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INTENTIONS OF ELECTRIC CAR USE – VALIDATION OF SCALES BASED ON TECHNOLOGY ACCEPTANCE THEORY

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Purpose: The aim of this paper is to answer the following research questions: 1) What observable variables can create constructs stemming from technology acceptance theory, where the technology under study is electric cars? 2) Do the observable variables creating constructs such as economic utility, environmental utility, social pressure, perceived ease/difficulty of use, attitudes, promotions and regulations, intentions to use electric cars form scales with acceptable validity and reliability? 3) Which of the studied constructs significantly affect the intention to use electric cars?
Design/methodology/approach: In order to achieve the stated purpose, literature research and empirical studies were conducted. The literature research was based on technology acceptance theory, which provided the theoretical basis for the questions for the survey, which was then conducted on a sample of 147 people. The obtained survey data were analyzed and used to: 1) validate the questionnaire scales that represent electric car acceptance factors and consist of observable variables; 2) model the factors affecting the acceptance of electric car technology. Structural Equation Modeling (pls-SEM) was used.
Findings: We found sets of statements, or observable variables building scales based on technology acceptance theory, where the technology under study was electric cars. Not all of these scales are of acceptable accuracy and reliability. Scales for the constructs of attitudes and promotions proved problematic. Therefore, these scales must be reexamined in another study. The remaining scales, after removing or recoding some variables, can be considered acceptable. We built a model in which the construct of attitudes toward electric cars was not included, while all other constructs except social pressure and promotion of electric cars were found to significantly affect intentions to use electric cars.
Research limitations / implications: The study sample was quite small, so we assume that our research will be repeated on a larger number of respondents.
Practical implications: Nevertheless, we consider our results on the validation of the scales of economic and environmental utility, social pressure and perceived difficulty of using electric cars to be valid. The scales we have proposed may prove useful for studying the acceptance of electric cars.
Originality/value: The originality of our article comes from a set of observable variables measuring constructs derived from Technology Acceptance Theory, where the technology under study is electric car technology.

Keywords: electric cars, questionnaire validation, pls-SEM.
Category of the paper: Research paper.

Introduction

With the advent of the 21st century, interest in green lifestyles has grown, along with the necessity to reduce greenhouse gas emissions and combat climate change. This, in turn, contributed to the popularization of electric cars. There is now strong pressure, especially in the European Union, to use electric cars for the sake of environmental goals and reducing CO_2 emissions. The European Union is aiming for climate neutrality by 2050, which requires a sharp reduction in emissions. As such, various incentives and regulations for electric cars are being pursued, such as subsidies, tax exemptions, investments in charging infrastructure, etc. However, despite the growing interest in electric cars, there are still some barriers and challenges that affect the acceptance and widespread use of this technology. Analyzing these factors and understanding the intentions of electric car use is key to the development of the electro-mobility market. These factors include, but are not limited to, economic, environmental, infrastructural or attitudes toward technology.

The main research problem of the paper is to determine how the factors influencing the intention to use electric cars are formed. Solving this problem became the main purpose of the paper.

To flesh out the research problem, the following research questions were raised:

1. What observable variables can create constructs stemming from technology acceptance theory, where the technology under study is electric cars?
2. Do the observable variables creating constructs such as economic utility, environmental utility, social pressure, perceived ease/difficulty of use, attitudes, promotions and regulations, intentions to use electric cars form scales with acceptable validity and reliability?
3. Which of the studied constructs significantly affect the intention to use electric cars?

In order to achieve the stated purpose, literature research and empirical studies were conducted. The literature research was based on technology acceptance theory, which provided the theoretical basis for the questions for the survey, which was then conducted on a sample of 147 people. The goal of the surveys was to find quantitative data on the variables driving acceptance of electric car technology. The obtained survey data were analyzed and used to:

1. validate the questionnaire scales, which are factors of electric car acceptance and consist of observable variables,
2. model the factors affecting the acceptance of electric car technology.

We used Structural Equation Modeling (pls-SEM) to analyze the survey data.

The paper consists of five chapters. The first chapter serves as an introduction to electric cars. It also covers the Technology Acceptance Model (TAM) theory complemented by the Theory of Planned Behavior (TPB). With these theories mentioned, the factors that can shape the acceptance of electric car technology are presented. Thus, the following constructs were included in the research model: economic and environmental utility of electric cars, social pressure to own them, promotion and regulation of electric cars, attitudes toward electric cars, and intentions to use them. The construct of intention to use became the dependent variable (target variable), and the other constructs became predictors. Chapter two deals with the methodological aspects of the empirical study. The research methods used to analyze the survey data are discussed therein. It also outlines the questionnaire, the research model and describes the research sample. Chapter three presents the results of the empirical study, and chapter four provides the main conclusions.

1. Electric cars in the context of technology acceptance theory

To answer the first research question, a literature review in the field of electric cars was conducted, which was aligned with the technology acceptance theory. Technology Acceptance Model (TAM) theory provides the theoretical basis for the research presented in the paper. The basic constructs in this theory are: perceived utility, perceived effort, attitudes toward the technology, intentions to use the technology, and actual use (Davis, 1985).

The *perceived utility* of electric cars consists of economic, environmental and social issues, among others. *Economic* issues include range and equipment of electric cars. They offer extensive modern equipment, are dynamic and quiet thanks to electric propulsion, often have two trunks and are safer, since they do not have fuel tanks. One can easily see that electric cars are more expensive than internal combustion ones by reviewing the offerings of various brands. The main contributor to higher prices is the cost of the battery, which accounts for half or more of the electric car's value. The high price of batteries is due to expensive raw materials and a complicated manufacturing process. The results of the study indicate that the current average price of an electric car is about € 33,000, compared to € 19,000 for a car with an internal combustion engine. Forecasters say that by 2026 the prices of both models should level off at € 19,000, and in 2030 the electric car should be several thousand euros cheaper than its combustion counterpart (Auruszkiewicz, 2022). In Poland, there is also the "Mój elektryk" program, which subsidizes the purchase of an electric car for individuals as of July 12, 2021, and for entrepreneurs and companies as of November 22, 2021. Subsidies apply to either purchases, leases or rentals (Rychlewicz, 2022). The maximum subsidy is PLN 18,750, while for Large Family Card holders it is PLN 27,000. It is crucial that the price of the car does not exceed the amount of PLN 225 thousand (Gov.pl, 2023). More rights on the roadway include:

the possibility to drive electric vehicles on bus lanes in Poland until 2026, free parking in paid zones or free charging (Grabek, 2022).

Also related to perceived utility are issues of *environmentalism*. Sustainability is the most important and most talked about aspect in the context of electric cars. It is true that electric vehicles (EVs) are carbon-zero; however, the issue of contention is the production of electricity and batteries needed to use them. The ideal scenario would be to produce energy from renewable sources, but unfortunately not all countries are well developed in this regard (Chłopek, 2013). In Poland, the production of electricity for electric cars is not environmentally friendly, as electricity in Poland comes mainly from fossil fuels. Unfortunately, the emissions from energy production for EVs is 0.29 due to NO_x emissions, which means it only meets the EURO III standard. However, a life-cycle comparison model between a turbocharged gasoline vehicle and an EV shows that electric cars allow a greater chance of reducing climate change impacts. The chances increase as the use of renewable energy sources increases. On the other hand, electric cars produce more pollution than combustion cars during production. One additional problem is the greater wear and tear on the tires, as electric cars weigh more due to their batteries and rechargeable batteries (Pero et al., 2018). The production of batteries for electric cars requires the consumption of a large amount of energy, and since production is mainly carried out in countries where electricity generation is based on the intensive use of fossil fuels (mostly China), this has a detrimental impact on the environment (Sendek-Matysiak, 2019). With the growing trend toward environmentalism and the various restrictions on reducing pollution or the benefits of using green equipment and products, it can be said that social pressure to be "eco-friendly" has emerged. This is well illustrated by the previously mentioned topic of restrictions that will be introduced by 2035 in the European Union.

The perceived *ease of use* in the context of electric cars is mainly a matter of the availability of car chargers. As of January 21, 2023, there were 2,565 electric chargers (Forum Energii…, 2023). Unfortunately, one of the problems of electric chargers is their uneven distribution, the Automotive Market Research Institute SAMAR found, based on data from the European Automobile Manufacturers Association (ACEA). This problem can be mainly seen in Europe, where the number of electric chargers in the Netherlands is more than 90 thousand, while in Romania, which is six times larger, there are about 500 (Krzyczkowska, 2021). Long distance travel through Europe can be problematic in this regard. A similar aspect of the ease of use of an electric car may be its charging time as well as its associated cost. It all depends on the size of the car's battery and the type of charger. The cheapest, albeit slowest, way to charge an electric car is to plug it into an outlet at home. Assuming an average rate of PLN 0.8/kWh, the cost of driving 100 km will be PLN 14. However, one has to expect a long charging time, which can take up to a dozen or more hours. It is possible to reduce this time by purchasing a wall charger plugged into a home outlet. It will charge the car 3 times faster (CORAB, 2022). The car can also be recharged in the city. Unfortunately, one must then expect a cost in the range of PLN 2 per kWh, but then the car will recharge in about an hour (Rychlewicz, 2022).

A concern for potential buyers of electric cars is the qualifications of mechanics. Electric cars are built with fewer parts, cheaper to run and may require less frequent repairs than internal combustion cars (costs such as changing oil, replacing plugs, clutch, air and fuel filters, are gone). Mechanics would have to get additional training in electrics as well as in the use of the diagnostic computer (AutoŚwiat, 2020).

The general public shows different mindsets, or *attitudes*, toward electric cars. Some see them as the future and love them, others sincerely hate them. Car shows are beginning to increasingly portray electric cars in a good light and present this technology as a good alternative with room for growth. In Poland, there are 31,249 electric cars (as of December 2022) and they outnumber hybrid cars. In comparison, in 2020 there were only 7231 electric cars in Poland. The (Klamut, 2018) paper conducted a survey of *purchase intentions* toward electric cars on a group of technical college students. The level of interest in electric cars was 80%. 78% of respondents would buy an electric drive vehicle if they had the financial capacity and only 10% of respondents would not consider buying an electric car despite meeting their requirements (Klamut, 2018).

2. Methodological aspects of the study

2.1. Research model

Based on the literature analysis, a research model was created for use in empirical studies. The model is presented in Fig. 1. Perceived utility was divided into two constructs, i.e. economic utility and environmental utility. Perceived ease/difficulty of use was incorporated into the research model as directly derived from the TAM (Technology Acceptance Model). Both the perceived economic and environmental utility, as well as the ease of use of electric cars, affect attitudes toward these cars. Social pressure (a construct derived from the theory of planned behavior) was also included as an important construct shaping attitudes. According to the TAM model, attitudes significantly influence intentions to purchase electric cars. It was also assumed that purchase intentions are also influenced by promoting and regulations. The aim of the empirical study is to examine each construct in terms of relevance and reliability, and then to model the impact of the constructs on intentions to use electric cars. Structural Equation Modeling (pls-SEM) was used to achieve this.

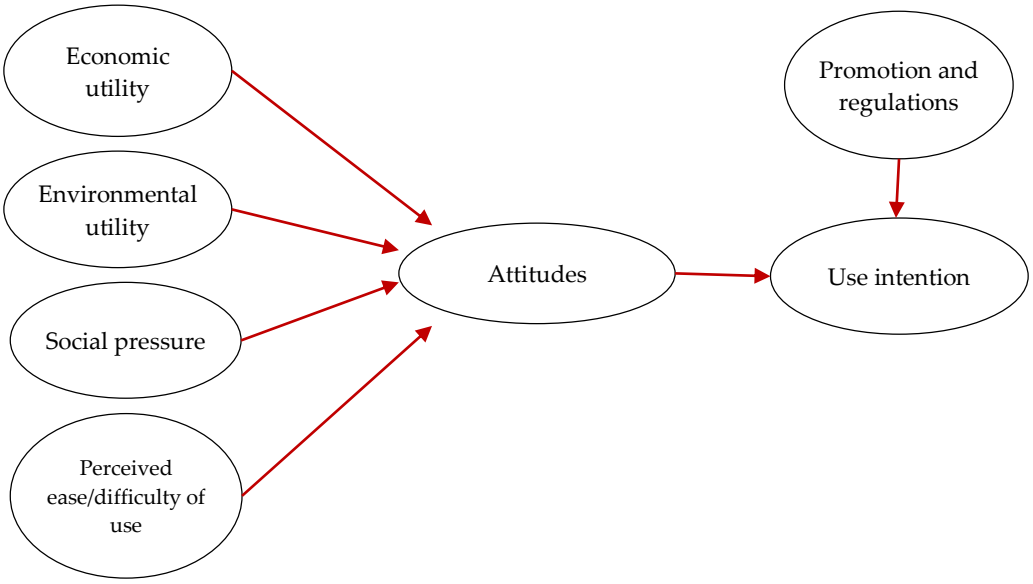

Figure 1. Research model.

Source: own study.

2.2. Measurement tool

Each construct in the research model was treated as a hidden (latent) variable. Therefore, a set of observable variables was developed to measure the listed constructs. These variables took the form of statements that were given to survey respondents. Respondents were asked to respond to these statements on a 7-point Likert scale. The observable and latent variables are shown in Table 1.

Table 1.
Questionnaire structure

Construct	Variable symbol	Questionnaire questions
Environmental utility (ECOL)	Ekol 1	Electric cars are environmentally friendly
	Ekol 2	Electric cars help reduce CO_2 emissions
	Ekol 3	Disposal of electric car batteries is not eco-friendly
	Ekol 4	Electric car production is not eco-friendly
	Ekol 5	Generating electricity in Poland for electric cars is not eco-friendly
Economic utility (ECON)	Ekon 1	Electric cars have low running costs
	Ekon 2	The cost of driving an electric car is lower than the cost of driving an internal combustion car
	Ekon 3	The cost of maintaining an electric car is lower than the cost of maintaining an internal combustion car
	Ekon 4	Electric cars require less frequent repairs than internal combustion cars
	Ekon 5	Electric cars are expensive
Social pressure (SN)	Spol 1	My family expects me to have an electric car
	Spol 2	My employer would like me to have an electric car
	Spol 3	My friends and acquaintances expect me to have an electric car
Perceived ease/difficulty of use (POU)	PoU 1	I am concerned about general mechanics' lack of skills in repairing electric cars
	PoU 2	The charging time discourages me from using an electric car
	PoU 3	The charging infrastructure discourages me from using an electric car
	PoU 4	Electric cars are safe
	PoU 5	Electric cars offer high driving comfort

Cont. table 1.

Attitudes (POST)	Post 1	Electric cars will dominate the market in the future
	Post 2	I am concerned that electric cars are not reliable
	Post 3	I am concerned that electric cars do not deliver the expected benefits
	Post 4	We should strive to reduce CO_2 emissions in transportation
Promotion and regulations (PRM)	Promo 1	Nowadays, you can see the State and the European Union support purchasing electric cars
	Promo 2	I agree with the ban on the sale of new internal combustion engine cars in the EU from 2035
	Promo 3	Automotive TV shows encourage people to buy electric cars
	Promo 4	In the future, electric cars will have more rights on the road than combustion cars
Use intentions (INT)	Int 1	I'm thinking of buying an electric car in the future
	Int 2	I'm thinking of using an electric car in the future (e.g. renting)

Source: own study.

2.3. Research sample

The survey was conducted in March and April 2023 and a total of 147 responses were collected via an electronic survey. The survey included 93 women and 53 men; one person did not define their gender. In order to ascertain the age of respondents, they were divided into six age groups. The most numerous of these is the 18–25 age group (82 individuals), followed by the 45–55 age group (26 individuals). The survey was most frequently taken by people with secondary education (71 individuals), and higher education (65 individuals). Almost half of the respondents were interested in motor vehicles (72 individuals). Only 27 respondents used an electric powered car, and the prevailing number of respondents did not own an electric car (142 individuals).

3. Results

3.1. Questionnaire validation

To validate the scales used in the questionnaire, their relevance and reliability were examined. To do so, for each scale the following were calculated: 1) factor loadings derived from conformational factor analysis, 2) Cronbach's alpha coefficient (alpha), 3) rhoA and rhoC coefficients and average, variance extracted (AVE) coefficient. The R environment and the seminr package were used for this. To be considered an accurate and reliable scale, the alpha, rhoA and rho C should exceed a threshold value of 0.7, and AVE a value of 0.5 (Hair et al., 2011, 2014, 2019). The obtained results are shown in Fig. 2.

	alpha	rhoC	AVE	rhoA
ECON	0.661	0.782	0.486	0.799
ECOL	0.036	0.228	0.594	0.851
SN	0.879	0.818	0.614	-0.209
POU	0.449	0.016	0.390	0.654
POST	0.082	0.000	0.399	0.592
PRM	0.308	0.626	0.327	0.376
INT	0.839	0.925	0.861	0.841

Figure 2. Measures of relevance and reliability of scales with original selection of variables
Source: own study.

As the results obtained were not satisfactory, we decided to remove or recode the observable variables within each construct. First, variables with unsatisfactory values of factor loadings (i.e., smaller than |0.5|) were removed. Deletions were made in the following constructs: economic utility, perceived ease/difficulty of use, attitudes, and promotion. It should be noted that for the construct of perceived ease/difficulty of using electric cars, of the five statements, only two describe the latent variable well. These statements read as follows: "The charging time discourages me from buying an electric car" and "The charging infrastructure discourages me from using an electric car." Therefore, these are statements that negatively describe the ease of use of electric cars. Hence, the construct has been renamed "perceived difficulty of using electric cars." Moreover, in the case of two constructs (attitudes, promotion) it was not possible to create a scale, and ultimately these constructs were defined by a single observable variable for modeling. Recoding of variables was also done during the examination of scales for some constructs. Such was the case with the construct of environmental utility. Recoding consisted of swapping answers 7 for 1, 6 for 2, 5 for 3, while 4 was left unchanged. Recoding was done for the variables ekol, 3, ekol 4, and ekol 5. The necessity of recoding was due to the fact that in the questionnaire, environmental utility was presented to respondents as environmental advantages and drawbacks of electric cars. It was therefore necessary to establish a single direction, which was achieved by recoding the variables describing the drawbacks. The final result was the model presented in Fig. 3 of which tested measures (Cronbach's alpha, rhoA, rhoC and AVE) met the preset thresholds of relevance and reliability.

	alpha	rhoC	AVE	rhoA
ECON	0.784	0.860	0.607	0.834
ECOL	0.831	0.878	0.590	0.844
SN	0.879	0.882	0.716	0.279
POU	0.772	0.895	0.811	0.831
PRM	1.000	1.000	1.000	1.000
POST	1.000	1.000	1.000	1.000
INT	0.839	0.925	0.861	0.841

Figure 3. Measures of relevance and reliability of scales with modified selection of variables.
Source: own study.

To test discriminant accuracy, the HTMT criterion was used. The results are shown in Fig. 4. It shows that none of the values exceeds the preset threshold value of 0.9 (Hair et al., 2011, 2014, 2019), which indicates satisfactory values.

	ECON	ECOL	SN	POU	PRM	POST	INT
ECON	.	.	.	.	.	.	.
ECOL	0.344	.	.	.	.	.	.
SN	0.149	0.111	.	.	.	.	.
POU	0.329	0.330	0.065	.	.	.	.
PRM	0.405	0.133	0.047	0.231	.	.	.
POST	0.107	0.389	0.066	0.119	0.048	.	.
INT	0.486	0.478	0.070	0.442	0.290	0.263	.

Figure 4. The HTMT criterion representing discriminant accuracy for scales with modified variable selection.

Source: own study.

3.2. Factors determining intentions of electric car use

Once the questionnaire is validated, a model can be built to explain the intentions of car use. During the research process, we built a number of models, which showed that attitudes strongly influence intentions of use, but also cause the relevance of other constructs to decline. This development is characteristic of the mediating variable, which in the light of technology acceptance theory is the attitude construct. Ultimately, due to the fact that attitudes were represented by only one observable variable, we created a model without this construct. Such a model is presented in the following figure (Fig. 5). It explains 32% of the variation in intentions to use electric cars. The model indicates that use intentions are most strongly influenced by the construct of environmental utility ($\beta = 0.279$) and this influence is positive. The second most influential construct is the economic utility ($\beta = 0.240$) and its influence is positive. Perceived difficulty of use negatively affects intentions to use electric cars ($\beta = -0.199$). Whereas social pressure proved statistically insignificant, as did the promotion of electric cars.

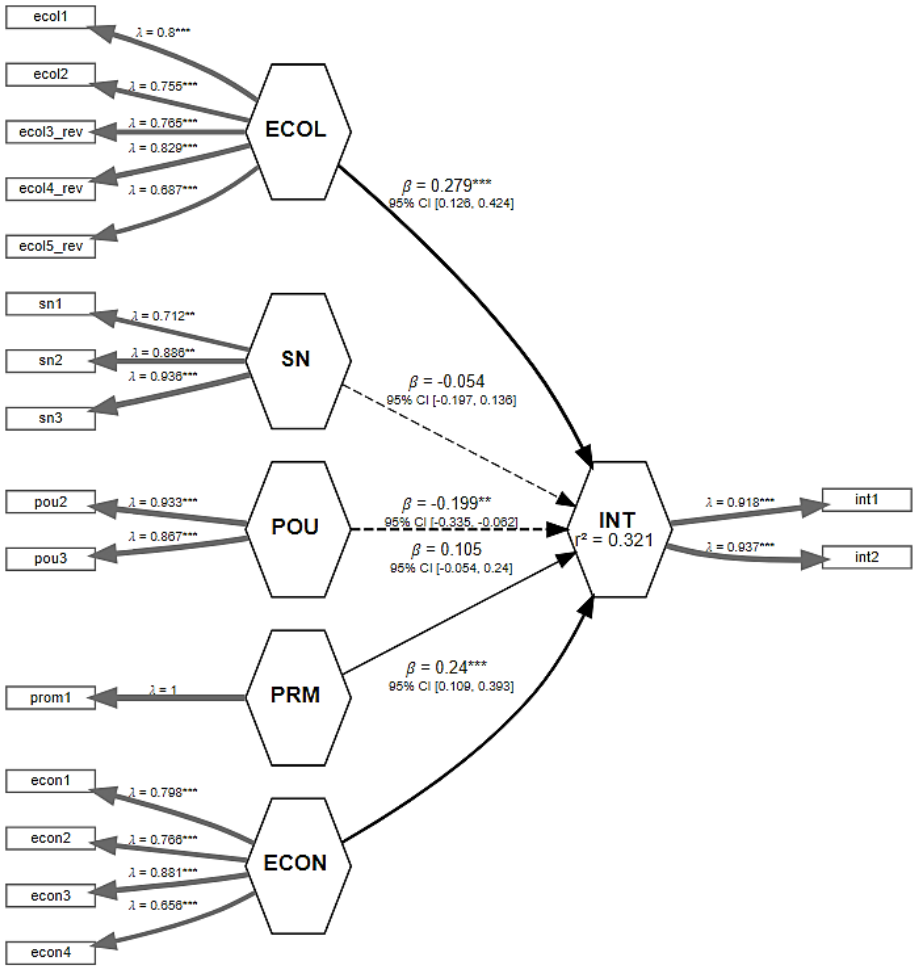

Figure 5. A model of the determinants of intentions of electric car use.
Source: own study.

4. Conclusion

The paper presented here poses three research questions, and then answers them on the basis of literature research and surveys. As to the first research question, we have found sets of statements, or observable variables that build scales based on technology acceptance theory, where the technology under study was electric cars. The answer to the second research question, however, has shown that not all of these scales have acceptable accuracy and reliability. Scales for the constructs of attitudes and promotions proved problematic. Therefore, these scales must be reexamined in another study. The remaining scales, after removing or recoding some variables, can be considered acceptable. To answer the third research question, we have built a model in which the construct of attitudes toward electric cars was not included, while all other constructs except social pressure and promotion of electric cars were found to significantly affect intentions to use electric cars.

Therefore, the first statistically significant factor for the intention to use electric cars turned out to be the ecological factor. Research has shown a positive impact of this factor on usage intentions. This proves the growing ecological awareness in Polish society. This is probably related to the perception of the problems of polluted air and climate change. The importance of ecological factors is undoubtedly a positive result of the research conducted. The second important factor turned out to be the economic factor. Research has shown a positive impact of this factor on usage intentions. This result is not surprising, as it is one of the most important factors motivating the acceptance of innovations (Mularczyk et al., 2022; Zdonek et al., 2022). The third important factor turned out to be the factor related to the perceived difficulty of use. Its impact on usage intentions turned out to be negative. It points to the problematic situation of infrastructure for servicing electric cars in Poland, which discourages the use of this type of cars. Social pressure and the promotion of electric cars turned out to be statistically insignificant factors. The lack of significance of social pressure can be explained by the fact that the use of electric cars in Poland is in the early phase of popularization. Therefore, the respondents did not feel any significant social pressure to use this type of car. Similar conclusions were also observed in other types of innovations in research (Mularczyk et al., 2022). The respondents also did not feel significantly motivated by the promotion of electric cars in the media. This factor turned out to be statistically insignificant. Therefore, in order to improve the intentions to use electric cars in Poland, the promotion of these cars should be strengthened. Promotional activities would also require influencing the respondents' closer and more distant social environment in order to influence the factor of subjective norms.

However, we would like to stress that the study sample was quite small, so we assume that our research will be repeated on a larger number of respondents. Nevertheless, we consider our results on the validation of the scales of economic and environmental utility, social pressure and perceived difficulty of using electric cars to be valid. The scales we have proposed may prove useful for studying the acceptance of electric cars.

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