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THE CONCEPT OF ELECTROMOBILITY: THE VIEWS OF UNIVERSITY STUDENTS IN POLAND

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Abstract:
The phenomenon of electromobility is the subject of discussion among many diverse groups. Although its implementation in individual countries poses many challenges that must be addressed, among others, by electric car manufacturers and sellers (for example, in the form of developing technological solutions to increase the safety of electric cars or adapting recycling processes to specific technological solutions), the benefits it brings are measurable. Therefore, the main objective of the research conducted in this manuscript is to analyse the advantages and disadvantages of the concept of electromobility based on the opinions of university students in Poland. A total of 859 respondents were selected to participate in the study, including 488 men (56.81%), 353 women (41.09%), and 18 people who identified their gender as other (2.10%). The statistical calculations used included the Mann-Whitney U test, Spearman rank correlation, multidimensional cluster analysis, and Profit analysis. University students are sceptical about the concept of electromobility. They attach greater importance to the disadvantages of this concept (related to the high purchase cost of electric cars and their repairs). Among the advantages of electromobility, the most important (in the students' opinion) are technological progress, no need to purchase increasingly expensive fuel, and the low failure rate of electric cars.

Key words: electromobility, advantages of electromobility, disadvantages of electromobility, elv, university students

INTRODUCTION

Electromobility, considered a promising future for road transport [1], poses a challenge for modern cities [2]. It has emerged as a promising solution to achieve the goals of carbon neutrality by replacing traditional fossil fuel-powered transport with electric vehicles [3]. It also prevents anthropogenic climate change [4].

The dynamic development of electromobility in the European Union is one of the most important pillars from the transition of transport to sustainable mobility [5] and therefore requires comprehensive cross-sectoral solutions [6].

The climate change caused by CO_2 emissions, the depletion of oil resources, and their clear link to road transport are the main factors behind the development of this sector [7]. To achieve the common goal of reducing greenhouse gas emissions, a significant proportion of current sales of passenger vehicles and light commercial vehicles must include electric vehicles [8, 9].

It should be noted that electromobility is also intended to be a remedy for the growing needs of societies around the world, related to passenger transport, but its use in freight transport is also planned [10].

The influence of the European energy market on the Polish energy sector is increasingly significant, both in terms of regulation and environmental issues [11, 12]. To meet new requirements, Poland is striving to keep up with innovative ideas about the transport and energy market [13]. It should also be emphasised that the adoption of electric vehicles is highly dependent on economic and political incentives that reduce their cost and increase their attractiveness to both manufacturers and consumers [14]. Therefore, to promote electric vehicles, it is necessary to understand the perceptions and behaviours of consumers, particularly with respect to the main factors that influence their purchase and acceptance of electromobility [15]. These include innovations, technology, image, and properties of energy saving and environmental

protection [16]. The large-scale introduction of a fleet of electric vehicles will have a direct impact on the lives of Polish citizens and on the functioning of various sectors of the Polish economy. A significant impact will be visible in the national power sector, affecting all its subsectors: generation, transmission, and distribution [17].

As a result, there will also be a growing need to provide charging infrastructure for an increasing number of vehicles [18] and to effectively manage it [19]. Owners of these vehicles will look for charging options and locations, considering availability, electricity prices, and the convenience of using the charging infrastructure [20].

Environmental sustainability must also include the management of batteries used [21]. Many batteries will reach the end of their life cycle and will need to be disposed of [22]. Lithium-ion batteries contain hazardous substances such as lithium, cobalt, and nickel, which can pose a threat to the environment if managed improperly [21]. Furthermore, batteries can catch fire [23] or explode [24]. Other significant barriers to purchasing electric cars include their high price, limited availability [25], long charging times [26], unstable energy prices [27], vehicle range [28] and greater weight compared to traditional vehicles [29].

However, it is worth highlighting the undoubted advantages of this type of vehicle, including zero-emission mobility [30], (which fits the concept of a smart city) [31, 32, 33, 34], a sustainable alternative to traditional vehicles [35], the aforementioned technological progress [36, 37] and their charging process (which, with proper management, can become a flexible resource supporting the stability and balance of the power system) [38].

Therefore, based on the above considerations, the aim of this study was to analyse the opinions of university students on the future of the electromobility market in Poland. To achieve this goal, the following research questions were formulated:

- How do university students perceive the concept of electromobility?
- What are the most important challenges in the field of electromobility facing you and/or the Polish government and your home university soon, in the opinion of university students?
- What is the level of personal support among university students for the concept of electromobility in Poland?
- Does the length of time university students have held a category B driving licence affect their level of personal support for the concept of electromobility in Poland?
- Does the level of personal support among university students for the concept of electromobility in Poland depend on sociodemographic factors?

MATERIALS AND METHODS

The authors wish to emphasise that artificial intelligence was not involved in either the research process or the writing of the article.

Research Tool

The final version of the questionnaire was preceded by pilot studies conducted in October 2023. Based on the pilot studies, the questions were modified in terms of clarity and demographic questions that were not statistically significant were removed.

To collect the research material, a self-designed questionnaire was used consisting of 18 survey questions, including four questions designed to collect anonymous sociodemographic information. The remaining questions asked respondents about their experience holding a category B driving licence, using an electric car, and their opinions on the concept of electromobility in Poland, including its advantages and disadvantages and the actions that need to be taken in this area in the near future. Some of the questions were based on a matrix, in which respondents rated individual items on a 5-point Likert scale. The reliability of the questionnaire was evaluated using Cronbach's internal alpha consistency coefficient, the results of which indicated a high level of reliability (alpha = 0.91).

The survey was conducted between 15 November 2023 and 25 May 2024 electronically via the Interankiety.pl online platform. The criterion for inclusion in the survey was the student status in a higher education institution in Poland. Each respondent was informed of the scientific purpose of the study and the anonymous and voluntary nature of the participation. Completion of the questionnaire was considered equivalent to consenting to participate in the study.

Subject of analysis

The opinions of university students on the future of the electromobility market in Poland were the main subject of this analysis. The analysis of these opinions focused on assessing the importance of the individual advantages and disadvantages of the concept of electromobility, evaluating the electromobility measures that need to be taken by the Polish state and/or government and the respondent's university in the near future, and the level of personal support for the above-mentioned concept in Poland.

Statistical verification of the material collected consisted primarily of a general analysis of the distribution of the survey results, including an examination of how respondents perceived the concept of electromobility. As part of these analyses, the electromobility measures that the Polish state and/or the government and the home university need to take in the near future, and which are of similar importance from the point of view of the students surveyed were examined. The next step was to examine the relationship between the personal support for the concept of electromobility in Poland and factors such as the length of time they had held a category B driving licence, sex, form of study, and place of residence.

The impact of the time the respondents had held a category B driving licence on their assessment of the importance of the individual advantages and disadvantages

of the concept of electromobility was verified. The final area of statistical research was a comparison of groups distinguished by their preferred form of transport and distinguished by gender and form of study in terms of their assessment of the importance of the individual advantages and disadvantages of the concept of electromobility. The aim was to develop models of how the concept of electromobility is perceived depending on the preferred form of transport and in diverse groups of students depending on the gender and form of study.

Analysis Methodology

The material collected during the study was subjected to quantitative and descriptive analysis. Quantitative variables analysis was carried out by calculating the mean, standard deviation, median, quartiles, minimum, maximum, confidence interval, and standard error. The qualitative variable analysis was conducted by calculating the number (n) and percentage (%) of occurrences of each value. The compliance of the quantitative variables under consideration with the normal distribution was evaluated using the Shapiro-Wilk test. The following were used for statistical calculations: Mann-Whitney U test, Spearman rank correlation, multidimensional cluster analysis, and PROFIT analysis.

Statistical analysis of the results was performed using the Statistica v.13.3 PL statistical software from Tibco Software Inc. A significance level of $p < 0.05$ was assumed.

Characteristics of the study sample

A total of 859 university students were qualified to participate in the study, including 488 males (56.81%), 353 females (41.09%), and 18 people who identified their gender as other (2.10%). Most of the participants (88.47%) were aged 18-25. Detailed sociodemographic data on respondents are presented in Table 1.

In order for the sample to be representative and allow conclusions to be drawn about the population based on the sample, sample selection was random and covered the entire country. Data on universities, including their e-mail addresses, were obtained from the POL-on register. A random number table was used to randomly select from among 344 universities in Poland. The links and QR codes were then sent to 183 randomly selected universities with a request to participate in the study. Email and/or telephone confirmation was received from 182 universities that they would forward the links and QR codes to their students.

RESULTS AND DISCUSSION

Analysis of the General Results

The vast majority of the students surveyed had a category B driving licence; mainly for a period of 2 to 5 years (39.43%) or from 1 to 2 years (29.48%), slightly fewer respondents had the above-mentioned document for a period of 5 to 10 years (13.32%) or less than a year (11.71%), and the smallest share was holder of a category B driving licence for more than 10 years (6.06%).

Car was the preferred form of transport for three out of four respondents (75.55%). Public transport such as buses, trolleybuses, trams, underground trains, and trains was chosen by 11.41% and 8.15% of respondents, respectively. Other forms of transport, such as bicycles, scooters, and motorcycles, were chosen by 2.10% and 1.75% of respondents, respectively. Meanwhile, 1.05% of the respondents declared a preference for other forms of transport, without specifying them in detail.

Most of the students surveyed had never used an electric car (82.31%) or travelled as a passenger in an electric car (61.47%). In addition, almost all respondents (97.56%) denied owning an electric car. Furthermore, the vast majority of respondents (74.34%) did not consider buying an electric car; One in five respondents (20.17%) planned to make such a purchase in about 10 years; 5.01% of respondents intended to buy an electric car in the next 5 years; only four people (0.48%) planned to purchase an electric car within a year.

The results concerning the importance of individual advantages of the electromobility concept are presented in Table 2.

The results regarding the significance of individual disadvantages of the electromobility concept are presented in Table 3.

Table 1

Sociodemographic characteristics of the respondents

		n	%
Gender	Women	353	41.09%
	Men	488	56.81%
	Other	18	2.10%
Age	18-25 years old	760	88.47%
	26-32 years old	61	7.10%
	33 years old and above	38	4.42%
Type of studies	Full-time studies	518	60.30%
	Part-time studies	341	39.70%
Place of residence	Village	179	20.84%
	City with up to 20,000 inhabitants	93	10.83%
	City with more than 20,000 to 100,000 inhabitants	196	22.82%
	City with more than 100,000 to 200,000 inhabitants	300	34.92%
	City with more than 200,000 inhabitants	91	10.59%

Table 2

Responses to the importance of individual advantages of the concept of electromobility

Evaluation of the importance of individual advantages of the concept of electromobility	Descriptive statistics					
	Mean ± SD	Median [Q25 – Q75]	Min./Max.	Confidence interval		Standard error
				–95.00	+95.00	
No need to purchase increasingly expensive fuel	2.96 ± 1.24	3 [2 – 4]	1 – 5	2.88	3.04	0.04
Lower operating costs of electric cars	2.74 ± 1.25	3 [2 – 4]	1 – 5	2.65	2.82	0.04
Technological progress	3.03 ± 1.27	3 [2 – 4]	1 – 5	2.94	3.11	0.04
Environmental protection	2.9 ± 1.44	3 [1 – 4]	1 – 5	2.81	3.00	0.05
Positive impact on the country's economic development	2.69 ± 1.24	3 [2 – 4]	1–5	2.61	2.78	0.04
Long warranty period for electric cars	2.82 ± 1.27	3 [2 – 4]	1 – 5	2.74	2.91	0.04
Long battery life in an electric car	2.79 ± 1.39	3 [1 – 4]	1 – 5	2.70	2.88	0.05
Negligible noise level during electric car operation	2.86 ± 1.37	3 [2 – 4]	1 – 5	2.77	2.95	0.05
Low failure rate of electric cars	2.95 ± 1.32	3 [2 – 4]	1 – 5	2.86	3.04	0.04
Ease of use of an electric car	2.91 ± 1.32	3 [2 – 4]	1 – 5	2.82	3.0	0.04
Introduction of a Tax on combustion engine cars	2.38 ± 1.38	2 [1 – 4]	1 – 5	2.29	2.47	0.05
Subsidies for the purchase of electric cars	2.93 ± 1.34	3 [2 – 4]	1–5	2.84	3.01	0.05
Access to specially designated "Clean Transport Zones" in city centres	2.67 ± 1.35	3 [1 – 4]	1 – 5	2.58	2.76	0.05

Table 3

Responses to the importance of individual disadvantages of the concept of electromobility

Assessment of the importance of individual disadvantages of the concept of electromobility	Descriptive statistics					
	Mean ± SD	Median [Q25 – Q75]	Min./Max.	Confidence interval		Standard error
				–95.00	+95.00	
Rising energy prices	3.89 ± 1.03	4 [3 – 5]	1–5	3.82	3.96	0.03
Insufficient number of electric car charging stations	4.21 ± 1.02	5 [4 – 5]	1 – 5	4.15	4.28	0.03
Long charging time for electric cars	4.23 ± 0.98	5 [4 – 5]	1 – 5	4.16	4.30	0.03
Significantly higher prices at fast charging stations compared to traditional or home stations	4.02 ± 1.01	4 [4 – 5]	1 – 5	3.95	4.09	0.03
High purchase costs of electric cars	4.31 ± 0.97	5 [4 – 5]	1 – 5	4.24	4.37	0.03
Relatively high operating costs	4.07 ± 0.95	4 [4 – 5]	1 – 5	4.01	4.14	0.03
Flammability of electric cars	4.11 ± 1.14	5 [3 – 5]	1 – 5	4.03	4.19	0.04
Significant depreciation of electric cars	3.82 ± 1.11	4 [3 – 5]	1 – 5	3.75	3.89	0.04
Relatively limited range of electric car use	4.25 ± 1	5 [4 – 5]	1 – 5	4.18	4.32	0.03
Battery failure after the warranty period	4.18 ± 0.94	4 [4 – 5]	1 – 5	4.12	4.24	0.03
High repair costs	4.33 ± 0.89	5 [4 – 5]	1 – 5	4.27	4.39	0.03
Need to repair the car at an authorised service centre	4.14 ± 1.04	4 [4 – 5]	1 – 5	4.07	4.21	0.04
The need to introduce modern methods of recycling used batteries used in electric cars	3.99 ± 1.13	4 [3 – 5]	1 – 5	3.91	4.06	0.04

The average scores assigned to individual disadvantages of the concept of electromobility show that the students surveyed put greater importance to the disadvantages of this concept than on its advantages (the importance of the least important disadvantage is greater than the importance of the most important advantage).

The students surveyed considered the social support for the concept of electromobility in Poland to be rather low (44.12%), and 16.41% of the respondents rated this support as definitely low. Respondents who rated the above-mentioned support as high accounted for one-ninth of the respondents (11.41%), while 1.63% of the respondents considered that public support for electromobility in Poland was definitely high. One in four respondents (26.43%) had no opinion on this topic. When asked about their personal support for the concept of electromobility in Poland, a substantial proportion of university students expressed moderate or low opinions, as well as a lack of clear position. 27.59% of the respondents declared a definite low level of support for the above concept, while one in four respondents expressed a rather low level of support (26.78%) or did not have a clear opinion on the matter (26.54%). High support was expressed by 16.07% of the survey participants, while 3.03% of the respondents strongly supported the concept of electromobility in Poland.

According to the students surveyed, the challenges facing electric car manufacturers in the near future are primarily the development of new technologies to increase the range of electric cars (M = 4.04; SD = 1.12) and reduce the production costs of electric cars (M = 3.93; SD = 1.06). The respondents attributed slightly less importance to the question of adapting recycling processes to specific technological solutions (M = 3.82; SD = 1.15). On the other hand, the least important challenges facing electric car manufacturers in the near future, according to the students surveyed, are the implementation of technological solutions to increase the safety of electric car use

(M = 3.68; SD = 1.14) and gaining a competitive advantage on the market (over combustion and hybrid cars) (M = 3.43; SD = 1.23).

When assessing the individual measures in the field of electromobility that the state and/or the Polish government must take in the near future, the students surveyed considered the most important measures to be measures to increase the level of security in the energy market (M = 3.75; SD = 1.22). In second place in terms of importance, respondents rated the adaptation of road infrastructure solutions to electromobility needs (M = 3.54; SD = 1.27). Respondents paid slightly less attention to the issue of introducing subsidy programmes for electric cars (M = 3.3; SD = 1.33) and creating a preferential system for replacing combustion engine cars with electric cars (M = 3.24; SD = 1.32). On the other hand, according to the students surveyed, the least important measures for electromobility that need to be taken by the state and/or the Polish government need to take are changing legislation to promote the development of emobility (M = 2.98; SD = 1.1) and organising social campaigns on electromobility (M = 2.73; SD = 1.13).

Next, to identify groups of electromobility activities that the state and/or the Polish government need to undertake in the near future, a multidimensional cluster analysis was used. The results of this analysis, using the agglomerative method, showed that the students surveyed, when assessing the importance of individual activities on the part of the state and/or the Polish government, had a similar attitude towards issues related to the purchase and practical use of electric cars (i.e., introducing subsidy programmes for electric cars, creating a preferential system for replacing combustion engine cars with electric cars, and adapting road infrastructure solutions to the needs of electromobility). Another group of measures that received a similar assessment were those related to legislation and social campaigns (i.e. changing legislation to promote the development of e-mobility and organising social campaigns on electromobility). The last third group of activities was related to safety (i.e. taking measures to increase the level of safety in the energy market). The results of the cluster analysis using the nonhierarchical feature grouping method, known as k-means clustering, fully coincided with the results of the agglomerative method analysis. Further analysis of descriptive statistics for the activities included in each group showed that the most important activities for the students surveyed were those related to safety on the part of the Polish state and/or government ($M_{Cluster\ No.\ 2}$ = 3.75; $SD_{Cluster\ No.\ 2}$ = 1.22); slightly less important were actions related to the purchase and practical use of electric cars ($M_{Cluster\ No.\ 1}$ = 3.36; $SD_{Cluster\ No.\ 1}$ = 1.31); in turn, respondents attributed the least importance to actions related to legislation and social campaigns ($M_{Cluster\ No.\ 3}$ = 2.86; $SD_{Cluster\ No.\ 3}$ = 1.12) (Fig. 1).

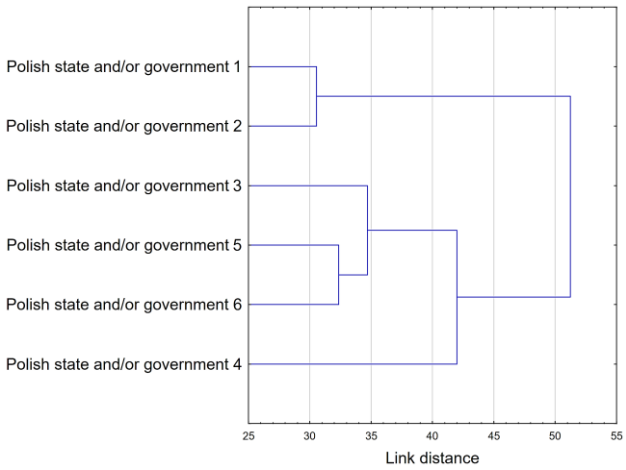

Fig. 1 Dendrogram obtained for the electromobility activities that need to be undertaken by the Polish state and/or the government soon

The students surveyed considered that the most important electromobility activities that their home university in the near future would be cooperation between the university and electric car manufacturers in terms of R&D (M = 3.24; SD = 1.22), supporting projects related to the concept of electromobility (M = 3.18; SD = 1.23) and creating courses at the university tailored to electromobility (M = 3.13; SD = 1.19). Less important, in the opinion of the respondents, was the organisation of regular competitions for the best innovative solutions in the field of electromobility (M = 2.92; SD = 1.23) and the creation of IT platforms that allow the exchange of views on electromobility (M = 2.82; SD = 1.17). However, participants considered the organisation of conferences/symposiums that publicise/promote the concept of electromobility (M = 2.56; SD = 1.15) is the least important activity in the field of electromobility of their home university.

In the next step, multidimensional cluster analysis was used again, this time to identify groups of electromobility activities that the home university needed to undertake soon. It turned out that the surveyed students had similar attitudes towards issues related to competitions and projects in the field of electromobility (i.e., organising regular competitions for the best innovative solutions in the field of electromobility and supporting projects related to the concept of electromobility). The second group of activities undertaken by the home university that were similarly assessed were those related to the university's participation in the electric car market (i.e. cooperation between the university and electric car manufacturers in terms of R&D and the creation of commissioned courses in electromobility at the university). The third group of activities undertaken by the home university of similarly assessed students were those related to facilitating the exchange of knowledge and views (i.e. organising conferences and/or symposia publicising and/or promoting the concept of electromobility and creating IT platforms enabling the exchange of views on electromobility). The results of the cluster analysis using the nonhierarchical feature grouping method, known as k-means clustering, again fully coincided with the results of the agglomerative analysis. In

the next stage, descriptive statistics for the activities included in each cluster were analysed. The mean values indicate that for the students surveyed, the most important activities were those of their home university related to the university' participation in the electric car market ($M_{Cluster\ No.\ 2}$ = 3.19; $SD_{Cluster\ No.\ 2}$ = 1.21), while issues related to competitions and projects in the field of electromobility were slightly less important ($M_{Cluster\ No.\ 1}$ = 3.05; $SD_{Cluster\ No.\ 1}$ = 1.24). On the other hand, the students surveyed considered the least important activities of their home university to be those related to facilitating the exchange of knowledge and views ($M_{Cluster\ No.\ 3}$ = 2.69; $SD_{Cluster\ No.\ 3}$ = 1.17) (Fig. 2).

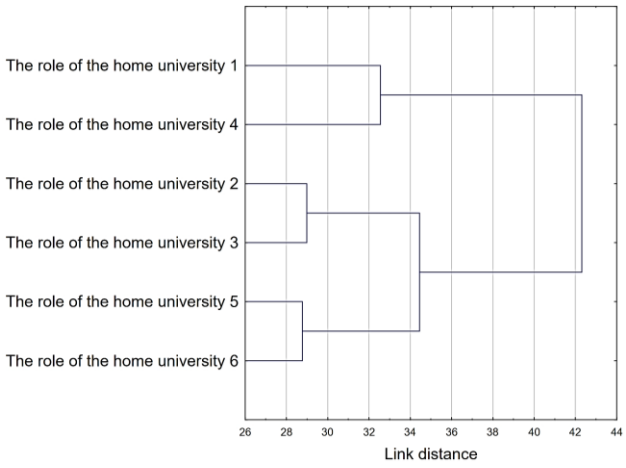

Fig. 2 Dendrogram obtained for the activities analysed in the field of electromobility that need to be undertaken by the home university soon

The impact of the length of time to hold a category B driving licence on the level of personal support for the concept of electromobility in Poland

The length of time that the students surveyed had held a category B driving licence was significant for their level of personal support for the concept of electromobility in Poland. Analysis using Spearman's rank correlation method showed that there was a negative and statistically significant relationship between the above variables, although the strength of this correlation was negligible. R = –0.08; t(N-2) = –2.3; p < 0.05. In turn, the direction of the correlation indicates that a longer period of driving a category B driving licence fostered a more sceptical attitude towards the concept of electromobility in Poland. The distribution of data recoded to a point scale concerning the level of personal support for the concept in groups distinguished by the length of time they had held a category B driving licence indicates that respondents who had held a driving licence for 2-5 years and 5-10 years were less supportive of the above-mentioned concept mentioned above (Fig. 3).

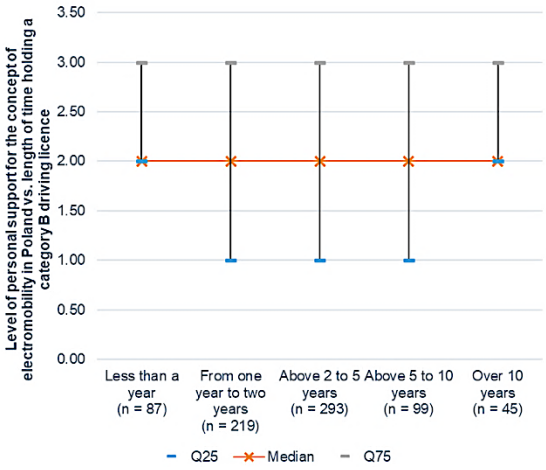

Fig. 3 Level of personal support for the concept of electromobility in Poland broken down by the length of time the respondents have held a category B driving licence

The impact of selected sociodemographic factors on the level of personal support for the concept of electromobility in Poland

The gender of the students surveyed significantly differentiated the level of their personal support for the concept of electromobility in Poland. It turned out that women supported the concept to a greater extent than men (M_{Women} = 2.61; SD_{Women} = 1.09 and M_{Men} = 2.24; SD_{Men} = 1.15). The difference between the two groups was considered statistically significant on the results of the Mann-Whitney U test: Z = 4.68; p < 0.001; r_g = 0.19.

The level of personal support of the students surveyed for the concept of electromobility in Poland also depended on the form of their studies. Full-time students showed a more positive attitude towards the concept of electromobility in Poland than part-time students ($M_{Full\text{-}time}$ = 2.54; $SD_{Full\text{-}time}$ = 1.13 and $M_{Part\text{-}time}$ = 2.19; $SD_{Part\text{-}time}$ = 1.12). This difference was shown to be statistically significant, as determined based on the results of the Mann–Whitney U test: Z = 4.43; p < 0.001.

However, the place of residence of the respondents did not influence their personal support of the concept of electromobility in Poland. In individual groups distinguished by place of residence, the students surveyed supported the concept to a similar extent, ranging between M_{Rural} = 2.34; SD_{Rural} = 1.1 and $M_{Town\ up\ to\ 20,000\ inhabitants}$ = 2.47; $SD_{Town\ up\ to\ 20,000\ inhabitants}$ = 1.19. Based on the results of the Spearman rank correlation analysis, no statistically significant relationship was found between the above variables: R = 0.02; t(N-2) = 0.49; p = 0.624.

Model of how the concept of electromobility is perceived in groups of students distinguished by gender and form of study

Model of perception of the advantages of the concept of electromobility

The next step was to build a model of perception of the advantages of the concept of electromobility in groups distinguished by gender and form of study. As part of this research, the following groups were analysed in the developed model:

- Women studying full-time [K/S],
- Women studying part-time [K/N],
- Men studying full-time [M/S],
- Men studying part-time [M/N].

The model was developed using the average significance scores (scale of 1 to 5) for the individual advantages of the electromobility concept in the above-mentioned groups, which are presented in the table below Table 4.

Table 4
Average frequencies of individual advantages of the concept of electromobility in groups distinguished by gender and form of study

	K/S	K/N	M/S	M/N
A1	3.32	3.10	2.97	2.54
A2	3.17	2.97	2.64	2.28
A3	3.23	3.09	3.00	2.82
A4	3.56	3.37	2.57	2.34
A5	3.11	2.88	2.58	2.29
A6	3.19	2.97	2.73	2.47
A7	3.14	2.99	2.68	2.42
A8	3.21	2.95	2.64	2.67
A9	3.21	3.18	2.87	2.65
A10	3.25	3.01	2.82	2.58
A11	2.72	2.56	2.22	2.07
A12	3.24	3.15	2.82	2.58
A13	2.99	2.87	2.50	2.41

Next, multidimensional scaling was performed to develop a graphical representation of the similarity (or dissimilarity) structure between the analysed objects in relation to a selected set of variables (features). The *STRESS* coefficient for multidimensional scaling considering all features was 0.00, which meant that the results of the multidimensional scaling procedure were highly reliable.

At a later stage, the fit of individual objects was verified. As part of this research, a regression analysis was performed in which the explained variable was the individual advantages of electromobility, and the explanatory variables were the values of two dimensions for each unit, obtained because of multidimensional scaling. DIM.1 and DIM.2. All the dimensions of significance evaluated had an exceptionally large impact on the diversity of the units studied (the lowest result in this respect was recorded in the case of no need to purchase more expensive fuel, where $R^2 = 0.81$). Therefore, there was no need to limit the number of characteristics studied in the model.

The final stage of these analyses was to use PROFIT analysis to develop a model of the perceived advantages of the concept of electromobility in relation to gender and the form of study, the results of which are presented below Fig. 4.

As can be seen in the figure, women, regardless of the form of study, recognised the advantages of the above-mentioned concept, with women studying full-time (K/S) mainly pointing out the negligible noise level during the operation of an electric car (A8); the possibility of entering specially designated " Clean Transport Zones" in city centres (A13) was equally important for women studying full-time (K/S) and part-time (K/N); while all other advantages of the concept of electromobility were more often recognised by women studying part-time (K/N).

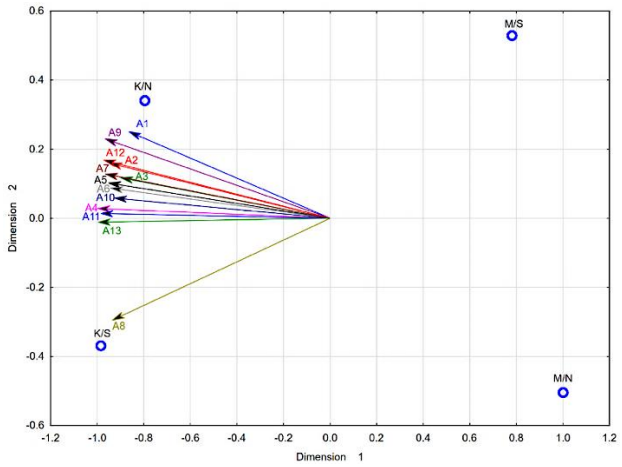

Fig. 4 Biplot showing the results of multidimensional scaling for individual objects (groups distinguished by gender and form of study) based on the individual advantages of the electromobility concept

Men, on the other hand, were far from recognising any advantages of the above-mentioned concept, and their location on the map shows the opposite of women (advantages important for women studying full-time were particularly irrelevant for men studying full-time; similarly, in the case of part-time students).

Model of perception of the disadvantages of the Electromobility concept

The final stage of these analyses was the construction of a model of perception of the shortcomings of the Electromobility concept in groups distinguished by gender and form of study. Within the framework of this research, the objects analysed in the developed model were analogous to the previous groups. The model was developed using average scores for the significance of individual disadvantages of the concept of electromobility in the groups mentioned above, which are presented in the table below Table 5.

Table 5
Average frequencies of individual disadvantages of the concept of electromobility in groups distinguished by gender and form of study

	K/S	K/N	M/S	M/N
D1	4.01	3.86	3.79	3.92
D2	4.26	4.29	4.08	4.29
D3	4.24	4.34	4.07	4.39
D4	4.07	4.13	3.89	4.08
D5	4.31	4.37	4.21	4.40
D6	4.12	4.14	3.89	4.19
D7	4.20	4.35	3.88	4.17
D8	3.74	4.02	3.68	4.03
D9	4.28	4.27	4.08	4.44
D10	4.15	4.29	4.09	4.31
D11	4.37	4.41	4.20	4.42
D12	4.12	4.40	3.95	4.24
D13	3.98	4.10	3.75	4.21

Next, multidimensional scaling was performed to develop a graphical representation of the similarity (or dissimilarity) structure between the analysed objects in relation to the selected set of variables (features). The *STRESS* coefficient for multidimensional scaling considering all features was 0.00, which meant that the results of the multidimensional scaling procedure were highly reliable. In the next step, the fit of the individual objects was verified. For this purpose, a regression analysis was performed, in which the explained variable was the successive disadvantages of the electromobility concept, and the explanatory variables were the values of two dimensions for each unit, obtained as a result of multidimensional scaling: DIM.1 and DIM.2. All the dimensions of significance evaluated had an exceptionally large impact on the diversity of the units studied (the lowest score in this respect was recorded for the relatively small range of use of electric vehicles, where $R^2 = 0.80$). Therefore, there was no need to limit the number of characteristics studied in the model.

At the end of the activities that aimed to develop a model of the perception of the disadvantages of the concept of electromobility in relation to gender and form of study, a PROFIT analysis was carried out, the results of which are presented in the figure below Fig. 5.

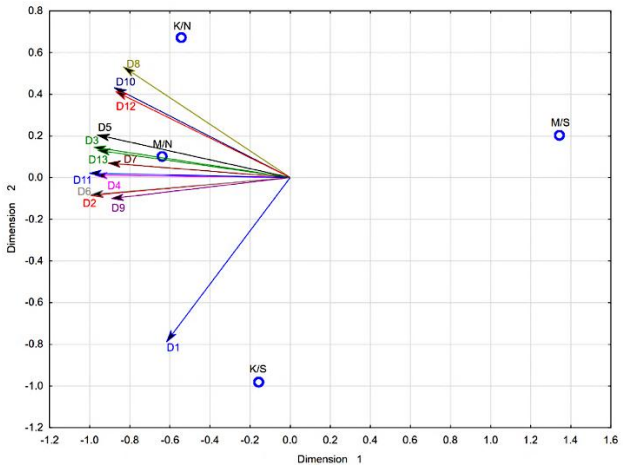

Fig. 5 Biplot showing the results of multidimensional scaling for individual objects (groups distinguished by gender and form of study) based on the individual disadvantages of the concept of electromobility

As can be seen in the figure, women studying full-time (K/S) paid particular attention to rising energy prices (D1), while women studying part-time (K/N) paid attention to the high depreciation of electric cars (D8). All other disadvantages of the electromobility concept were particularly noticed by men studying part-time (M/N). However, for men studying full-time (M/S), none of the disadvantages of the electromobility concept were particularly relevant.

Research on consumer attitudes towards electric vehicles considering the literature on the subject

Numerous studies have been conducted worldwide to verify consumer attitudes towards electric vehicles. One of them analysed user attitudes towards EVs in Spain, with particular emphasis on factors such as resource availability, safety, economic impact, environmental responsibility, and frequency of use. The questionnaire was completed by 326 respondents. The results indicate a generally positive attitude towards EVs, particularly regarding their environmental benefits and technological advances that facilitate their use. At the same time, there are significant concerns about economic costs and infrastructure availability, which limit the wider adoption of electric vehicles [36].

Another study, conducted on the island of Java, looked at factors that have a positive impact on the adoption of electric vehicles. It involved 210 respondents. The results of the study show that perceived safety and trust in technology, social status enhancement and subsidies policies have a significant impact on the intention to adopt [39].

The charging infrastructure also undoubtedly influences consumer attitudes towards electric cars. A study conducted among 409 electric vehicle owners in the US (from December 2023 to January 2024) showed that users value accessibility, reliability, and location safety above all else in this regard [40].

CONCLUSIONS

University students are sceptical about the concept of electromobility; they attach greater importance to the disadvantages of this concept (related to the high cost of purchasing and repairing an electric car). Among the advantages of the concept of electromobility, the most important, in the students' opinion, are technological progress, the lack of need to purchase increasingly expensive fuel, and the low failure rate of electric cars.

In the opinion of university students, the most important challenges in the field of electromobility facing you and/or the Polish government soon are related to safety.

In the opinion of university students, the most important challenges in the field of electromobility facing their home university are those related to their participation in the electric car market.

Assessment of the importance of the individual advantages and disadvantages of the concept of electromobility is related to the length of time university students have held a category B driving licence. The longer university students have held a category B driving licence, the more sceptical they are about the above-mentioned concept, i.e. they attach greater importance to its disadvantages (i.e. rising energy prices, insufficient number of electric car charging stations, long charging times for electric cars, much higher prices at fast charging stations compared to traditional or home stations, the need to have the car repaired at an authorised service centre and the need to introduce modern methods of recycling used batteries used in electric cars) and less, respectively, advantages (i.e. no need to purchase increasingly expensive fuel, positive impact on the country's economic development, and long warranty period for electric cars).

The advantages of the concept of electromobility are recognised by students who prefer buses, trolleybuses, trams, and/or the underground as a form of transport; students who prefer motorcycles are the least likely to recognise any advantages of this concept. On the other

hand, the most disadvantages of the concept of electromobility are recognised by students who prefer cars as a form of transport (mainly the high cost of purchasing an electric car, relatively high operating costs, the need to repair the car at an authorised service centre, the flammability of electric cars and the high loss of value of electric cars). Students who prefer motorcycles point out the high repair costs, as well as the much higher prices at fast charging stations compared to traditional or home stations, the short range of electric cars and the long charging time. Those who prefer buses, trolleybuses, trams and/or the underground, trains, bicycles, and/or scooters are far from seeing any disadvantages in the concept of electromobility. However, those who prefer other forms of transport pay attention primarily to the rising energy prices.

In groups distinguished by gender and form of study, the advantages of the concept of electromobility are recognised by women, regardless of the form of study; women studying full-time pay attention primarily to the negligible noise level during the operation of an electric car; the possibility of entering specially designated "Clean Transport Zones" in city centres as an advantage of the above-mentioned concept is equally important for women studying full-time and part-time; the other advantages of this concept are important for women studying part-time; men are far from recognising any advantages of the electromobility concept. Among the disadvantages of the above concept, women studying full-time mainly point to rising energy prices, while those studying part-time point to the significant loss in value of electric cars. All other disadvantages of the concept of electromobility are particularly important for men studying part-time. In turn, for men studying full-time, none of the disadvantages of the above concept are significant.

Based on the research conducted, practical implications for electric car manufacturers, decision-makers, and educational institutions were formulated. Electric car manufacturers should focus primarily on developing technologies that increase the range of use, reduce charging time, and improve the safety of electric cars (including eliminating their flammability). Decision-makers, in turn, should focus on introducing a consistent subsidy policy for electric cars and continuing measures to ensure energy stability. Educational institutions, on the other hand, should support diverse projects related to the concept of electromobility and create courses in this field.

The study has certain limitations, namely that it was conducted only among university students in Poland. In the future, it is planned to conduct this research on a much larger scale (in other European countries) to be able to perform a reliable comparative analysis on the subject in question.

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