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Comparative Analysis of the Development of Electromobility Strategies in Selected Cities in Poland

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Agnieszka Pokorska[1]

Abstract:

Purpose: *The aim of the article is to assess the level of development of electromobility strategies in selected cities in Poland based on the results obtained from the expert method.*
Design/Methodology/Approach: *The article uses the method of multidimensional comparative analysis, which, based on the results of expert method research, allowed for the assessment of cities in Poland in terms of the development of electromobility strategies, understood in the work as the number of low-emission cars, i.e. electric and hybrid.*
Findings: *Despite the turbulence in the international environment, the electric car market is constantly developing. The article contains ranking information regarding the predispositions of cities to achieve sustainable mobility in terms of implementing electromobility strategies, along with descriptions indicating the determinants of a given position.*
Practical Implications: *The analysis carried out can provide cities and their local authorities with a ready-made solution supporting the development of electromobility strategies in the form of a key set of indicators for sustainable urban mobility along with the desired direction of their development. In addition, the article contains ranking information on the management of sustainable urban mobility in the aspect of implementing electromobility strategies in the largest Polish cities, along with an analysis of the reasons for taking a specific place in the ranking, which may influence the change of electromobility strategies in these cities.*
Originality/Value: *Taking into account the current stage of development of electromobility in Poland, attention should be paid to the lack of comprehensive analyzes of the impact of the phenomenon in question on this area.*

Keywords: *Electromobility strategy, sustainable development.*

JEL codes: *C15, Q56, R41.*
Paper type: *Research article.*

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[1]*Ph. D., University of Szczecin, Faculty of Economics, Finance and Management, Szczecin, Poland, agnieszka.pokorska@usz.edu.pl;*

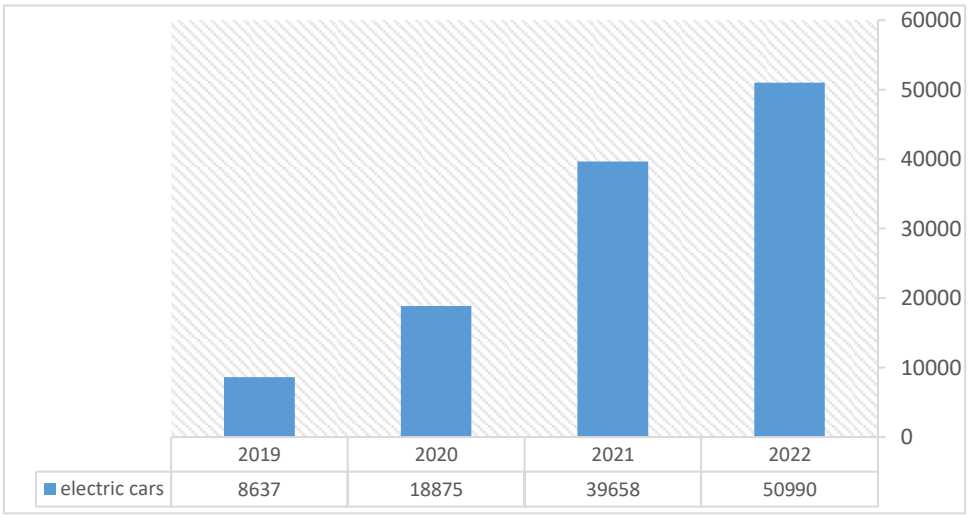
1. Introduction

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 EV 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. At the end of December 2021, a total of 11 cars were registered in Poland 091 micromobility vehicles, and at the end of the second quarter of 2022 their number increased to 14,962.

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.*

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.

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 newly registered electric cars was 6.6 million. 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 ocena stopnia zaangażowania wybranych miast w Polsce w rozwój strategii elektromobilności w latach 2017-2021. An answer was sought as to whether, despite the challenges facing electromobility, it is developing in cities.

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.

2. Literature Review

In accordance with the nomenclature presented in foreign 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. 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.

Habib, Hansdóttir, and Habib (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. Benveniste, Rallo, Canals, Merino, and Amante (2018) and Frenzel, Kurzweil, Rönnebeck (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, Banister, Gilpin, Gössling, and Linnerud (2020). The topic of emerging economies, where electromobility is constantly developing, is discussed by Xue and Gwee (2017) and Marino and Marufuzzaman (2020).

Both publications indicate that Singapore and Latin America are starting to become places where electric cars and bicycles are the first choice for commuting to work.

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.

Moreover, electromobility should be understood as coherent infrastructure that will facilitate the easier movement of low-emission vehicles, convenient transport connections and related improvements (bicycle paths, parking spaces, stops, bus lanes). The aim of the strategy is to reduce the negative impact of transport on the environment, improve travel comfort within the city, which is associated with protecting the health of residents and improving the quality of life.

It is expected that as a result of the implementation of the strategy, 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 strategy 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.

3. 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 (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.

The task of linear ordering of a set of objects is to rank, i.e. determine the order of objects or their sets according to a specific criterion. These methods can therefore be used when it is possible to adopt a certain criterion based on which it will be possible to arrange objects according to some ranking. The linear ordering tool is a certain function that aggregates partial information contained in individual variables, designated for each object.

Carrying out linear ordering requires the following assumptions:

- there is at least a two-element and finite set of objects,

- there is a finite set of variables substantively related to a given criterion,
- these variables are preferential, i.e. they include nominants, destimulants and stimulants,
- variables used to describe objects are measured at least on an ordinal scale.

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, 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:

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

For destimulant:

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

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:

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

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 - i.e. the procedure appropriate for reference methods,
- 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 (in its classic form with double standard deviation) can assume negative values.

4. 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 cars and 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.

Analyzing Table 1, it can be seen that 1 item of indicators was adopted as

destimulatory - desired values in a decreasing direction, and the remaining 5 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.

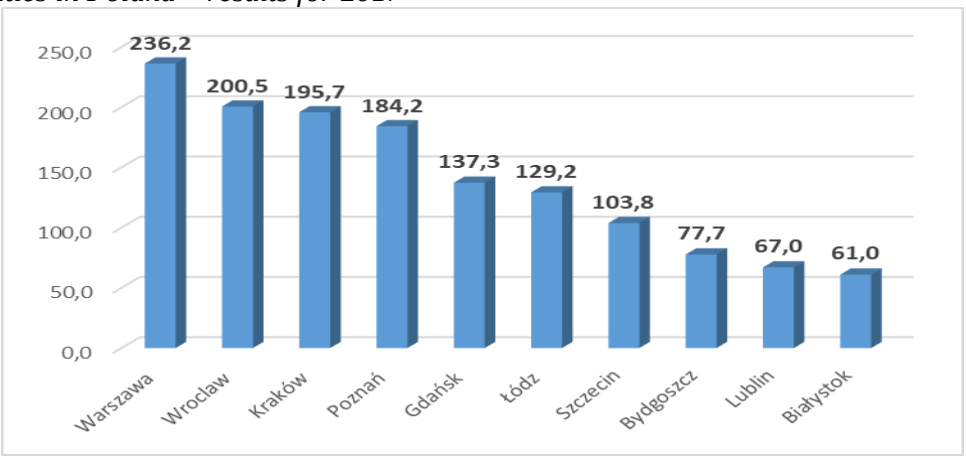
Table 1. *Determining the weights and nature of selected indicators*

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.*

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.

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

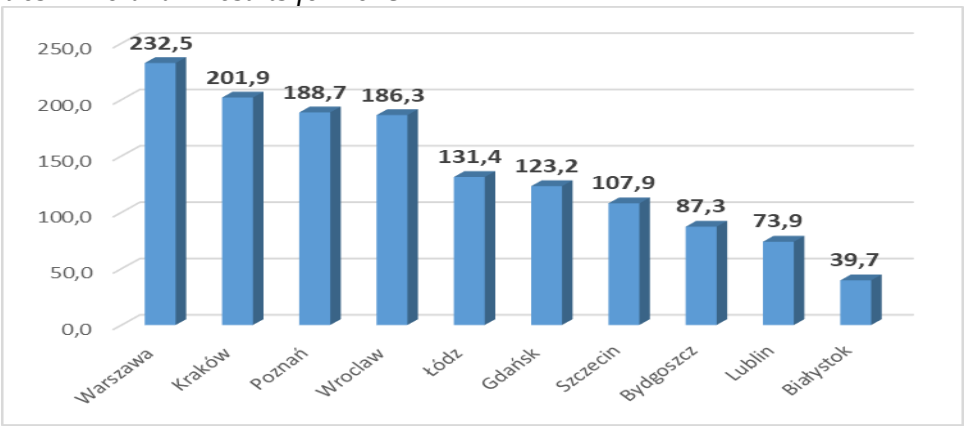


Source: *Own research.*

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.

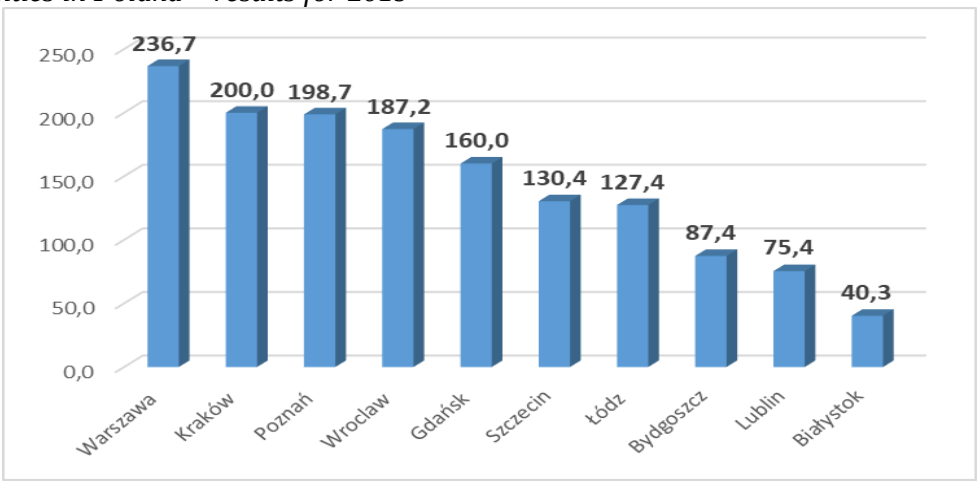
Figure 3. *Predispositions for the development of electromobility in selected cities in Poland – results for 2018*



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.

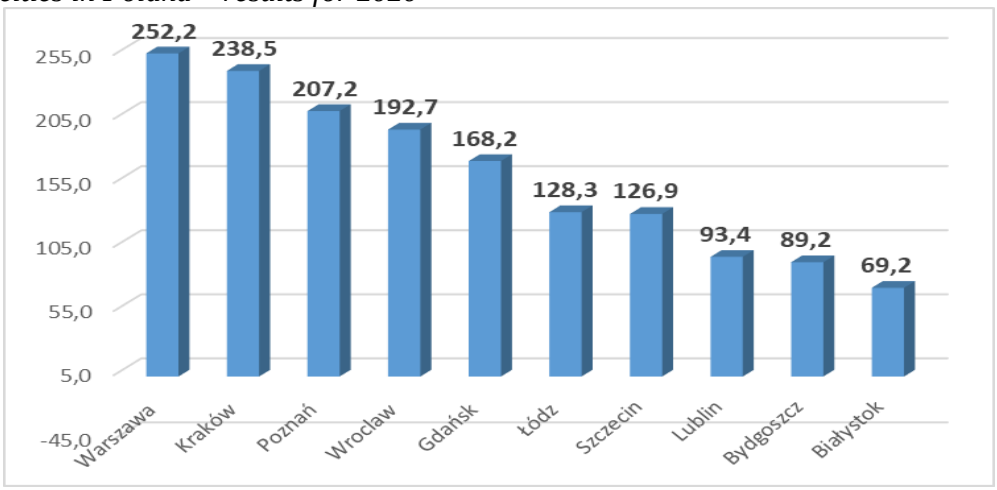
Figure 4. *Predispositions for the development of electromobility in selected cities in Poland – results for 2019*



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.*

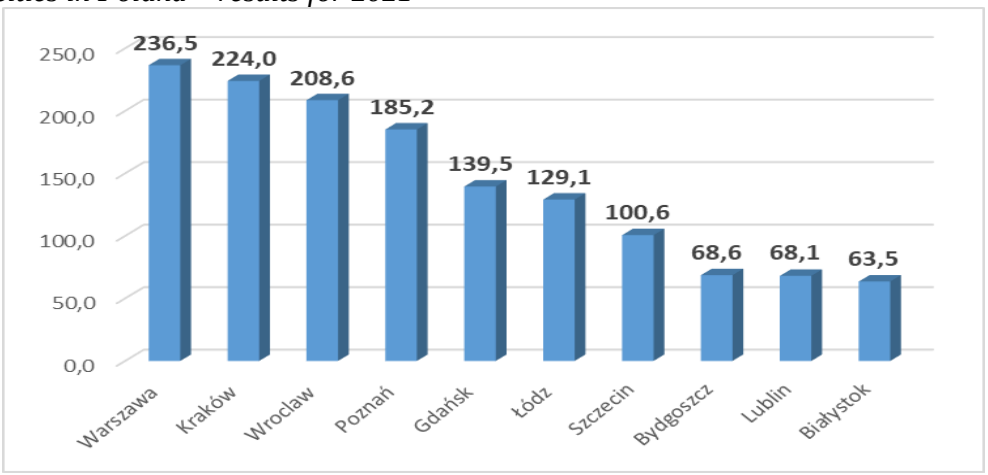
The year 2020 was marked by the fight against the COVID-19 pandemic, which not only significantly hampered the everyday life of city residents and limited access to a number of services, but also influenced the functioning of local government institutions. On the one hand, there was a decline in income 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 strategy, 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 examined strategy 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.

5. Discussion

There is no doubt that 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 necessitates the search for new solutions to support it.

We can probably expect changes in transport models, including the increase in the number of electric and hybrid cars. Cities should take this into account in their strategies and plans to meet EU requirements and the needs of residents.

6. 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. Observable global trends and the resulting legislative, social and economic changes increasingly take into account the environmental aspect in their assumptions.

Comparing the ranking results is not only an instrument for measuring progress in Polish cities' efforts to develop electromobility strategies, 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 strategies.

An indicator, structured set of data, 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 strategies, can support and inspire changes in the way the city is managed in accordance with the principles of sustainable development.

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