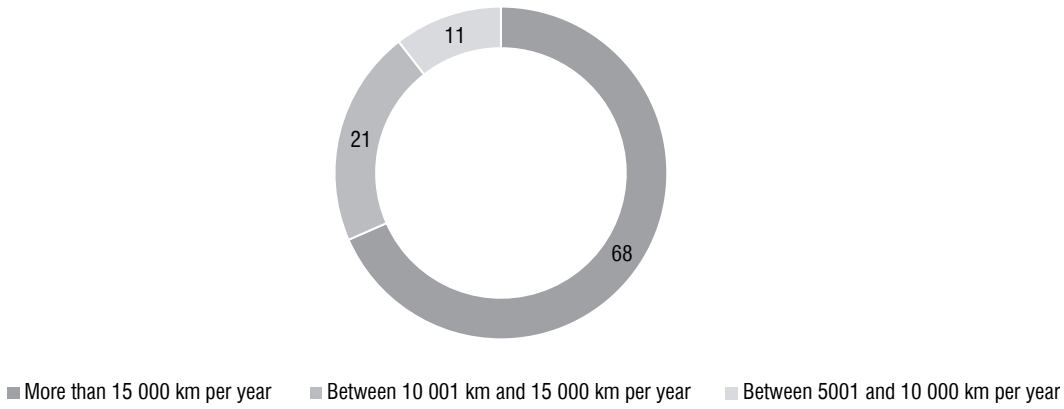
The Authors attempted to measure the perception of disadvantages among BEV users with a survey questionnaire. The breakdown of inconveniences was based on descriptions from the literature and an analysis of other secondary sources (internet forums, articles from the automotive industry). In terms of disadvantages, electric vehicles represent a fundamentally different technology compared to internal combustion engines, which suggests the emergence of new types of threats, primarily related to high electric voltage, battery safety and the complexity of handling and maintaining electric powertrains. The study employed a literature analysis and a survey targeting users and individuals planning to use an electric car. The survey was anonymous, with no possibility of respondent identification, with a non-random sample selected based on convenience, with only users who were accessible and expressed willingness to participate in the study taking part. The survey was conducted using the CAWI technique, with an electronic survey questionnaire completed by 67 respondents, of whom 59 were electric car users and 8 planned to use an electric car in 2023. The survey was conducted with the support of EV Club Polska, which provided access to the questionnaire for its members between 7–12 March 2023. Additionally, a representative of a car brand in Poland offering electric vehicles was asked about his sales experience in a qualitative interview, with the questionnaire structured with a section on the car in use (or planned to be used), the charging method and the number of kilometres driven per year. In turn, respondents were asked to rate on a Likert scale (from 1 to 5) how likely the inconvenient incident is to materialise and how important it would be to them (see Table 1). Descriptive statistics, including measures of central tendency such as the mean and median, were employed to organise, analyse, present and summarise the collected statistical data. These methods facilitated a comprehensive understanding of the distribution and key characteristics of the dataset, allowing for interpretation of trends and patterns. Furthermore, to examine the relationships between variables, the Pearson correlation coefficient was utilised. This statistical measure assesses the strength and direction of the linear relationship between two continuous variables, providing insights into potential associations. Due to the small number of respondents, the group of potential EV users was omitted from the analysis.

Of the respondents who used an electric car during the survey period (n=59), 56% bought an EV outright, while the remainder mainly used solutions such as leasing and long-term rental. The majority (75%) purchased a new vehicle, which is not surprising given the early stage of market development, as used electric cars are not yet as widely available as combustion

cars. Nearly half (46%) of the respondents used both an EV and a car with another type of engine (internal combustion, diesel or hybrid). Most of those surveyed (59%) used EVs for both private and business matters, while 37% of respondents, on the other hand, used EVs for private purposes only. Respondents' experience of electric cars was relatively recent, with the majority driving EVs from 2021 (27%) or 2022 (36%). The survey was conducted in early 2023, but as many as 10% of respondents said they started using EVs in the first two months of 2023. The remainder had started their adventure with electric cars earlier. These results are in line with the growth in the number of electric cars in Poland observed by PSPA in recent years.

The majority of users surveyed drove their car more than 15,000 kilometres per year. The daily distance, according to the authors, is one factor in the total cost ownership of EVs on par with traditionally powered cars. The results suggest how this relationship was perceived in the study group (Figure 1).

Figure 1. Travel distances among EV users (%)



Source: own material.

The majority of respondents were male (79%). Only 10% were women, while the rest did not specify their gender. The largest number of respondents was recorded in the 36–45 and 46–55 age groups (27% and 25% respectively), while in contrast, 15% of respondents fell into the 25–35 age bracket. Considering the cost of purchasing an electric car and the innovation of this solution, the age distribution of respondents seems to be adequate. A relatively large group (17%) did not indicate their age.

In the first instance, users were asked to determine the likelihood of certain inconvenient events occurring related to the ownership and operation of electric vehicles, arising from their differences compared to conventional vehicles. In the second stage, respondents evaluated the severity of potential events resulting from the characteristics of electric vehicles, including the associated costs. In the course of working on the article, knowledge gained from reviewing scientific literature indexed in the largest scientific databases, such as Google Scholar, Scopus and ScienceDirect, was also utilised.

Results

The findings of the primary research suggest that respondents' primary concerns were focused on issues related to vehicle charging and range limitations. The highest rating – on a 5-point Likert scale – was given to the need for an app or card (from the operator of choice) to use the public charger (in terms of the probability of an event occurring: median – 5; mean – 4.3) perceived as significant. At the same time, the need to have multiple solutions is not very important to EV holders (median – 3, mean – 2.9). The discrepancy between the two results indicates a certain market standard in the handling of charging points.

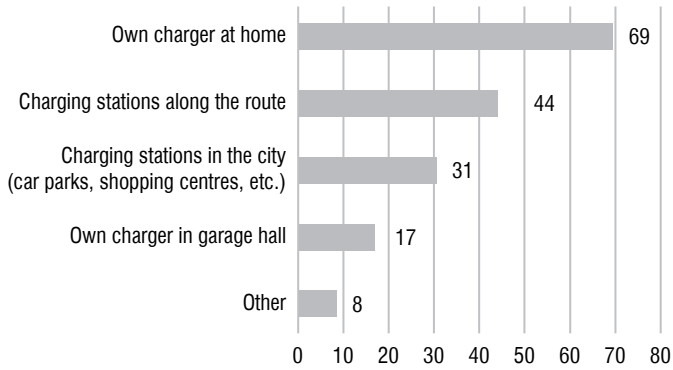
Infrastructure problems were also rated highly: too few fast-charging points (DC) along the route (median – 4, mean – 4.1), too few charging points in the city (median – 4, mean – 3.7). Infrastructure deficiencies in terms of importance were key for users (for urban chargers: median – 4, mean – 3.3; for route chargers: median – 4, mean – 4). Moreover, having one's own charger in the garage and perceiving the number of fast charging points (DC) on the route as too few were also negatively correlated, while similarly, a negative correlation was observed for the variable "Too few charging points in the city". All of this suggests that individuals who charge their vehicles at home are less concerned about the availability of fast charging points both on the road and within city limits, which could be because they feel more secure in their ability to charge conveniently at home, reducing their dependency on public charging infrastructure.

Interestingly, in parallel, the disadvantage of battery drain was rated very low – both on the road (median – 2, mean – 2.6) and in the city (median – 1, mean – 1.7). Also, the significance of this inconvenience was not rated highly, although there was a difference between battery discharge on the road (median – 3, mean – 2.9) and in the city (median – 2, mean – 2.1). The perception of the situation may have been influenced by the charging structure of electric vehicles, with as many as 77% of respondents using their own charger at home or in the garage hall of a block of flats (some respondents declared using both of the above methods) (Figure 2). The issue of charging was also investigated using correlations, with a negative correlation observed between charging the car at home and the perception of the likelihood of a reduction in vehicle range due to extreme temperatures ($r = –0.23$). Similarly, having a home charger was moderately negatively correlated with the perception that charging times are too long ($r = –0.23$), which suggest that individuals who own and use a personal BEV charger perceive challenges related to public charging availability and the need for more frequent charging due to weather conditions as less significant compared to those who rely solely on public charging stations.

The correlation matrix presented in Table 1 indicates that positive correlations also exist between the individual assessments of different risks. In many cases these correlations are also quite strong (above 0.6), which means that respondents who perceive one risk or electric car disadvantages as significant tend to perceive other risks and disadvantages as significant as

well. This suggests that there is a common pattern of risk perception, which may result from general uncertainty associated with BEV usage or a lack of trust in the charging infrastructure. Strong correlations may also suggest that respondents view different risks as interconnected. For example, range limitations due to extreme temperatures may be linked with concerns about long charging times or the availability of fast charging points on the route.

Figure 2. Method of charging an electric car among EV users



Source: own material.

Table 1. Correlation matrix between BEV charging location (at home, both at home and away from home, away from home) and the assessment of individual risks related to BEV charging

Factor	1	2	3	4	5	6	7	8
1: Charging location (at home, both at home and away from home, away from home)	1.00	–0.04	–0.05	–0.23	–0.07	–0.23	–0.18	–0.20
2: Battery depletion on the route	–0.04	1.00	0.68	0.60	0.32	0.48	0.21	0.41
3: Battery depletion in the city	–0.05	0.68	1.00	0.65	0.32	0.45	0.43	0.35
4: Reduced range of the car due to extreme temperature (heat, cold)	–0.23	0.60	0.65	1.00	0.52	0.65	0.45	0.37
5: The need to have an app or a card (from the selected operator) to use the charger	–0.07	0.32	0.32	0.52	1.00	0.52	0.11	0.35
6: Too long battery charging time at the charging point	–0.23	0.48	0.45	0.65	0.52	1.00	0.39	0.50
7: Too few charging points in the city	–0.18	0.21	0.43	0.45	0.11	0.39	1.00	0.74
8: Too few fast-charging points (DC) on the route	–0.20	0.41	0.35	0.37	0.35	0.50	0.74	1.00

Source: own material.

The strongest correlation between "Battery depletion on the route" and "Battery depletion in the city" indicates that respondents perceive the risk of battery depletion as a similar issue, regardless of whether it occurs in the city or on a longer journey. Additionally, the strong correlation between "Too few charging points in the city" and "Too few fast-charging points (DC) on the route" suggests that respondents view charging infrastructure issues as a general concern, not limiting these worries to just one type of location.

The inconvenience of an increase in the cost of using an EV due to rising electricity prices was also reported as highly likely by respondents (median – 4, mean – 3.8), while in terms of materiality, this factor ranked third with a median of 3 and a mean of 3.3. Energy costs affect the total return on investment presented in the theoretical chapter, which is a likely reason for this factor being perceived as significant. Another cost factor investigated was the excessive price of servicing and repairs at service centres due to their small number, although from the users' perspective they proved neither likely (median – 2, mean – 2.1,) nor significant (median – 2, mean – 2.3).

Despite some incidents of spontaneous combustion – as described in the theoretical section – fire safety issues were of little concern to respondents and unlikely in their opinion, as were issues related to battery replacement and recycling. Simultaneously, a dealer's representative declared that customers ask about safety issues related to the use of electric cars, in particular related to the risk of fire or possible failure of the electrical system. However, staff at the dealerships are systematically trained in this area and the importer also organises dedicated training for the Fire Brigade and selected electric car service specialists. In addition, the representative stated that a key aspect regarding customer caution in the use of electric cars is to follow the guidelines that are provided by the manufacturer of the respective model, as well as read the manual in detail, which includes a description of the various warning signs (safety lights) placed in the car. The user manual for a particular electric car model, which comes with new cars, contains instructions on what to do in the case of a fire. The results (medians and averages) can be found in Table 2.

The factors identified by respondents were closer to the concepts of safety and cost-effectiveness than environmental awareness, which is in line with previous research on the Polish market. These findings are significant, as the media narrative and promotional campaigns for electric vehicles predominantly emphasise their environmental benefits.

Table 2. Perceived likelihood and materiality of key disadvantages in electric vehicle ownership and usage

Factor	Likelihood		Materiality	
	Median	Mean	Median	Mean
The need to have an app or a card (from the selected operator) to use the charger	5	4.3	3	2.9
Too few fast-charging points (DC) on the road	4	4.1	4	4.0
The cost of using the car will increase due to the increase in electricity prices	4	3.8	3	3.3
Reduced range of the car due to extreme temperature (heat, cold)	4	3.7	3	2.7
Too few charging points in the city	4	3.7	4	3.3
Decrease in EV prices over the next 3 years	3	3.4	3	3.0
Takes too long to charge the battery at the charging point	3	3.3	3	2.9
EV fire as a result of an accident or collision	3	2.8	3	2.8
Battery drainage on the road	2	2.6	3	2.9
The high cost of recycling batteries after their lifetime	2	2.1	2	2.1

cont. Table 2

Factor	Likelihood		Materiality	
	Median	Mean	Median	Mean
The need to adapt the garage hall for EVs	2	2.1	2	2.3
The need to replace batteries after the warranty period	2	2.1	2	2.4
Too high prices for servicing and repairs due to the small number of car mechanics	2	2.1	2	2.3
Car battery fire due to extreme external conditions	2	2.0	3	2.6
Restrictions on entry or parking for electric cars	2	1.9	2	2.5
Battery drainage in the city	1	1.7	2	2.1

Source: own material.

Summary

With the goal of this article in mind, it is essential to discuss the directions of ongoing changes in key areas of electric vehicle disadvantages. The surveyed respondents identified the insufficient availability of charging stations, both along motorways and in urban areas, as one of the main inconveniences of operating BEVs, which is reflected in the data on the actual state of charging infrastructure development in Poland. It should be noted that from the first measurement by the Polish Alternative Fuels Association (PSPA) in March 2019 to the most recent measurement in September 2023, the number of charging stations increased from 646 to 3,068 points, with a 4.7-fold increase recorded. In September 2023, there were 2 times fewer fast-charging than regular stations (DC – 1,008; AC – 2,060), while in the same period the number of electric vehicles increased from 4,987 to 87,724, of which 51.5% were BEVs (the remainder were PHEVs), showing a 17.6-fold increase in EVs on Polish roads in 4.5 years [PSPA, 2023]. The rate of development of charging infrastructure should be correlated with the increase in the number of electric vehicles in order to limit the loss due to a shortage of charging station users [Dróżdż et al., 2020], suggesting an apparent disparity between EV growth and the expansion of charging infrastructure. On the other hand, the International Council on Clean Transport suggested that even after considering the number of EVs, the overall population and population density, there are no universal indicators that define the optimal amount of charging infrastructure in a city [Hall, Lutsey, 2020].

In the coming years, the development of BEV charging infrastructure is expected to accelerate, partly due to the implementation of the EU AFIR directive. As a result, concerns raised by BEV owners regarding the state of the charging network, identified during the study, should gradually diminish over time. However, it should be emphasised that the vast majority of respondents indicated during the survey that they charge their BEVs using their own chargers at home or in garage halls. From a vehicle owner's point of view this is convenient and economically justifiable, with lower night-time tariffs ensuring that the cost of the journey is very competitive. Another important conclusion drawn from the study is that the use of a personal charger is correlated with a decreased perception of BEV charging infrastructure as

problematic. Specifically, individuals who charge their vehicles at home are less likely to view the availability and accessibility of public charging points as insufficient.

Another major drawback of BEVs, as highlighted by the respondents of this study, is their inconsistent range on a single charge, partly due to changing weather conditions. Low temperatures have been shown to decrease the lifespan and performance of EV batteries [Bupesh Raja et al., 2021]. On the other hand, driving style, weather conditions, infrastructural design, traffic intensity and desired comfort (like using conditioning during travel) can also influence the ability to complete a trip [Donkers et al., 2020]. Moreover, the analysis shows that electric vehicles are more efficient when driving on urban routes than on motorways, as energy conservation tends to favour low-speed routes (such as urban roads), while time saving generally favours high-speed routes (i.e., motorways). Hence, when the amount of EV users is significant, the energy-saving or time-saving choices of EV drivers can considerably influence the allocation of traffic on transport networks. EV users may potentially switch from the shortest route to an energy-saving route, partly due to the visibility of energy consumption for EV drivers [Wu et al., 2015]. In the coming years, as battery technology advances, traction battery capacity is expected to increase, while their unit cost, measured in USD per kWh, is expected to decrease, resulting in the average range of BEVs on a single charge also being likely to improve.

Although in theoretical studies there are considerations regarding the battery – including its ignition – the conditions associated with this were not important to our respondents. As battery technology advances, including the increasing popularity of solid-state batteries, their operational safety will continue to improve.

Given the results of the survey and the business applicability, standardisation of charging systems and related applications could be an interesting research area. An additional area could be charging habits: the literature points to the low cost-effectiveness of investments in charging stations, while the dissatisfaction of EV users with the infrastructure is also evident, which is potentially a major barrier to the development of the concept. There is also some sensitivity to charging prices, which translates into the total operating cost of the EV user. It could therefore be interesting to study the impact of electricity prices on the decision to purchase an EV.

Despite the small sample, the study confirms the difficulties in issues related to charging. An interesting practical problem is solving the situation in which, on the one hand, EV users use their own energy to charge their car, while on the other, they expect access to extensive infrastructure. It is obvious that companies providing such infrastructure focus on profit in their planned investments, hence it is important for them to ensure proper demand for their own services. The situation is made worse by legislative requirements, therefore charging cars using one's own energy sources is a competitive solution. On the other hand, EV users rationally strive to ensure the efficiency of their own investment in an EV, the market price of which is much higher than that of combustion cars. Another interesting empirical problem is the management of vehicle charging applications, where customers recognise the need to install numerous applications, but this is not particularly important to them.

In conclusion, due to the ongoing changes in the legal, economic, technological and social environment surrounding BEVs, it can be expected that in the coming years, the scale of the most significant disadvantages of BEVs identified by respondents in this study will decrease. This pertains to improved access to the charging station network, a reduction in BEV prices, and an increase in driving range per charge, and given the aim of implementing transport policies that promote the adoption of BEVs, it is crucial that electricity prices stabilise in the coming years. Among all the major concerns regarding BEV operation highlighted by respondents, the future trend of electricity pricing remains the most uncertain factor.

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