PREDISPOSITIONS TO THE DEVELOPMENT OF ELECTROMOBILITY IN SELECTED CITIES IN POLAND

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Abstract: Without a doubt, the issue of electromobility is as important as it is complex. All the more so because, on the one hand, there are limitations and obstacles to its development on many levels, and on the other hand, especially in the current political and economic situation in the national and international arena, this solution has a huge potential to alleviate the effects of the crisis. The complexity of the issue of electromobility entails the need to look for new, supporting solutions and research, such as the multidimensional comparative analysis method carried out in this work, which, based on the results of expert research, allowed to determine indicators that influence the development of electromobility strategies in cities.

Keywords: electromobility strategy, sustainable development, Hellwig's method

JEL classification: C15, Q56, R41

INTRODUCTION

The development of electromobility in Poland is increasingly accelerating, which is reflected in the growing sales of electric vehicles. According to data from the end of December 2021, a total of 39,658 passenger and commercial cars with electric drive were registered in Poland. In 2021, the electric cars park more than doubled (by 101% y/y). The upward trend also continues in 2022: at the end of the second quarter, the fleet of electric cars had grown to 50,990 units - 45% more than in the same period in 2021 [Morgan 2022].

A quantitative summary of the electric car market in Poland in 2019-2022 is shown in Figure 1.

Figure 1. Number of electric cars in Poland in years 2019 – 2022
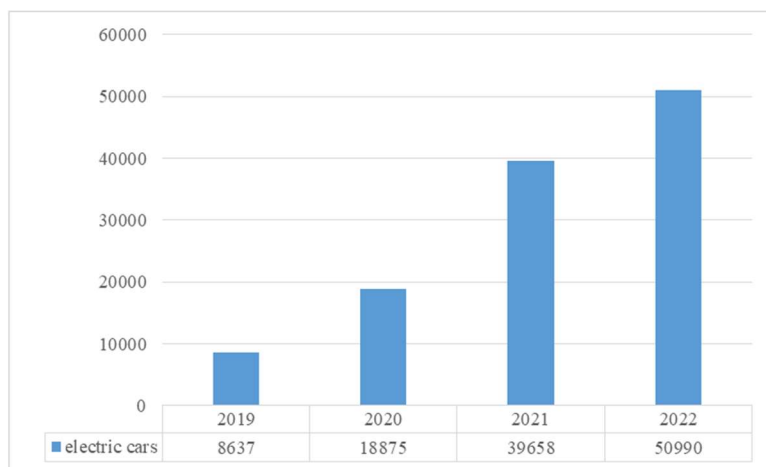
Source: own research based on [ACEA 2023]

The condition for further development of the fleet of electric cars is the expansion of the charging infrastructure. As of the end of 2021, there were 1,932 publicly available electric

vehicle charging stations in Poland (3,784 points). 30% of them were direct current (DC) fast charging stations, and 70% - slow alternating current (AC) chargers with a power of less than or equal to 22 kW [International Renewable Energy Agency 2022].

The year 2022 was another year in a row full of challenges. War in Ukraine, disruptions to global supply chains, rising prices of key raw materials, galloping inflation and the risk of a return of the COVID-19 pandemic. Limited supply in the automotive sector caused by, among others, shortage of semiconductors or the COVID-19 pandemic did not stop the very dynamic development of electromobility in 2022.

Many markets saw a record number of registrations of electric cars with significant declines in sales of combustion vehicles. In 2022, the number of registered electric passenger cars in the European Union countries was approximately 3.2 million and in the world 10.5 million [IEA 2022]. Zero-emission transport has been recognized by the EU institutions as one of the priorities as part of the economic recovery after the COVID-19 pandemic.

As a result, electromobility on the European market is developing very dynamically, and in these specific conditions, electromobility in Poland is developing unexpectedly well.

The aim of the article is to analyze the predispositions of cities in Poland to develop electromobility. The research includes the analysis of predispositions using the method of multidimensional comparative analysis, based on the results of our own expert research.

The article contains an introduction, a review of the literature, a discussion of research methods and results, as well as a discussion and conclusions. Detailed results are presented for electric cars in selected cities in Poland.

LITERATURE REVIEW

In accordance with the nomenclature presented in literature, it is postulated that one of the possible measures of the level of electromobility is the number of electric and hybrid cars registered in a given area. Authors [Bartłomiejczyk, Kołacz 2020], [Połom 2021] and [Fernández 2021] note that the introduction of electric cars is the main sign of the development of electromobility and sustainable transport in cities.

Authors [Habib, et al. 2020] and [Kimbrell 2021] write about the electrification of the transport sector as a determinant for reducing direct greenhouse gas emissions and the burden of fossil fuels. Authors [Benveniste et al. 2018] and [Frenzel et al. 2011] point out that the share in the market of electric and hybrid vehicles is growing with the development of electromobility. The experience of other countries, such as Norway and France, with the implementation of electromobility, understood as a high rate of registered electric vehicles, is described by [Holden et al. 2020].

The electromobility strategy should therefore be understood as creating conditions for the development of electromobility in cities, through the adaptation of existing infrastructure and other adjustment activities aimed at improving its functioning and developing the market for low-emission vehicles in private and public transport. It is expected that as a result of the implementation of the electromobility, there will be a partial reduction in the emissions of harmful substances and noise generated by communication in cities. In the long run, this will improve the quality of life, including the health of residents and the natural environment.

The literature review and considerations made it possible to clarify the scope of the empirical study. Therefore, the electromobility examined in this work concerns the market of low-

emission cars (electric and hybrid). The study omitted low-emission buses and elements of micromobility in cities, such as public bicycles, scooters and scooters, which will be subject to further research.

DATA AND METHODS

Methods of multidimensional comparative analysis enable comprehensive research on various complex phenomena, thus creating the possibility of a broad and objective view of these phenomena. In Poland, Hellwig [Hellwig 1968] made the first attempt to describe complex phenomena using a synthetic feature. An important issue when building a ranking due to the level of complexity of the phenomenon is the choice of ordering method.

At the beginning of the analysis, the nature of each variable taken into account should be determined. It is necessary to determine whether "large" values of a variable have a beneficial impact on the examined issues (such variables are called stimulants) or whether small values favor development (then such a variable is a destimulant.

A description of the properties of methods and more important normalization formulas was provided by, among others authors [Borys 1978, Grabiński 1984 and Abrahamowicz 1985]. The latter work suggests that the choice of normalization formula should be combined with the choice of aggregation formula.

Analyzes presented in the literature show that the best formal properties have: the classic standardization method and the unitarization method, in which the distance of a given value from the observed "worst" value is divided by the range. This second method also satisfies the non-negativity condition postulated by some authors. Normalization follows the formulas:

For stimulant:

$$x'ij = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}}, \tag{1}$$

For destimulant:

$$x'ij = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}}, \tag{2}$$

where:
- i - object number
- j – feature number
- $\max\{x_{ij}\}$ and $\min\{x_{ij}\}$ we are looking for a given feature in a set of objects.

In particular, in linear ordering methods based on a synthetic variable, an important step is the standardization of diagnostic features and the method of constructing the synthetic variable.

In the article, it was decided to use an aggregate measure, which provides for the calculation of the arithmetic mean of diagnostic variables, which were made comparable through unitarization, and expressing this mean on a point scale in the range <0;100>.

Therefore, the formula for the aggregate measure takes the form:

$$W_i = \frac{100}{m} \sum_{j=1}^{m} \alpha_i \cdot x'_{ij}. \tag{3}$$

where:
- m- number of features (criteria) taken into account
- α_i – weight of the i-th feature (criterion)

The reasons why in this article it was decided to use the previously presented procedure for obtaining an aggregate measure using the linear ordering method:

- unitarization in the postulated form and averaging using the arithmetic mean are methods to which there are no formal reservations,
- they meet a number of detailed conditions for synthetic measures [Abrahamowicz 1985],
- the weights obtained by experts (on a scale of 1-5) regarding the impact of a given criterion were averaged,
- the proposed measure combines the features of a non-standard and standard measure. Averaging normalized values is an approach typical of patternless procedures. On the other hand, the adopted method of normalization and aggregation is to calculate the urban distance from the "anti-pattern", averaged over one feature,
- the superiority of the recommended measure over the most popular Hellwig measure in Polish literature [Hellwig 1968] results from the fact that the postulated indicator is strictly normalized in the range <0;100>, while the Hellwig measure can assume negative values.

RESULTS

An ordered set of sustainable urban mobility indicators that have been identified by experts in the field of electromobility as having the greatest impact on the number of electric cars, along with information on whether it is a stimulant or destimulant and the average weight obtained from the experts, are presented in table 1.

From the Arthur D. Little Urban Mobility Index 3.0 indicator database [Little 2018], experts in the field of electromobility, both practitioners - car manufacturers, city authorities, electricity distributors in Poland, and theoreticians publishing in the field of electromobility - were asked to have a broad view of the examined problem. The experts task was to

indicate the variables that, in their opinion, have a significant impact on the possibility of developing electromobility, i.e. the predispositions of cities to its development. 15 experts responded, the results are presented in the table 1.

Table 1. Determining the weights and nature of selected indicators

Indicator	Stimulant	Distimulant	Weight
Monthly salary per inhabitant	x		5
Number of charging stations in relation to the city area	x		5
Diesel price	x		3
Average annual value of PM2.5 concentration	x		3
Energy price per inhabitant		x	4
Dedicated bus lane in km in relation to the city area	x		5

Source: own research

Analyzing Table 1, it can be seen that one of indicators was adopted as destimulatory - desired values in a decreasing direction, and the remaining five as stimulants. Determining the nature of the variables and the average rating given by the experts was used to conduct further analyses. The set of indicators obtained in the expert study became the basis for determining the rankings of the examined cities in the analyzed time period using the linear ordering method.

The prepared rankings concern the predispositions for the development of electromobility in individual cities due to the number of low-emission cars in use over the years 2017-2021. The positioning results are presented in Figures 2 - 6.

Taking into account all the separate indicators of sustainable urban mobility for the development of the low-

emission car transport subsystem, in 2017 the highest measures are taken by the largest cities in Poland, i.e., Warsaw, Wrocław, Kraków, and vice versa, the lowest can be observed for those with the smallest ones.

Figure 2. Predispositions for the development of electromobility in selected cities in Poland – results for 2017
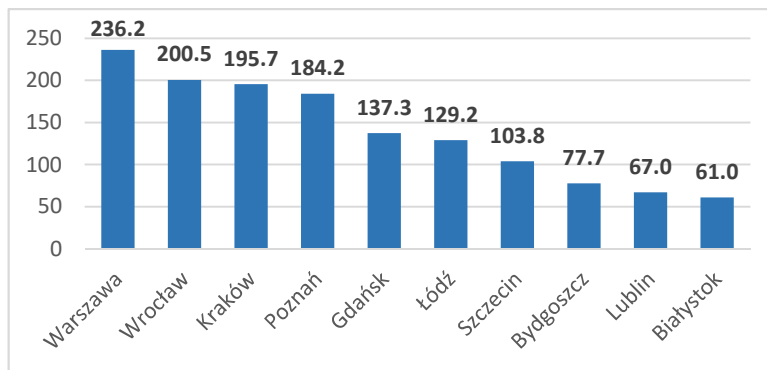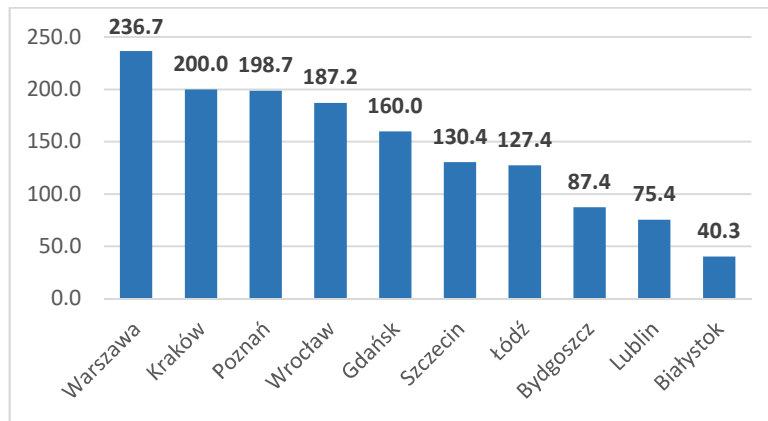

Source: own research

Figure 3. Predispositions for the development of electromobility in selected cities in Poland – results for 2018
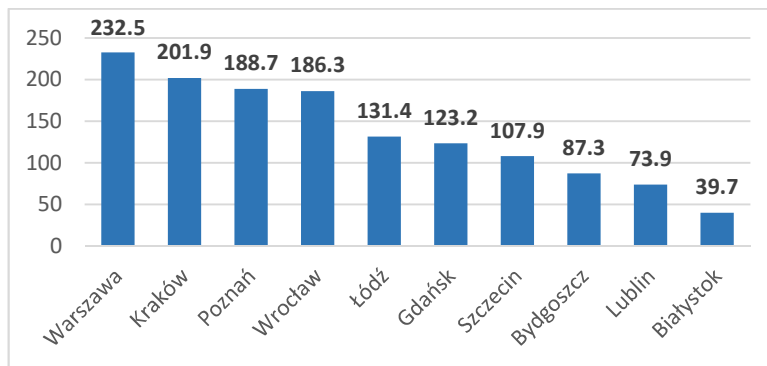
Source: own research

In 2018, behind Warsaw, which takes first place every year, we can see growing conditions for the development of electromobility strategies in Krakow and Poznań, which may result from the growing awareness of its positive impact among both city authorities and residents.
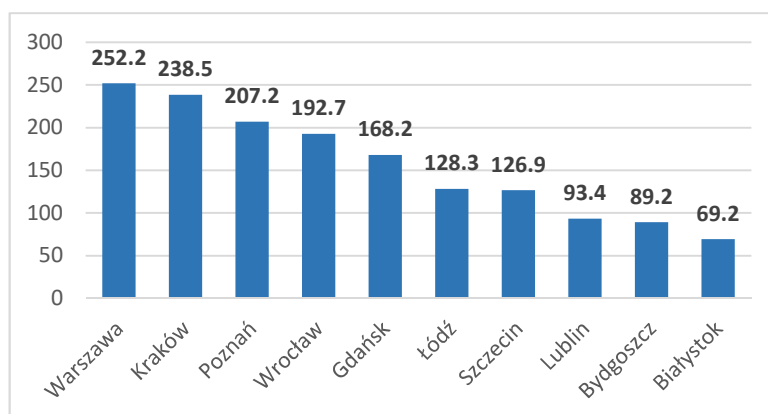
Figure 4. Predispositions for the development of electromobility in selected cities in Poland – results for 2019

Source: own research

The same trend for the surveyed cities continued in 2019.

Figure 5. Predispositions for the development of electromobility in selected cities in Poland – results for 2020
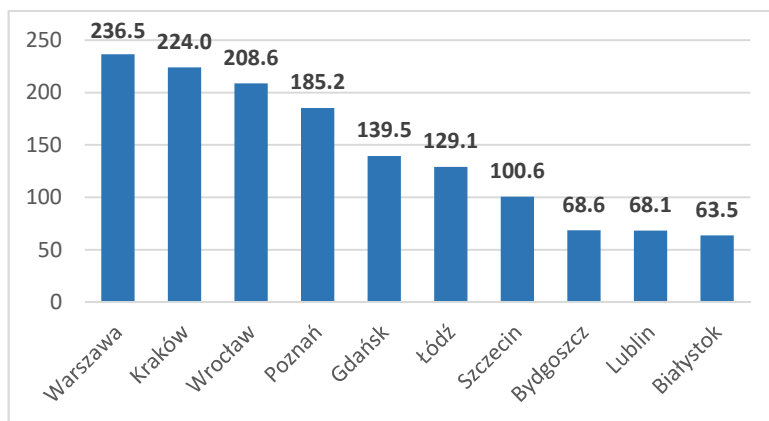

Source: own research

The year 2020 was marked by the fight against the COVID-19 pandemic, which not only significantly hampered the everyday life of city residents and limited access to a number of services. On the one hand, there was a decline in income with a simultaneous increase in expenses, including: provision of public services, expenditure on health care or education. The pandemic also changed residents perception of urban space.

Functioning in an environment full of restrictions related to COVID-19: restrictions on the operation of educational institutions, cultural institutions and services as well as the change to remote working in many enterprises had an impact on the change in the lifestyle and activity of residents in urban space. Access to green areas turned out to be important from the point of view of residents' health, and travel difficulties meant that public spaces were perceived as places that should be attractive and encourage people to spend free time and relax. Residents of large cities began to attach more importance to the

environment in which they live. It has been noticed that low-emission transport can impact comfort and improve the quality of life.

Analyzing the results obtained for the last analyzed year, it is possible to confirm the correlation between the city size and the predisposition to develop an electromobility, which may result from many aspects. In urban agglomerations, the occurrence of increased concentrations of pollution related to transport has been observed for many years. An opportunity to improve the situation is created, among others, by the development of the low-emission vehicle market, and the awareness of residents is increasing in this respect.

Figure 6. Predispositions for the development of electromobility in selected cities in Poland – results for 2021

Source: own research

The development of the electromobility is also closely related to the availability of charging points for electric cars and encouraging solutions, such as a dedicated bus lane on which electric cars can move without any obstacles, and in the largest cities there is the largest number of them. A higher

monthly salary may influence the purchase of more low-emission cars, the price of which is still higher than a combustion car, which in the case of cities with lower wages may constitute a significant barrier to development.

CONCLUSIONS

Undoubtedly, the subject of electromobility is extremely interesting in terms of the potential for scientific exploration and practical implementation. At the same time, it is a very complex, current and multidimensional issue. The proenvironmental approach to city management redefines the traditional approach, forcing the implementation and support of solutions that reduce external costs, especially carbon dioxide emissions. The concept of electromobility seems to be such a solution. It should be noted that the environmental factor should become an important variable supporting the development of the electromobility market in cities in Poland, like in the global trends.

Comparing the ranking results is not only an instrument for measuring progress in Polish cities efforts to develop electromobility, but also allows for assessing the progress of implementing investments, activities and goals over time. The ranking may therefore become a helpful tool in determining the goals of further development of cities electromobility. An indicator providing analytical and synthetic information about the position of a specific city compared to other cities in terms of predispositions to the development of electromobility, can support and inspire changes in the way the city is managed in accordance with the principles of sustainable development.

What is new and a contribution to the development of the discipline is the use experts answers in the development of electromobility and the assessment of cities in Poland in the implementation of their development. The originality of the

considerations and their novelty lies in the use of expert knowledge to assess the predispositions of cities to the development of electromobility. Until now, issues have not been presented in this way. Identifying predispositions can have practical implications, particularly in a governance context, providing guidance particularly for local authorities. Understanding the factors of electromobility development according to their stimulants and destimulants may constitute the basis for further future activities and their extension to other areas related to transport. The main limitation of the study is that only individual motorization was taken into account. This approach results from the fact that this is a preliminary study examining the predispositions of individual electromobility in cities and the destimulant and stimulant indications were indicated as the first step in the study. This is a major limitation, but subsequent research and research considerations will include further types of transport and considerations to show a holistic view of the subject.

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