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THE DETERMINANTS OF ELECTRIC SCOOTER ACCEPTANCE AMONG STUDENTS AS A MANIFESTATION OF ADAPTING TO THE REQUIREMENTS OF E-MOBILITY, USING THE TECHNOLOGY ACCEPTANCE MODEL

One of the biggest challenges for modern metropolises is the problem of public transportation. Barriers to the development of urban transport, the expansion of private vehicles, congestion of beehives, traffic jams, parking problems, and the negative impacts of transport on the environment are causing an increase in interest in shared micromobility. Electric scooters are one of these innovative solutions. This article aims to construct a model for the acceptance of electric scooters among students. The authors employed the technology acceptance model, and used the SmartPLS 4. Program to reconstruct the model. The basis of the model was a CAWI survey on a sample of 442 students. On this basis, the study verified the hypotheses on the relationships between the factors influencing the acceptance of electric scooters: demographic characteristics, perceived usefulness, ease of use, attitudes towards this solution, and behavioral intentions.

Keywords: micromobility, e-mobility, shared mobility, e-scooter, environmentally friendly technologies, Technology Acceptance Model (TAM).

1. INTRODUCTION

The functioning of modern metropolitan cities poses great challenges in many areas. One of them is the problem of developing urban transportation means (United Nations, 2017; Mavlutova et al., 2023; Barreto, Neto, Carazza 2021; Cloud, Heß, Kasinger, 2023).

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With the development of civilization, increasing urbanization, growing urban population, and emerging barriers to public transportation due to the dynamic intensification of urban traffic, there has arisen a need for new means of transport that would relieve the road infrastructure from excessive congestion while providing the ability to travel short distances without the need to use public transport. The resolution to this issue has been the implementation of a shared mobility system, i.e. movement by means of transportation used by multiple users (cars, bicycles or electric scooters) rented for a specified period of time (Mering, Wachnicka, 2021) in the form of collaborative consumption (sharing economy), which is viewed as an essential element of sustainable development (Dąbrowska, Janoś-Kresło, 2018).

In addition, the escalating issue of environmental pollution, including greenhouse gas emissions has drawn attention to the need to seek environmentally friendly transportation means, resulting in the development of e-mobility. The introduction of innovative mobility solutions that utilize collaborative consumption has a positive impact on the environment (Lienkamp 2012; Baptista, Melo, Rolim, 2014; Severengiz, Finke, Schelte, Forrister, 2020). Promoting these solutions can bring tangible results in reducing air pollution and noise (European Commission, 2018).

Electric mobility (e-Mobility) is a term related to the development of electric-powered vehicles. Responding to the increasing need for sustainable transportation, electric vehicles emerge as a compelling choice for both businesses and individuals. They serve as either an initial investment in cleaner transport or a strategy for partially or wholly converting existing fleets from dependence on fossil fuel, thereby reducing greenhouse gas emissions (GHG).

The newest means of transportation that fulfils both the criteria of collaborative consumption and e-mobility are electric scooters. Electric scooters are gaining increasing popularity and are becoming more readily available (Foissaud, Gioldasis, Tamura, Christoforou, Farhi, 2022) and used primarily for short (up to 10 km) distances (Yang et al., 2020). Their development dates back to the last few years - worldwide, between 2018 and mid-2022, more than $5 billion was invested in the development of services enabling shared electric scooters (Heineke, Kloss, Scurtu, 2020).

In Poland, the e-mobility market is characterized by high dynamics (Kubik, 2022). According to data from September 2023, nearly five years after the introduction of the first electric scooters, there are almost 93,000 electric scooters available for rent through apps in nearly 210 localities (*Between euphoria...*).

The phenomenon of the perception and acceptance of electric scooters as new and environmentally friendly means of public transportation, especially those rented via applications, has not been thoroughly examined in academic literature. The available publications - both in Poland and in other countries - generally refer to aspects of their use in the context of solving traffic problems (Smith, Schwieterman, 2018), environmental pollution (Moreau et al., 2020), the lack or inadequacy of existing regulations (traffic laws) regarding driving or parking (Mering, Wachnicka 2021; Allem, Majmundar, 2019; Ajao, 2019) or the safety or risk of scooter use related to accidents and injuries (Mering, Wachnicka 2021; Yang et al., 2020; Badeau et al., 2019; James, Swiderski, Hicks, Teoman, Buehler, 2019; Sikka, Vila, Stratton, Ghassemi, Pourmand, 2019; Trivedi, 2019; Blomberg, Rosenkrantz, Lippert, Christensen, 2019; Yang, 2010; Namiri et al., 2020; Stigson, Malakuti, Klingegard, 2021). In contrast, the issue related to factors influencing the acceptance, or lack thereof, of such transportation solutions among potential users has received relatively little attention. In this context, the authors felt it appropriate to undertake such a research problem.

This article aims to construct an acceptance model for electric scooters among Warsaw university students. For this purpose, the authors used the technology acceptance model proposed by Davis, Bagozzi, Warshaw (1989). As a tool for reconstructing the model, the authors applied the SmartPLS 4. program by Ringle, Wende, Becker (2022).

This article consists of several sections. In the first section, the authors present the theoretical framework of the problems addressed in the study. The second section describes the methodology of the research. The third section presents the results obtained. The fourth section contains a discussion of the findings, while the fifth section includes a summary, conclusions, limitations and directions for further research.

2. THEORETICAL FRAMEWORK

2.1. Electric scooters as a means of urban transportation

In recent years, cities worldwide have witnessed the emergence of new mobility alternatives, including micromobility. The concept of micromobility, as exemplified by electric scooters, finds its origins in the development of the new mobility paradigm (Sheller, 2011; Fortunati, Taipale, 2017; Brunner, Hirz, Hirschberg, Fallast, 2018). While the term is becoming more prevalent in literature on transportation (e.g. Anderson-Hall, Bordenkircher, O'Neil, Scott, 2019; Clewlow, 2018; McKenzie, 2019), it often lacks a precise and universally accepted definition. Broadly speaking, micromobility encompasses short-distance personal transportation using lightweight vehicles or small-size devices, especially powered two-wheelers (Eccarius, Lu, 2020). The growing interest in micromobility is firmly grounded in the broader notion of fostering sustainable and eco-friendly consumption practices. We can cite numerous studies that underscore the significance of this trend across diverse regions worldwide and in Poland (Zhao et al., 2020; Yao, Guo, Wang, Jiang, 2022; Hasterok et al., 2021; Sobczyk, Sobczyk, 2021; Witek, Kuźniar, 2021; Lundheim, Pellegrini-Masini, Klöckner, Geiss, 2022).

Micromobility, as a concept, highlights several primary advantages within the area of transportation. Potential benefits encompass a reduced carbon footprint and a decrease in road space occupancy. In addition, a shared micromobility service can improve access to motorized personal transportation for economically or socially disadvantaged groups that cannot afford a private vehicle.

This paper focuses on the introduction of electric scooters, often referred to as "e-scooters", which represent a relatively new form of micromobility experiencing growing adoption rates globally (Yang, 2010; Clewlow, 2018; McKenzie, 2019; Reck, Guidon, Haitao, Axhausen, 2021; Sandt, 2019; Seebauer, 2015) in both urban and suburban landscapes (Aartsma, 2020; Aguilera-García, Gomez, Sobrino, 2020; Tyrinopoulos, Antoniou, 2020).

In contemporary urban settings, electric scooters have emerged as the primary mode of shared transportation. In the US, for example, the number of trips already exceeded the number of rides on shared bikes without docking stations in 2018 – one year after the access system was launched (James, Swiderski, Hicks, Teoman, Buehler, 2019; *National Association...*). In most systems, electric scooters can be parked anywhere in the service area. As a flexible mode of transportation, electric scooters can play a key role in solving the first- and last-mile problem by bridging the gap between a cyclist's home or destination and public transportation stops. Electric scooters can be part of car-free mobility, along with bicycles, public transportation and walking (Ajao, 2019).

The use of electric scooters has many advantages, benefiting both individual users and society as a whole. Due to their increasing availability, electric scooters are seen as an increasingly common and convenient means of transportation (Shaheen, Cohen, 2019; Guidon, Becker, Dediu, Axhausen, 2019). Their advantages also include small size and weight (Matyja, Kubik, Stanik, 2022), making travel more attractive, reducing travel time, allowing its users to avoid urban traffic jams (Kijewska, Iwan, 2019), alleviating traffic problems by reducing road congestion (traffic jams), lowering the number of traffic accidents (Shaheen, Cohen, 2019; Gössling, 2020; Abduljabbar, Liyanage, Dia, 2021; Astegiano, Fermi, Martino, 2019; Sperling, Pike, Chase, 2018; Qiu, He, 2018; Bieliński, Ważna, 2020), and reducing greenhouse gas emissions and noise (Leuenberger, Frischknecht, 2010; Bishop, Doucette, Robinson, Mills, McCulloch, 2011; Sheng, Zhou, Zhou, 2016; Hsieh, Chang, Yu, Wu, 2018). In this context, electric scooters are seen as vehicles which are environmentally friendly (Moreau et al., 2020). The common characteristic of all e-scooter providers is that they position e-scooters as a "green" solution for mobility. Considering different modes of transportation, electric scooters are among the most energy-efficient – apart from walking and cycling, where energy consumption does not occur at all. E-scooters are also seen as the most efficient means of transportation (energy use per meter per person is only 20 joules, while, for example: subway – 30 joules, electric bus – 87, car – 380) (*Tier The 7 Myths...*). However, some authors point out the short life cycle of electric vehicles and the high energy in tensity of their production (Elliot, McLaren, Sims, 2018).

Still, the negative effects of the development of this mode of travel are also recognized. They are primarily related to the safety of road users due to the lack of or failure to comply with appropriate regulations pertaining to electric scooter usage such as the age of users, speed, the arteries of traffic (such as sidewalks) used, the allocation of right-of-way in relation to pedestrians, bicycles or cars, safety related to the abandonment of vehicles in public spaces, in a way that impedes other users (James, Swiderski, Hicks, Teoman, Buehler, 2019; Hollingsworth, Copeland, Johnson, 2019; Sanders, Branion-Calles, Nelson, 2020). The discussion of safety risks associated with electric scooters is also related to the relatively high number of injuries from electric scooter-related accidents (Choron, Sakran, 2019).

There are also some limitations related to access to equipment and docking stations, as well as long charging times for the scooters. There is also no clear evidence that the use of electric scooters is beneficial to the development of the urban mobility model (Kos, Krawczyk, Tomanek, 2020). This is because the use of electric scooters necessitates the use of a digital media platform, often a mobile application ("app") provided by the electric scooter company on a smart device (Ratan et al., 2021).

Multiple studies point to the increasing popularity of electric scooters, revealing variations in the acceptance of e-mobility solutions based on demographic characteristics (Akar, Fischer, Namgung, 2013; Murphy, Usher, 2015). It emerges that these are primarily modes of transportation used by young people (Hardt, Bogenberger, 2019).

Studies on shared e-mobility indicate that the main users are young people, usually between the ages of 21 and 45, well-educated, with medium to high incomes, living in urban areas (Kubik, 2022; Lin, Liu, Yang, Lin, 2021). The special characteristics of the young generation of consumers, especially those belonging to Generation Z, include the fact that they are confident, open-minded, accepting of diversity and innovation in many areas (which also applies to movement and transport), expecting immediate satisfaction of their needs, living and functioning according to the principle of just in time, oriented toward convenience in the use of goods and services, combining work and private life, socially oriented and deeply committed to social responsibility, including alleviating the issue of global warming and pollution, wanting to be seen as caring for the environment without, however, incurring substantial expenses in the process (Kim, McInerney, Rüdiger Smith, Yamakawa, 2022; Wielki, 2020).

Motivations regarding scooter use and perceptions are multidimensional. They are influenced by whether the respondent has already used them or not (James, Swiderski, Hicks, Teoman, Buehler, 2019; Kopplin, Brand, Reichenberger, 2021), situational context (Choi, Kwak, Yang, Lim, Woo, 2022; Jiao, Bai, 2020) concern for the environment (Seebauer, 2015; Gössling, 2020; Zhang, Chang, 2023) or the demographic characteristics of a given respondent (Laa, Leth, 2020; Lee, Baek, Chung, Kim, 2021; Mitra, Hess, 2021; Reck, Axhausen, 2021).

Badia and Jenelius (2023) distinguished between six types of purposes for using e-scooters: work (commuting, work-related trips and school), public transport (connection to stops/stations), social/entertainment (restaurants, visits to friends, etc.), fun/recreation (exercise or tourism among others), shopping/errands (e.g. health appointments), and other. McKenzie (2019) and Sanders et al. (2020) note, in turn, that electric scooters are used differently, either as a means of transportation for commuting to work/school or for recreation. In doing so, some studies show that electric scooters are used more often for commuting to work or school than for recreation (Gebhardt, Ehrenberger, Wolf, Cyganski, 2022), while others indicate that they are used more often for tourist and recreational trips (McKenzie, 2019).

2.2. Legal regulations concerning the use of electric scooters in Poland

One of the key aspects of using electric scooters is the issue of ensuring the safety of all traffic participants. Given that electric scooters represent a relatively new phenomenon, a comprehensive regulatory framework is still in development. This lack of established regulations leads to a certain degree of freedom of use and consequently carries risks for both e-scooter users and other road traffic participants (Sanders, Branion-Calles, Nelson, 2020). In many European countries or the USA, attempts are being made to regulate this phenomenon. They primarily concern the minimum age of the user, maximum speed, the need to ride on the roadway or bike path and the prohibition of riding on sidewalks, treating electric scooters similarly to bicycles (Mering, Wachnicka, 2021).

In Poland, the first regulations on electric scooters (*Road Traffic...*) came into force on May 20, 2021. Previously, scooters were included in road regulations, which led to conflicts between pedestrians and scooter riders and resulted in dangerous situations on the roads. The new regulations have introduced a definition of an electric scooter as “an electrically-powered, two-axle vehicle, with a steering wheel, without a seat or pedals, structurally designed to be driven solely by the driver on the vehicle” (*A guide before...*), and categories of assistive mobility devices (UWR, *urządzenie wspomagające ruc*h) and personal transportation devices (UTO*, urządzenie transportu osobistego*), which included electric scooters, rollerblades, skateboards, etc. (*Electric scooters...*).

Drivers of electric scooters must use bicycle paths or bike lanes, if available (*Regulation of the..., 2021*), and the maximum speed effective from November 2, 2021 is 20 km/h on bike paths and roadways (*New rules from...*). Riding on sidewalks is allowed only in special cases, at a speed close to that of a walking pedestrian.

Adults do not need a driver's license to use an electric scooter, but minors (10–18 years old) must have a bicycle card or a driving license in category AM, A1, B1, or T. (*E-scooters...*). Children under the age of 10 can ride a scooter only under the supervision of an adult in a residential zone.

These vehicles are not subject to technical inspection (*On November...*) but the regulations specify the size and technical parameters and mandatory equipment of the electric scooter (*The Minister has...*). The scooter needs to be equipped with appropriate lights, brakes, reflectors and a bell or horn. Using a phone while riding is prohibited, as is transporting other people, animals or cargo/load. According to regulations, parking a scooter is only allowed in designated areas (*Electric scooters...*), and leaving it on the sidewalk requires compliance with certain rules.

Violating these regulations can result in fines and, in cases of parking violations, the scooter may be removed from the road at the owner's expense The introduction of new regulations was aimed at regulating the use of electric scooters, ensuring the safety of users and other road users, and adapting the law to the new realities of electric personal transportation devices.

2.3. Development of Hypotheses

The use of electric scooters is significantly conditioned by demographic variables, among which young age plays a primary role (Mitra, Hess, 2021). Laa and Leth (2020) emphasize that electric scooters are most commonly used by young, educated males. Reck and Axhausen (2021) add to these three variables the additional factors of not having a family and being employed. The factors influencing the use of electric scooters are perceived somewhat differently by Lee et al. (2021), who do not focus on demographic characteristics, but rather on users having a higher income and being dissatisfied with public transportation. Costs associated with the use of an electric scooter are also an important factor – sometimes regarded as a decisive factor (Glavić, Milenković, Trifunović, Jokanović, Komarica, 2023).

H_1 – There is a relation between the age of respondents and the perceived usefulness of electric scooters.

H_2 – There is a relation between the size of the respondent’s place of residence and the perceived usefulness of electric scooters.

H_3 – There is a relation between the financial situation of respondents and the perceived usefulness of electric scooters.

According to research conducted by Li, Sinniah, Li. (2022) the perceived ease of use of e-bikes has a positive effect regarding the perceived usefulness. The availability of electric scooters often presents a significant challenge. E-scooters are associated with barriers related to being able to find working equipment when needed (Sanders, Branion--Calles, Nelson, 2020).

H_4 – There is a relation between the perceived ease of use of electric scooters and their perceived usefulness.

Research conducted among Asian consumers shows that the ease of use of electric motorcycles perceived by people positively influences their attitudes toward using electric motorcycles (Mitra, Hess, 2021).

H_5 – There is a relation between the perceived usefulness of electric scooters and attitudes toward this device (Attitude towards technology).

H_6 – There is a relation between attitudes toward electric scooters (Attitude toward technology) and behavioural intentions to use them.

Research conducted among Asian consumers shows that people's attitudes toward using electric motorcycles positively influence their behavioural intentions toward electric motorcycles (Zhang, Chang, 2023). This is especially true for a comfortable way to travel, especially on hot days and compared to walking (Hollingsworth, Copeland, Johnson, 2019). However, negative aspects of using electric scooters are also recognized, with safety concerns coming to the forefront. Studies indicate that e-scooters are also associated with concerns about traffic safety (Sanders, Branion-Calles, Nelson, 2020).

H_7 – There is a relation between the perceived usefulness of electric scooters and behavioural intentions toward using them.

The study of Kopplin et al. (2021) shows that the intention to use e-scooters impacts their actual usage.

H_8 – There is a relation between behavioural intentions to use electric scooters and their actual usage.

H_9 – The relation between perceived usefulness associated with the use of e-scooters and behavioural intentions to use e-scooters is mediated by attitudes toward e-scooter technology.

3. METHODS

The aim of the article is to answer the question of which variables affect the intensity of the use of electric scooters among students. For this purpose, the authors used the technology acceptance model proposed by (Davis, Bagozzi, Warshaw, 1989) customizing it to suit the requirements of the technology acceptance concerning electric scooters. The survey was conducted in April 2023 on a sample of 442 students at the University of Warsaw. It is a public university located in the capital of Poland, Warsaw. To invite students to participate in the study, the system administrator sent them an email containing information about the research and a link to the online survey. Table 1 shows the characteristics of the survey sample. Among the respondents, more than 60% were women. The majority of respondents were individuals in the age group up to 24 years old. The average age of the respondents was 22. Nearly 60% of the respondents were individuals residing in cities with a population exceeding 200,000 residents. The overwhelming majority of respondents rated their financial situation as good and very good.

Table 1. Characteristics of the research sample

Specification		**N**	**%**
Total		442	100.0
Gender	Male	160	36.2
	Female	282	63.8
Age	Under 24	393	88.9
	25–34	36	8.1
	35–55	13	2.9
Size of place of residence	Village	76	17.2
	Town up to 20 thousand residents	25	5.7
	Town 21–50 thousand residents	37	8.4
	City 51–200 thousand residents	44	10.0
	City of more than 200 thousand residents	260	58.8

Table 1 (cont.). Characteristics of the research sample

Specification		N	%
Perceived financial situation	Bad (I have barely enough for basic products and services)	2	0.5
	Sufficient (I can still make ends meet)	26	5.9
	Average (I have enough to live frugally)	72	16.3
	Good (I am not complaining, but it could be better)	248	56.1
	Very good (I have enough for everything, with some savings)	94	21.3

Source: own studies.

We adopted the variables proposed by Davis et. (1989) in the Technology Acceptance Model as variables affecting the intensity of electric scooter use and adapted them for the needs of this study. These variables include: perceived usefulness of using electric scooters (PU), ease of using electric scooters (PEOU), attitude toward electric scooters (ATT), behavioural intention related to using electric scooters (BI), and current use of electric scooters (AU). In addition, the model included variables such as the age of students (AGE), size of residence of students (POR) and financial situation of students (FS). Variables such as PU, PEOU, ATT, BI and AU are latent variables, composed of their respective loadings. Each loading was rated by respondents on a 5-point Likert scale, where 1 meant completely disagree with a given statement, 2 – disagree, 3 – neither disagree nor agree, 4 – agree, 5 – completely agree. Table 2 lists the statements/loadings describing the above latent variables.

Table 2. Description of the latent variables used in the model

Perceived usefulness of electric scooters (PU)	
PU1	Electric scooters are useful for commuting to work/university
PU2	Electric scooters are useful for running daily errands (shopping, picking up packages from parcel machines, etc.)
PU3	Electric scooters are useful for riding for pleasure
PU4	Bad weather conditions discourage me from using electric scooters
PU5	Using an electric scooter, I can charge my cell phone
PU6	Using electric scooters available for minute rentals allows for reducing costs of transportation (e.g., fuel costs, bus tickets, etc.).
PU7	The offer of electric scooters available for minute rentals is cost-effective
PU8	Using electric scooters available for minute rentals saves time
PU9	Electric scooters available for minute rentals are useful because they allow people to avoid infection by not having to use public transportation

Table 2 (cont.). Description of the latent variables used in the model

Perceived ease of use of electric scooters (PEOU)	
PEUO1	Riding an electric scooter is very simple / easy
PEUO2	Riding an electric scooter allows you to get virtually anywhere you want to go
PEUO3	The quality of the wheels on electric scooters enables a comfortable ride on uneven or poorly laid sidewalks.
PEUO4	While riding an electric scooter, overcoming unevenness on the road, e.g., holes in sidewalks, curbs are not a challenge
PEUO5	The technical capabilities of electric scooters enable reaching an adequate/satisfactory speed
PEUO6	There is a large number of electric scooters available for minute rentals near my location.
PEUO7	The application or applications enabling the use of electric scooters available for minute rentals are very user-friendly.
PEUO8	Electric scooters available for minute rentals are technically efficient.
PEUO9	Electric scooters available for minute rentals have a sufficient range
PEUO10	Operators provide transparent access to information about the pricing of electric scooters available for minute rentals.
PEUO11	Electric scooters available for minute rentals have high-quality brakes that enable comfortable riding.
PEUO12	Electric scooters available for minute rentals have high-quality suspension that allows for comfortable riding.
Attitude towards technology like electric scooters (ATT)	
ATT1	Riding an electric scooter is safe for users
ATT2	Riding an electric scooter is safe for the environment/other road users such as pedestrians
ATT3	Electric scooters provide entertainment associated with riding them
ATT4	Using electric scooters reduces noise pollution
ATT5	Riding an electric scooter improves physical fitness
ATT6	The use of electric scooters reduces congestion on roads
ATT7	Popularization of electric scooters contributes to reducing greenhouse gas emissions
ATT8	The popularization of electric scooters for minute rentals can make life difficult for other users because they are left / abandoned anywhere.
Behavioural intentions regarding the use of electric scooters (BI)	
BI1	In the future, I will be using the services of operators offering the option to rent electric scooters available for minute rentals
BI2	In the future, I intend to buy my own electric scooter
BI3	I will recommend others to use electric scooters available for minute rentals
BI4	I will recommend others to buy their own electric scooter

Source: own studies.

The age variable was described on a quantitative scale. Based on the year of birth given by the respondents, age was assigned to each of them. The variable size of residence was described on a five-point rank scale, where 1 – indicated a village, 2 – a town of up to 20,000 residents, 3 – a town of 21,000 – 51,000 residents, 4 – a city of 51,000 – 200,000 residents, 5 – a city above 200,000 residents. Perceived own financial situation was also described on a five-point rank scale, where: 1 means bad financial situation (barely enough for basic products and services), 2 sufficient (I still can make ends meet), 3 average (enough to live frugally), 4 good (I'm not complaining, but it could be better), 5 very good (I can afford everything and I can save some money). We used Partial Least Square Structural Equation Modelling (PLS-SEM) technique with SmartPLS software to verify the relations between the analysed variables (Wielki, 2020). Figure 1 shows our proposed conceptual model for the acceptance of electric scooters.

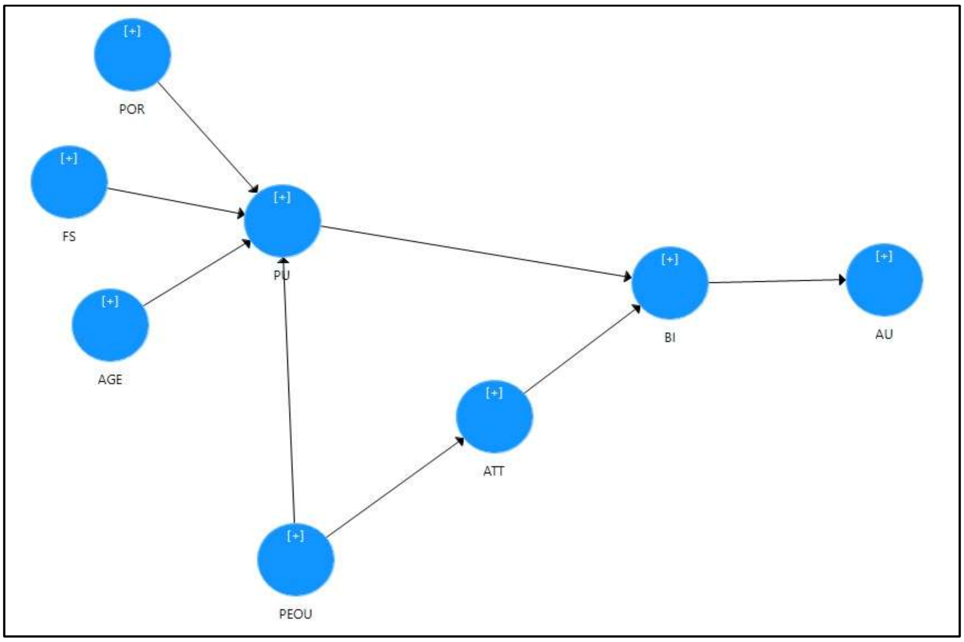

Figure 1. Conceptual model

Source: own studies.

4. RESULTS

4.1. Quality assessment of the proposed model

Using the aforementioned SmartPLS software (Wielki, 2020) we tested the reliability of the variance using Cronbach's alpha and Composite Reliability (CR). The reliability can be defined as the degree to which "measurements of individuals on different occasions, or by different observers, or by similar or parallel tests, produce the same or similar results" (Streiner, 2003). Cronbach Alpha measures the internal consistency of a test or scale; it is expressed as a number between 0 and 1. Internal consistency describes the extent to which all the items in a test measure the same concept or construct (Tavakol, Dennick, 2011). As Streiner (2023)points out, the minimum alpha value depends on the context. 0.50 to 0.60 for early stages of research, 0.80 for basic research tools and 0.90 for clinical trials. On the other hand, Hair, Ringle, Sarstedt (2011) propose the minimum acceptable value as 0.7. In Table 3, we see that for three variables, alpha is above 0.7. On the other hand, for the ATT variable, it takes a value just below 0.7. On the other hand, Composite reliability for all latent variables analysed is above 0.7. Hair et al. [100] state that Composite reliability should be higher than 0.70 (in exploratory research, 0.60 to 0.70 is considered acceptable). In turn, the average variance extracted (AVE) should be higher than 0.50 (Hair, Ringle, Sarstedt, 2011; Chin, 2010. An AVE value of 0.50 and higher indicates a sufficient degree of convergent validity, meaning that the latent variable explains more than half of its indicators' variance (Hair, Ringle, Sarstedt, 2011). The first column refers to factor loadings. All items having factor loadings smaller than 0.6 were discarded and were not taken into account in further analysis. As stated by Hair, Ringle, Sarstedt (2011), indicators with loadings below 0.7 should be deleted. Factors loadings between 0.40 and 0.70 should only be considered for removal from the scale if deleting this indicator leads to an increase in composite reliability above the suggested threshold value. Another consideration in the decision to delete indicators is the extent to which their removal affects validity. Weaker indicators are sometimes retained on the basis of their contribution to content validity. Indicators that exhibit very low loadings of 0.40 and lower should, however, always be eliminated from reflective scales. In our case, further removal of items no longer increased validity and reliability.

Table 3. Items loadings, reliability and validity

	λ	**Alpha**	**CR**	**AVE**
ATT1	0.797	0.689	0.811	0.520
ATT2	0.727			
ATT3	0.719			
ATT4	0.631			
BI1	0.871	0.766	0.866	0.686
BI2	0.694			
BI3	0.905			
PEOU1	0.725	0.833	0.875	0.501
PEOU7	0.752			
PEOU8	0.776			
PEOU9	0.622			
PEOU10	0.679			
PEOU11	0.750			
PEOU12	0.636			
PU1	0.867	0.784	0.861	0.609
PU2	0.765			
PU3	0.757			
PU8	0.726			

Source: own studies.

The structural model in PLS can be evaluated using a coefficient of determination R^2. It measures the variance, which is explained in each of the endogenous constructs, and is therefore a measure of the model's explanatory power. The R^2 ranges from 0 to 1, with higher values indicating a greater explanatory power (Hair, Risher, Sarstedt, Ringle, 2019). For the perceived usefulness of e-scooters $R^2 = 0.376$.

It means that variables such as POR, FS, AGE, and PEOU explain 37.6% of the variance in perceived usefulness. In the case of actual usage of electric scooters, $R^2 = 0.310$, for attitude toward e-scooters $R^2 = 0.429$ and for behavioural intention $R^2 = 0.342$.

Table 4. Discriminant validity – cross loadings

	ATT	BI	PEOU	PU
ATT1	**0.797**	0.429	0.504	0.417
ATT2	**0.727**	0.455	0.393	0.276
ATT3	**0.719**	0.316	0.572	0.559
ATT4	**0.631**	0.332	0.406	0.430
BI1	0.490	**0.871**	0.538	0.460
BI2	0.310	**0.694**	0.323	0.309
BI3	0.498	**0.905**	0.499	0.475
PEOU1	0.557	0.472	**0.725**	0.553
PEOU7	0.435	0.443	**0.752**	0.501
PEOU8	0.506	0.395	**0.776**	0.434
PEOU9	0.379	0.333	**0.622**	0.319
PEOU10	0.432	0.298	**0.679**	0.348
PEOU11	0.495	0.416	**0.750**	0.425
PEOU12	0.405	0.365	**0.636**	0.338
PU1	0.490	0.442	0.507	**0.867**
PU2	0.411	0.400	0.392	**0.765**
PU3	0.473	0.401	0.464	**0.757**
PU8	0.446	0.339	0.510	**0.726**

Source: own studies.

In turn, Table 5 shows Discriminant validity using the Heterotrait-Monotrait Method (HTMT) developed by Henseler et al. (2015). The HTMT is defined as the mean value of the item relations across constructs (i.e., the heterotrait-heteromethod relations) relative to the (geometric) mean of the average relations for the items measuring the same construct (i.e., the monotrait-heteromethod relations) (Hair, Risher, Sarstedt, Ringle, 2019). There are two approaches to the HTMT threshold, helping to verify that discriminant validity has been established between each two constructs. Some authors suggest a threshold of 0.85, whereas others propose a value of 0.90 (Henseler, Ringle, Sarstedt, 2015). In our analyses, almost all pairs of latent variables fall within the stricter approach – the HTMT value does not exceed 0.85. For only one pair of latent variables, the HTMT value is 0.851. Table 6 presents descriptive statistics of the variables included in the analyses: mean, standard deviation and median.

Table 5. Discriminant validity using the Heterotrait-Monotrait Method (HTMT)

	ATT	BI	PEOU	PU
ATT				
BI	0.724			
PEOU	0.851	0.680		
PU	0.794	0.648	0.729	

Source: own studies.

Table 6. Descriptive statistics

	Mean	Median	Std. Dev.
ATT1	3.000	3.000	1.053
ATT2	2.529	2.000	1.087
ATT3	4.097	4.000	0.852
ATT4	3.844	4.000	0.932
BI1	3.210	3.000	1.242
BI2	2.265	2.000	1.287
BI3	2.817	3.000	1.179
PEOU1	3.869	4.000	1.051
PEOU7	3.876	4.000	0.947
PEOU8	3.548	4.000	0.861
PEOU9	3.489	4.000	0.893
PEOU10	3.559	4.000	0.921
PEOU11	3.362	3.000	0.890
PEOU12	3.172	3.000	0.857
PU1	3.964	4.000	0.997
PU2	3.658	4.000	1.131
PU3	4.161	4.000	0.967
PU8	3.898	4.000	0.878

Source: own studies.

4.2. Verification of the hypotheses

Table 7 shows the verified hypotheses on the direct relations between the analysed variables. Hypothesis H_1 on stochastic independence between age and perceived usefulness of e-scooters: AGE → PU (β = -0.100, t = 2.703, p = 0.007) was supported. The size of the respondents' place of residence and their financial situation did not affect the perception of the usefulness of electric scooters: POR → PU (β = -0.046, t = 1.253, p = 0.211), FS → PU (β = -0.002, t = 0.041, p = 0.967). Thus, hypotheses H_2 and H_3 were not supported. Perceived ease of use of e-scooters affects the perceived usefulness of this mode of transport and attitude toward e-scooters: PEOU → PU (β = 0.597, t = 14.607, p<0.001), PEOU → ATT (β = 0.655, t = 21.634, p<0.001). Thus, hypotheses H_4 and H_5 were supported. Behavioural intention of use of e-scooters is affected by the attitude towards e-scooters and perceived usefulness of this mode of transport: ATT → BI (β = 0.356, t = 7.097, p<0.001), PU → BI (β = 0.299, t = 6.646, p<0.001). Thus, hypotheses H_6 and H_7 were supported. The H_{10} hypothesis was also confirmed. Behavioural intention to use of e-scooters affects the actual usage of e-scooters. BI → AU: (β = 0.558, t = 18.015, p<0.001). The last hypothesis concerned the mediating role of attitude toward e-scooters between perceived ease of use and behavioural intentions regarding the use of e-scooters: PEOU → ATT → BI (β =0.233, t = 6.499, p<0.001). Hypothesis H_9 was supported. Attitude toward e-scooters is a mediator of perceived ease of use and behavioural intentions regarding the use of e-scooters.

After confirming the above relations, we assessed the effect size of the predictor construct using f^2. The effect size is a measure used to assess the relevant impact of a predictor construct on an endogenous construct. According to Cohen (1899), the f^2 value of 0.02 or more is defined as a small effect, the value of 0.15 is seen as a medium effect, and the value of 0.35 or more is described as having a large effect. In the case of the relationship between the variables age and perceived usefulness, the effect size jest negligible, i.e., $f^2 = 0.016$. In the case of the relationship between perceived ease of use and perceived usefulness, perceived ease of use and attitude towards e-scooters, behavioural intention and actual usage of e-scooters there was a large effect size: PEOU → PU ($f^2 = 0.569$), PEOU → ATT ($f^2 = 0.752$), BI → AU ($f^2 = 0.449$). In contrast, there was a small effect size for the relationship between attitude toward e-scooters and behavioural intention, with: $f^2 = 0.127$.

Table 7. Summary of verified hypotheses

	B	t	*p*
AGE -> PU	-0.100	2.703	0.007
POR -> PU	-0.046	1.253	0.211
FS -> PU	-0.002	0.041	0.967
PEOU -> PU	0.597	14.607	0.000
PEOU -> ATT	0.655	21.634	0.000
ATT -> BI	0.356	7.097	0.000
PU -> BI	0.299	6.646	0.000
BI -> AU	0.558	18.015	0.000
PEOU -> ATT -> BI	0.233	6.499	0.000

Source: own studies.

5. DISCUSSION

Transportation difficulties have become one of the main problems for residents of large cities in Poland today (Dorocki, Wantuch-Matla, 2021; Płaziak, Szymańska, 2019). The increase in the number of vehicles and the need for ever – increasing mobility in commuting to work and school, especially from developing suburban areas, have contributed to the growing inconvenience of travel (Dorocki, 2022). These factors have simultaneously become the driving force behind the development of micromobility-based transport.

The 2020 survey found that most people used electric scooters for the first time to try out this innovative solution. The next most common motivation for the respondents was to use it purely for fun. The next less frequently selected responses were using an electric scooter as a cheaper or faster alternative, a more accessible solution or being encouraged to use it by family and friends. There were also isolated responses given by the respondents, such as an offer to purchase a scooter at an attractive price or a conscious choice of this mode of transport (Mering, Wachnicka, 2021). The results show that 45.9 per cent of people ride a unicycle with a maximum frequency being twice a week, while the remaining share, over 50 per cent, do so three or more times a week. Although many users use the scooter occasionally and mainly treat it as an attraction, the majority use it much more often for a specific purpose. The analysis of the responses revealed that 36% of respondents undertake journeys lasting between 10 and 20 minutes, 29.4% of respondents prefer journeys of up to 10 minutes, and 17.8% opt for commutes lasting between 20 and 30 minutes. The least frequently selected answer was an average journey time of more than 30 minutes, which was declared by only 16.8% of respondents. Determining the average travel time made it possible to determine the average length of the unicycle trips. The average speed of an electric scooter is taken as 25 km/h. Thus, users usually travel a distance of between 4 and 8 km by electric scooter.

Research by Eccarius and Lu (2018) found that among users of the shared e-scooter system; when commuting, the majority usually walked, cycled or used public transport. This is supported by research by James et al. (2019) which indicates that electric scooters are more likely to replace walking than other modes of transport, such as cars, bicycles, buses or taxis.

Previous experience with electric scooters is an important factor in increasing the propensity to use electric scooters. During a study of the Seoul metropolitan area in South Korea, Hong et al. (2023) discovered that people who have used an electric scooter at least once are more likely to travel by electric scooter. Based on the study findings, the authors suggest encouraging people to experience using an electric scooter by offering a free trial ride for first-time users.

Although the results show that e-scooters generate benefits, they also contribute to numerous safety problems (Félix, Orozco-Fontalvo, Moura, 2023). In their study, James et al. (2019) collected divergent responses regarding perceptions of safety and blocking of sidewalks by those using and not using electric scooters. As Gössling (2020) noted, it is important for urban planners to introduce policies in cities regarding maximum speeds, mandatory use of cycling infrastructure and dedicated parking. Also, it would also be necessary to limit the number of licensed operators.

According to studies published by McQueen and Clifton (2022) and Nikiforiadis et al. (2023), the acceptance of electric scooters increases when it is possible to use combined transport modes (e.g. e-scooter and a train or e-scooter and a car), but only if there is a clear reduction in travel time or convenient parking locations are available.

The crucial aspect in this context is the relationship between the availability of an electric scooter and the desire to combine it with another mode of travel. Those living in the central part of the city have greater access to electric scooters and are more likely to use them as part of their choice of transportation. For residents in suburban areas, electric scooters offer a convenient solution for travel, especially when public transportation options are limited in frequency and reach. Higher population density, number of residents, shorter distance to the city centre, and better street connectivity are correlated with more intensive use of e-scooters (Jiao, Bai, 2020).

Kroesen (2017) indicates that owning an electric scooter significantly decreases reliance on traditional vehicles, but also, to a lesser extent, reduces the use of cars and public transportation. Secondly, e-scooter owners reduce their car and public transport use more than those who own standard bicycles. And thirdly, on the level of vehicle ownership, the e-bike functions as an alternative to the conventional bicycle and does not act as a substitute for the car.

As shown by research conducted by Kopplin et al. (2021), e-scooter owners and non-owners differ in terms of their perception of the benefits connected with using e-scooters. More than half of e-scooter owners see them as a solution to the problem of air pollution, traffic jams and the low quality of public transport. Non-owners agree on the positive impact of e-scooters on noise reduction, but at the same time point to a high accident risk.

Some studies show that the development of electric, shared transport modes (scooters and electric bicycles) does not always have positive effects. Some studies (Hollingsworth, Copeland, Johnson, 2019) indicate that the intensification of the use of electric scooters may have a negative impact on the environment – results suggest that while electric scooters may be an effective solution to urban congestion, they do not necessarily reduce the negative environmental impact related to this mode of transport.

Another issue is the need to use specific applications to rent electric scooters. The user experience of mobile apps varies considerably from one electric scooter operator to another, as user interfaces are developed by entirely separate teams. While the usability of mobile applications is largely similar across companies, as they all provide essentially the same basic functionality (i.e. unlocking the scooter), they differ in their ease of use (Ratan et al., 2021).

When examining the issue of the development and acceptance of electric scooters, it is also important to consider the social context of the phenomena. Nowadays, the success of any new solution relies on its widespread dissemination through mass communication channels. Contemporary consumers not only seek and share information online, but they also actively create it. Moreover, they show a keen interest in content shared by influencers (Zatwarnicka-Madura, Nowacki, Wojciechowska, 2022). The communication of eWOM means that micromobility providers firstly need to be present on social media so that consumers can get to know them better, and secondly, they need to consciously shape the image of this form of urban transport in line with the expectations of their customers (Czarnecka, Kinelski, Stefańska, Grzesiak, Budka, 2022). At present, not only are social media users increasingly interested in environmental issues, but they also elicit more reactions to posts related to sustainability topics. Social networks provide a context in which users both reinforce their beliefs and values and try to replicate the behaviour of other users, which promotes the acceptance of new technological solutions (Domalewska, 2021).

6. CONCLUSION

This research represents one of the first studies into the acceptance of electric scooters as a manifestation of micromobility in Poland. Summarising the discussion, it can be concluded that micromobility is an important alternative to car transport in cities. Electric scooters offer great potential for the development of e-mobility and contribute to the reduction of car traffic congestion in cities, thus providing an important solution in terms of reducing urban traffic problems. However, local policy should consider the needs and circumstances of all road users as well as pedestrians using sidewalks. Indeed, the misuse of electric scooters can present significant risks. The challenge is to introduce appropriate regulations governing the use of electric scooters and an adequate system for monitoring their compliance. The introduction of legislation in numerous countries and cities is merely an initial step towards the comprehensive regulatory framework of this phenomenon.

In order to increase the level of acceptance of electric scooters and increase the frequency of their use, it is also necessary to develop measures that could promote or encourage sustainable mobility via trips that integrate public transport with electric scooters. This could be achieved by ensuring the availability of electric scooters near the main public transport hubs, making the combined journey more appealing and convenient, i.e. eliminating the need to find a rented electric scooter. This entails creating designated parking areas for e-scooters at strategic locations near public transport stations. Another benefit of designated e-scooter parking areas is the reduction of accidental scooter parking, a problem often associated with dockless systems.

7. LIMITATIONS AND DIRECTIONS FOR FURTHER RESEARCH

The study focuses only on university students in Warsaw, which may cause some limitations to the overall representativeness of the results. The extent to which electric scooters are used and the approach to this solution may be conditioned by demographic, sociocultural and economic variables as well as the place where the survey has been conducted, the availability of scooters, the availability of parking spaces, the condition of roads and the urban layout. It would therefore be reasonable to extend such surveys and include respondents with other demographic characteristics, living in both large agglomerations and smaller towns. This implies the need to carry out research covering a larger and more diverse population.

The present survey provides insights into current student behaviour, but it does not consider possible changes in the future. For example, developing public transport infrastructure or changes in legislation may affect the use of e-scooters. It would be worth conducting a cyclical survey covering this topic. A future survey may include factors such as the availability of cycling paths, the availability of parking spaces for scooters and other aspects of urban infrastructure affecting scooter use presented in the analysis.

Future studies on perceptions of electric scooters should also examine the issues related to the impact of pricing dynamics and promotional strategies. This might help to address the question of how promotions, discounts and changes in scooter rental prices affect students' decisions.

It may also be interesting to analyse how the use of scooters affects students' travel patterns, for example, whether it reduces the use of public transport or personal vehicles, how it shapes the habits and routines associated with the use of scooters, for example, where they are most often used, what routes are preferred and why, what factors influence travel time (e.g. distance, specific time or traffic).

It is also important to focus on the limitations of the original TAM model used. The model has continuously evolved, leading to the emergence of newer and increasingly complex versions (Venkatesh, Davis, 2000; Venkatesh, Morris, Davis, Davis, 2003). However, the application of any version of the model does not guarantee that all variables of interest in these models have been considered, which means that some important variables may have been omitted. Therefore, researchers should examine other potential options and models to examine the issue of technology adoption or application that have not been discussed in this paper.

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