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THE ASSESSMENT OF THE EXPERIENCES AND IDENTIFICATION OF THE EXPECTATIONS OF ELECTRIC CAR USERS REGARDING THE LOGISTICS INFRASTRUCTURE FOR ELECTROMOBILITY IN THE CITY OF PIŁA

Abstract

Aim: *The article aims to assess the logistics infrastructure for passenger car electromobility in the city of Piła, together with the identification of areas requiring development.*
Methodology: *To find out about the experiences and expectations of electric car users regarding the use of public charging stations available in urban areas, a survey questionnaire was used - a statistically representative sample of 180 respondents.*
Results: *Electric passenger cars are mainly used for short distances - up to 25 kilometres. Car users point out that there are not enough connectors at charging stations, especially the most popular ones - Type 2 and CCS. The next new charging station should be located in a high-traffic area - either a shopping centre or a buffer car park. The following were recommended as priority infrastructure investments for the time being: purchase of new chargers together with adaptation of charging stations and dedicated parking spaces for electric cars.*
Implications and recommendations: *The results of the study are directly relevant for a medium-sized city. However, they are also indirectly useful for smaller as well as larger cities - the possibility of further analyses of similarities and differences within and between agglomerations.*
Originality/value: *The objective formulated in the article and the research methodology used (questionnaire survey) are of a universal nature. According to the proposed research approach, each city can carry out its own assessment of the urban electromobility infrastructure.*

Keywords: *electromobility, vehicle charging stations, user experiences and needs, logistics infrastructure, city transport logistics, survey study*

1. Introduction

The dynamic development of technology and the growing environmental awareness of society are leading to increased interest in electromobility, particularly in urban areas. In the context of global climate change and sustainable development guidelines, cities face the challenge of adapting to new transport standards, including the implementation of infrastructure to support electric vehicles. As one of the key technologies of the future, electromobility is becoming an increasingly important element of global transport and energy policy. Its development has the potential not only to significantly reduce

greenhouse gas emissions, but also to revolutionise our approach to mobility and energy resource management. Addressing the topic of electromobility in the context of transport is therefore not only timely and important from a scientific perspective, but above all from a practical - applied - perspective. In the context of transport, the analysis of electromobility covers a wide range of issues, from technology and infrastructure, to economics and policy, to social and environmental considerations, making it a fascinating research topic.

Scientific literature reveals a wide range of interest in the topic of electromobility, both globally and locally. However, the literature review conducted in the subsequent section of this article indicates that no articles have been identified that address this topic in the context of the city of Piła in Greater Poland. This suggests the existence of a research gap (cognitive objective). The findings of this study will contribute to a more comprehensive understanding of urban electromobility in Poland.

This article aims to evaluate the logistical infrastructure for passenger car electromobility in the city of Piła and identify areas requiring development, particularly in terms of improving access to the examined infrastructure. It forms part of a broader study by the authors, whose results will be published progressively. In this article, several issues are compared to address the following research questions (cognitive aspect):

- Q1: How does the place of residence affect the daily mobility of electric car users?
- Q2: Are the connectors users have in their cars compatible with those on offer at charging stations and is adequate availability ensured?
- Q3: How do the new proposals for charging station locations fit in with the existing preferences of electric car users?
- Q4: What investments, in addition to more electric vehicle charging stations, would be advisable to make users feel more comfortable?

The thematic scope of the article focuses attention on the logistic infrastructure for electromobility - specifically point infrastructure. The subjects of the study were all public charging stations for electric vehicles located in the city of Piła (8 facilities). The subjects of the study were the users of passenger electric cars residing in the city and county of Piła. In the methodological layer,

an author's survey in the form of a questionnaire survey was used. The results of the study are statistically significant - care was taken to ensure the representativeness of the sample of respondents. The article focuses attention on users' experiences of daily use of electric vehicles in the context of availability and convenience of public charging points. It also examines users' preferences and expectations regarding the development of the urban charging network. The study takes into account the variety of charging technologies available on the market and their compatibility with different vehicle models. The outcome of the article will be the identification of challenges with recommendations for the future development of electric car charging infrastructure.

2. Literature Review

2.1. Electromobility – overall

The literature review was conducted in November 2024 using the Scopus database of scientific articles. This database was chosen because Scopus is the largest bibliographic database, aggregating information on peer-reviewed scientific publications. For this reason, it is the platform where researchers most frequently aim to publish their work.

As part of the literature query, 2,672 publications related to electromobility were selected, including 259 from Poland (ranking third among countries). A significant increase in interest in this topic was observed between 2018 (12 sources) and 2021 (65 sources). Following this peak, the number of publications steadily declined, reaching 25 in 2024 (as of November). The dominant thematic fields of these publications are primarily Engineering (29.0%), followed by Energy (19.7%) and Mathematics (14.8%), with additional contributions from Social Sciences (7.5%), Environmental Science (7.1%), and Computer Science (6.8%). Other fields account for 15.1% of the total. The leading institution in electromobility research in Poland is the Silesian University of Technology, with 49 sources. The keyword ranking of the publications includes 160 distinct terms. From the perspective of this article's topic, further narrowing of these keywords is required.

2.2. Electromobility – charging infrastructure

Accordingly, the following keywords were deemed the most relevant (in alphabetical order): charging infrastructure (5 sources)/ charging infrastructures (9); charging point (3); charging station (22)/ charging stations (9); EV charging (4)/ electric car charging (3)/ electric vehicle charging (12)/ vehicle charging (4). This ultimately led to the selection of 46 potential publications.

A qualitative analysis of the literature query provides the following perspective on electromobility infrastructure. The first group of articles focuses on actions aimed at the broader implementation and development of electromobility in cities. The first source presents an analysis of issues and challenges related to electric vehicles both globally and in Poland (Macioszek, 2020). Another source outlines the directions of changes and the concentration level of electromobility in EU countries (Rokicki et al., 2022). The next article highlights the level of electromobility development in Poland in the context of sustainable transport compared to other European countries (Ślusarczyk, 2019). Another publication examines the current state of electromobility in Poland relative to Slovakia, identifying key factors stimulating its growth (Sendek-Matysiak et al., 2020). Further, one source lists national-level actions, comparing Poland and Iran (Ahmadian & Sierpiński, 2021). The final publication discusses the electromobility strategy of the Upper Silesian-Zagłębie Metropolis (Bociąga, 2020).

The next group of articles broadly addresses charging topics. The first source provides an overview of the global EV infrastructure concerning the number of charging stations (Sendek-Matysiak, 2019). Another article discusses the overall development of electromobility, represented by the number of charging stations and growth projections for this infrastructure (Zema et al., 2023). The next publication examines general principles and solutions for ensuring effective charging infrastructure development (Dydkowski & Urbanek, 2021). Another source reviews the progress of electromobility development in Poland, including areas such as charging infrastructure (Sendek-Matysiak & Łosiewicz, 2021). Finally, a publication offers an in-depth understanding and comparison of attitudes towards electromobility infrastructure, comparing Poland and Germany (Tomczyk et al., 2023).

The following group of articles is dedicated to integrating charging infrastructure with urban infrastructure. The first publication explores the potential of utilizing railway power infrastructure (RPI) to charge electric vehicle batteries (Mazur et al., 2024a). Another article discusses the use of traction power systems (trams, trolleybuses, and metro) for charging electric cars, based on an example from Gdynia (Bartłomiejczyk et al., 2022).

The next group of articles focuses on the topic of charging station locations. The first source discusses general strategies for locating charging stations, using parcel delivery providers as an example (Kłos & Sierpiński, 2023). Another source identifies potential locations for EV charging stations based on two European cities with varying levels of electromobility maturity (Sierpiński & Macioszek, 2020). The following source examines the characteristics of EV charging points and stations across Poland (Macioszek & Sierpiński, 2020). Another publication outlines the selection of locations for high-power EV charging stations within the main TEN-T network in Poland (Mazur et al., 2024b). The next article presents a concept for locating EV charging stations in urban areas of the Upper Silesian-Zagłębie Metropolis (Sierpiński, 2020). Another source explores the optimization of charging device locations within urban road networks, using a medium-sized city in southern Poland as an example (Krol & Sierpiński, 2022). The subsequent publication focuses on designing EV charging station networks (EVCS) for personal and commercial vehicles, considering existing station locations, with Poznań as the case study (Schmidt et al., 2021). Another study introduces a method for determining optimal EVCS locations from the perspective of local authorities, which also ensures equal access to charging infrastructure for all residents—using Gliwice as an example (Soczówka et al., 2024). Finally, one source presents a decision-support method to help identify initial charging station locations within a given area, focusing on installations at existing gas stations, with Sosnowiec as a case study (Staniek & Sierpiński, 2020).

The next group of articles are those generally devoted to charging costs. The first source presents a general economic analysis of electric vehicle charging costs (Lewicki et al., 2024). The next source presents a general concept of a model in which, through the use of blockchains, it would be possible to account for the purchase and sale transactions of electricity at the charger

(Zielinska et al., 2019). The last source presents a comparative analysis of the costs associated with the use of electric vehicles when charging this type of car for the Polish market (Wiśniowski & Gis, 2020).

The subject of interest in the last group of articles is legal. The first source presents the totality of legal regulations in force in Poland concerning electromobility infrastructure and vehicles (Klimach & Figurska, 2022). The next source presents an overview of the requirements and procedures for the construction and launch of electric vehicle charging stations under Polish legislation (Kaluza & Sierpinski, 2019). The last source presents the issues of changes in design and operation that would have to take place, in the case of replacing internal combustion vehicles with electric ones - using the example of Wrocław (Kaznowski & Sztafrowski, 2021).

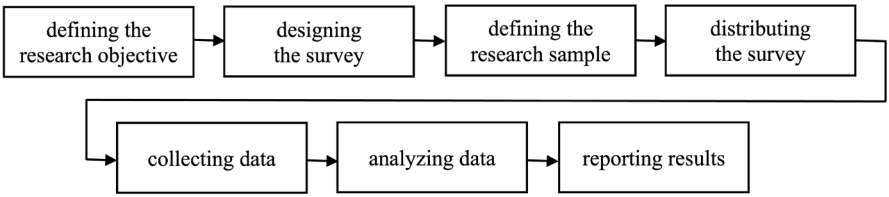
Of the 46 potential publications, 28 sources turned out to be substantively valuable for the topic of this article. The sources rejected during the qualitative analysis were related to: the quality of energy during charging, charging control algorithms, electromagnetic compatibility of vehicles and charging stations, integration of vehicles with energy infrastructure, electricity demand, operation of energy distribution networks, energy balance, use of photovoltaic cells for charging, and demand for electric vehicles.

Summing up the literature review, although articles on electromobility were identified, concerning Poland in general and selectively certain agglomerations and cities within it, no article on electromobility dedicated strictly to the city of Piła was found. It can therefore be assumed that there is a research gap (cognitive purpose). In the context of the literature search, the applied research approach (the next two sections) - the perspective of needs and expectations of electric passenger car users - should also be assessed as interesting. The implementation of the research part of this article will complete the picture of urban electromobility in Poland.

3. Methodology

In order to learn the opinions of respondents, it was decided to use the popularly used survey method in this regard. Process of the research consists of the following sequence of stages - Figure 1.

Figure 1. *Research process diagram*



Source: own study.

The objective of this study was to conduct a comprehensive assessment of the logistics infrastructure for electric passenger vehicles in the city of Piła, along with identifying areas requiring development, i.e., improving accessibility to the infrastructure under investigation. The subject of the study was public municipal charging stations for electric vehicles located within the city of Piła. The research instrument was a survey questionnaire. It was divided into 3 sections: an introduction to the study, questions about the respondents' metrics (3 characteristics), and the actual research questions (21 issues). Due to the need for unambiguous and transparent responses, the formulations in the survey questionnaire are in the form of closed-ended single-choice questions. The research subjects were users of electric passenger cars residing in the city and district of Piła. Based on the number of registered electric passenger cars (County Vehicle Register), the study population comprises 1859 respondents. Assuming a significance level of 5% (which ensures 95% certainty that the results obtained from the sample will be consistent with reality) and an allowable estimation error of 7% (which means the maximum acceptable margin of error in the survey results), the sample size, i.e., the minimum number of surveys that needed to be conducted, is 178. Although 5% or 10% is standard practice, the accepted 7% is the smallest

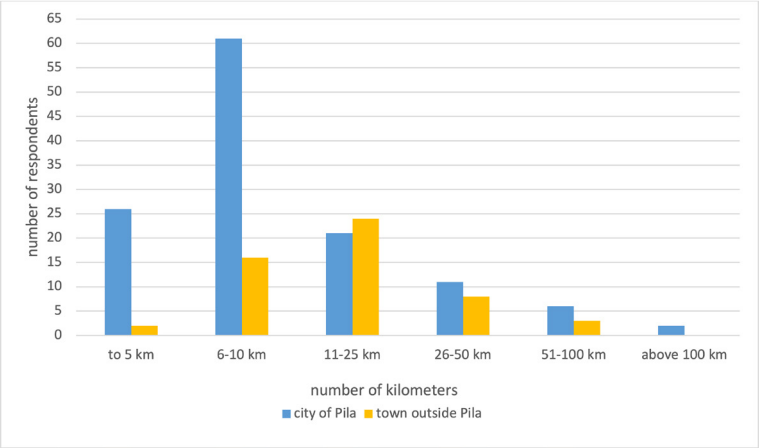
possible error that allows the statistical representativeness of the survey results to be maintained - there was no desire to increase the level of significance, and it was not possible to extend the survey (data collection). In reality, 180 correctly completed surveys were collected, which meets the requirements for the representativeness of the study. To collect data from various groups of respondents, the survey questionnaire was distributed through multiple channels (electronically and conventionally) - by making it available online (Google form) on social media, by making it available in the form of a QR code placed at electric vehicle charging stations, or during a direct survey action during parallel field research. The survey was conducted for 3 months - the second quarter of 2024. The data was collected and then analyzed in-house in an MS Excel spreadsheet. The reporting of results will be presented separately - as the next section of this article.

4. Results

This article presents a comparative analysis of selected questions from the survey, between which significant relationships were observed. Individual question results indicate that responses to some of them may be related to the results of others, which can provide valuable information about the research problem - as a complement to the overall picture. This will enable more comprehensive and precise inferences.

The first two questions compared relate to the respondents' place of residence and the number of kilometers traveled per day. The analysis of these two variables is crucial because it can reveal how the place of residence affects the daily mobility of respondents. The results of this comparison are presented in Figure 2, which illustrates the relationship between the location of residence and the number of kilometers traveled each day by the respondents. This allows us to observe whether people living in different types of locations (in the city or in areas outside of Piła) differ in terms of their mobility, which may be significant for transportation planning.

Figure 2. *Comparison of respondents' place of residence with the number of kilometers traveled during the day*



Source: own study.

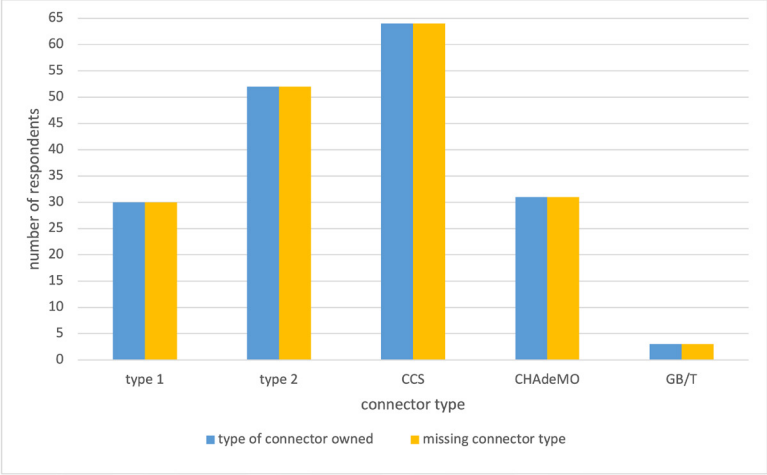
Residents of Piła, compared to those living outside Piła, generally cover more short and medium distances (up to 10 km) during the day. In contrast, those living outside Piła cover more medium and long distances (6-25 km), which may be due to the need to commute to work, school or other daily duties. This distribution suggests that people living in Piła have easier access to infrastructure at shorter distances, while those living outside the city have to cover longer distances, which may affect their mobility and daily transport habits.

The next set of questions in the survey focused on issues related to infrastructure for electric cars. Respondents were asked about the sockets they had in their electric vehicles and their opinion on the missing connectors at charging stations in the city of Piła. A comparison of the answers to these two questions is presented in Figure 3. Analysis of this data allows us to understand what types of sockets are most common in users' electric cars and how these needs correlate with the availability of appropriate connectors at city charging stations.

Respondents clearly indicate that there is a lack of connectors at charging stations corresponding to the sockets they have in electric cars. In each case, the number of answers to the question about missing connectors is

equal to the number of answers to the question about the sockets they have. The largest gaps concern Type 2 and CCS connectors, which may result from their popularity among electric car users. A smaller, but still significant part of the missing connectors concerns the CHAdeMO and Type 1 types, which may result from the smaller number of users of these standards, but still indicates the need to supplement the infrastructure.

Figure 3. *Comparison of the types of sockets owned by respondents with the missing connectors at charging stations in Piła*



Source: own study.

The list also includes questions about the preferred locations where respondents would like to charge their cars versus five potential locations for new charging stations. These five new proposals are the locations most frequently indicated by electric car users (free choice), which were mentioned in a field survey conducted in parallel with the questionnaire survey. In the opinion of the authors of the article, these are good suggestions. Due to the structure of the questions, a comparison of the answers to these two questions is presented in Table 1. A comparison of the preferred locations for charging electric cars with the proposals for new places for charging stations allows for an assessment of the compliance between user needs and the plans for the development of the charging infrastructure. This analysis can provide

valuable information that will help in the rational arrangement of new stations, increasing their usability and accessibility for the residents of Piła.

Table 1. *Comparison of respondents' preferred locations for charging electric vehicles with potential locations for new charging stations*

	home	workplace	car park at the station PKS / PKP	shopping malls	underground car parks	city parks	offices	TOTAL
shopping centre estate Górne	44	18	0	28	0	0	0	**90**
car park at the Island Municipal Park (Skateplaza)	25	23	0	5	1	3	0	**57**
area of os. Koszyce by the bus stop Wałecka / Podleśna	0	1	0	0	0	0	0	**1**
parking within the ROD Przemysłówka / Wypoczynek / Nafta	7	4	0	0	0	0	0	**11**
bus terminal Lotnicza / Chorwacka	12	7	2	0	0	0	0	**21**
TOTAL	**88**	**53**	**2**	**33**	**1**	**3**	**0**	**180**

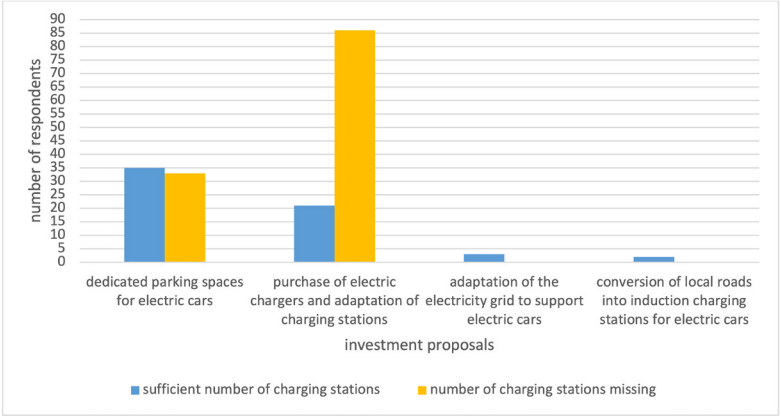
Source: own study

The Górne housing estate shopping center is clearly the preferred location for charging, both for those who want to charge their vehicles at work and for those who prefer to charge while shopping at malls. The high number of selections suggests that placing a charging station at this location would be very effective. The parking lot by the City Park on the island (Skateplaza) is also a popular location, especially for people who want to charge their cars near their home or workplace. The Koszyce estate area near the Wałecka/ Podleśna bus stop received very few indications, suggesting that it is not a preferred location for most respondents. The parking lot within the ROD Przemysłówka/ Wypoczynek/ Nafta area is moderately popular, with a greater emphasis on charging near home - the number of selections

is significantly lower compared to other locations. The Lotnicza/ Chorwacka bus loop is preferred primarily as a location for charging near home and work, although the number of selections is not very high.

The final set of questions, presented in Figure 4, shows the relationship between respondents' opinions on the number of electric vehicle charging stations in Piła and the proposed investments that could be implemented in the city. This analysis allows for a deeper understanding of how residents assess the current charging infrastructure and what investments they consider crucial for the city's future development. In this way, it is possible to find out whether there is a demand for an increase in the number of charging stations, or whether residents see other areas that require immediate improvement. The results of this analysis can serve as a valuable insight for decision-makers and investors, helping them focus on the most important issues for the community, which will contribute to the sustainable development of Piła and improve the quality of life of its residents.

Figure 4. *Comparison of respondents' opinions on the number of electric vehicle charging stations with proposed investments in Piła*



Source: own study.

Respondents who indicated the lack of charging stations were mainly in favor of purchasing new chargers and adapting charging stations. This indicates that the priority for this group is to increase the availability of charging

points in the city. In turn, respondents who believe that the number of charging stations is sufficient most often chose the option of dedicated parking spaces for electric cars. This suggests that additional parking facilities are more important for this group than the development of the charging infrastructure itself. Few indicated the remaining two options, which are: adapting the power grid to support electric cars and transforming local roads into inductive chargers for electric cars.

5. Discussion and Conclusions

Nowadays, in an era guided by sustainable development guidelines, environmental protection requirements and ecological paradigms, addressing the issue of electromobility is topical and important, both for individual and institutional stakeholders, not only because of the widespread fashion for eco-behaviour, but also because of a certain legislative compulsion (to achieve the required reference indicators).

The aim of this article was to assess the logistics infrastructure for passenger car electromobility in the city of Piła, together with the identification of areas in need of development, in particular the improvement of accessibility to the infrastructure under study. Electric passenger cars are mainly used for short distances - up to 25 kilometres (Q1). Car users point out the lack of a sufficient number of connectors at charging stations, especially the most popular ones - Type 2 and CCS (Q2). The next new charging station should be located in a high-traffic area - either a shopping centre or a buffer car park (Q3). The following were recommended as priority infrastructure investments for the time being: purchase of new chargers together with adaptation of charging stations and dedicated parking spaces for electric cars (Q4). The results obtained are mostly in line with studies by other authors.

The results of this study are directly relevant for the medium-sized city of Piła (a potential limitation). However, they are also indirectly relevant for smaller as well as larger cities. Within the directions of further research, there is the possibility of further analyses of similarities and differences both within cities (individually) and between agglomerations (comparatively).

The objective formulated in the article and the research methodology used (questionnaire survey) are universal in nature. According to the proposed research approach, each city can carry out its own assessment of the urban electromobility infrastructure. This can be taken as a reference for the development of a comprehensive report on urban electromobility infrastructure in a given city or region.

In summary, the article provides an in-depth quantitative and qualitative analysis of the specific research problem. The results obtained are highly utilitarian in nature, with great application potential. The methodological approach proposed in the paper is possible to implement in any city.

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