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Energy-Efficient City Transportation Solutions in the Context of Energy-Conserving and Mobility Behaviours of Generation Z

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Abstract: Undertaking various activities aimed at sustainable development, especially energy conservation, is becoming one of the challenges of modern economies, including developing urban areas. One of the most widely promoted activities is designing and implementing energy-conserving solutions for urban mobility. People play a vital role in this regard, especially young people, represented here by Generation Z. Their attitudes and behaviours regarding sustainability can significantly impact the effectiveness of energy-efficient technological solutions. The purpose of this article is to examine the nature of the relationship between the assessment of the importance of energy-efficient transportation solutions available in the city and the attitudes and behaviours of representatives of Generation Z relating to the idea of sustainability, broken down into two categories, i.e., energy-conserving behaviour and mobility. In this study, a diagnostic survey method was used. Based on the literature review, we designed a research tool in the form of a questionnaire. Four hundred and ninety representatives of Generation Z participated in the study. To verify the hypotheses, first, a qualitative analysis was carried out for the three study areas using measures of central tendency; then, a correlation analysis was performed based on Pearson's chi-square independence test, and to determine the strength of the relationship, the following symmetric measures were used: Cramer's V and the Contingency Coefficient. The normalisation of the data, giving them a quantitative character, allowed the possibility of examining the correlation using Pearson's test and the directionality of the analysed relationships based on simple and multiple linear regression results. Ananalys is of the obtained results allows us to conclude that energy-related sustainable behaviours in the acquisition of electrical appliances, their use and disposal, and mobility-related energy-conserving behaviours, resulting from the choice of means of transportation for moving in the city, influence the assessment of the importance of available energy-efficient mobility solutions. City administrations could use the study results as a guideline for the implementation of energy-conserving solutions in urban transportation, as well as the planning and promotion of appropriate activities related to the mobility of Generation Z, that are adequate to the attitudes and behaviours of young people.

Keywords: energy saving; energy saving technologies; energy-efficient transportation; urban mobility; transportation solutions; Generation Z; attitudes and behaviours; smart city

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1. Introduction

Ensuring sustainability has become an overriding priority for many countries and institutions in any strategic action, as it has been recognised as a critical issue for economic development [1]. Today, sustainability denotes balancing environmental, human and economic systems based on the premise that organisations exist in an ecosystem, not in isolation [2]. In 2015, these three areas became the basis for the U.N. 2030 Agenda for Sustainable Development strategy to achieve the Sustainable Development Goals. This document contains 17 SDGs, which form the basis for all sustainable development activities and research, and their full wording makes it possible to clarify their meaning and significance. Some of the goals of most significant importance are Goal 7: Ensure access to affordable, reliable, sustainable and modern energy and Goal 11: Make cities inclusive, safe, resilient and sustainable [3].

In the modern world, the issue of integrating energy conservation, mobility and urban transportation has become a topic of much consideration, and it has been analysed for years [4,5]. These issues play a central role in current EU policies aimed at achieving energy conservation goals, independence from fossil fuels, reduction of CO_2 emissions and rationalisation of urban systems [6].

A literature review indicates that sustainable development related to energy conservation and urban transportation is the subject of many theoretical considerations and empirical studies [7]. Their scope is often comprehensive and includes infrastructure, capital, and technology [8]. Such a wide variety of areas makes it necessary to narrow the field of research and often concerns energy-efficient urban mobility [9].

The approach that appears to be the most comprehensive and long term refers to the concept of strategic mobility management. This approach can achieve a broader range of planning goals than many other strategies, and is able to address measures such as, for example, increasing available road space, increasing vehicle efficiency, and rationalising travel routes, among others. Consequently, this implies a need to either change the approach to the design of new cities, or to redesign existing ones [10]. Another context seen in articles is the use of innovative technical solutions closely related to energy-conserving technology, such as sensors [11], battery electric vehicles [12,13], or the use of the Internet of Things [14].

An important area of research described in the literature concerns the various energy-efficient modes of transportation used, especially in cities. Mendoza et al. described the potential for promoting energy-efficient and CO_2-free pedestrian and electric bicycle (e-bike) mobility through the ecological design of urban elements [15]. Issues of electric and traditional bicycle use and infrastructure quality, along with analysis of the accessibility and usability of urban bikeway systems, are also frequent research topics [16–18]. In Taiwan, which has the highest density of motorcycles in Asia, electric motorcycles are an environmentally friendly mobility solution due to their energy-efficient nature in the global context of environmental protection and low carbon emissions [19]. It is also worth pointing out the growing development of low-speed automated electric shuttle services as an on-demand shared mobility service in densely populated urban areas [20].

Providing an adequate network of urban infrastructure and environmentally friendly means of transportation is essential to creating energy-efficient urban mobility systems. However, according to the authors of this article, the most critical factor for success is the behaviour of people who may or may not want to take advantage of all these solutions. Thus, their actual, rather than declared, pro-environmental attitudes and behaviours are crucial [21,22]. Their attitudes toward ways to save energy through their choices of preferred modes of transportation play a unique role here [23]. Considering the previously cited document, i.e., Agenda 2030, adopted by the U.N. General Assembly [24], which calls for raising awareness of the Sustainable Development Goals, it has becomes sential to understand consumer attitudes and behaviour in this regard [25]. Young people representing Generation Z will play an important role in this process. Their attitudes towards sustainable development challenges, and energy conservation in particular, can influence the future achievement of the goals set out in Agenda 2030 [26,27].

Energy-efficient mobility is an essential topic for Generation Z, which is increasingly committed to fighting climate change and countering global environmental problems. Energy-efficient forms of transportation, such as public transportation, electric vehicles, bicycles and scooters, and car sharing, are just some of the solutions that young people use to achieve environmental goals [28–31].

The problem areas outlined above, relating to the use of energy-conserving solutions and the approach to these issues of young people representing Generation Z, formed the basis of the literature analysis conducted by the authors. Based on this, we identified a significant research gap. The literature analysis showed that there are studies indicating the attitudes and behaviours of young people in the context of energy conservation and urban mobility choices. There are also studies on the determinants of patterns of energy-conserving solutions in urban transportation. On the other hand, to the best of our knowledge, there are no studies that treat these areas together and examine the relationship between the energy-conserving behaviour and urban mobility of Generation Z representatives and their assessment of the relevance of energy-conserving solutions in urban transportation. We can therefore assume that the study of this relationship is part of the novelty of this research. Thus, the main research objective of the authors was to investigate the nature of the relationship between the assessment of the importance of energy-efficient transportation solutions available in the city and the attitudes and behaviours of representatives of Generation Z relating to the idea of sustainability, divided into two categories, i.e., energy-conserving and urban mobility behaviours.

In order to fill the identified research gap, we formulated the following two research questions:

1. Do energy-related sustainable behaviours in the acquisition of electrical appliances, their use and disposal affect the assessment of the importance of energy-efficient mobility solutions available in the city?
2. Do energy-related mobility behaviours resulting from the choice of transportation means for getting around affect the assessment of the importance of energy-efficient mobility solutions available in the city?

The results obtained in the research and described in the article fill a research gap and provide a potential research field for other authors. The obtained research results confirm that energy-related sustainable behaviours in the acquisition of electrical appliances, their use and disposal, and energy-related mobility behaviours resulting from the choice of specific modes of transportation for moving around the city influence the assessment of the importance of available energy-efficient mobility solutions.

2. Literature Review

2.1. Energy-Efficient Mobility to Support Sustainable Urban Development

2.1.1. The Concept of Sustainable Development in the Context of a Smart City

As an area that brings organisations, companies, and people together, the city serves as a catalyst for innovation, diversity, and creativity [32,33]. Currently, over half of the world's population resides in urban areas, and by the end of 2050, this number will increase to over 66% [34]. In Europe, two-thirds of the population live in cities; in Poland, approximately 60% of the population resides in urban areas [35]. Moreover, cities generate over 80% of the world's GDP [36]. In the case of Poland, 12 metropolitan areas contribute over half of the country's GDP [37]. Although cities are centres of social life and economic growth [38], they also have the highest levels of pollution worldwide [39]. They are responsible for over 70% of greenhouse gas emissions and more than 66% of global energy consumption [36]. Therefore, it has become necessary to focus on the environmental aspect and incorporate the concept of sustainable development in urban management [38].

The concept of sustainable development gained popularity in the 1980s with the publication of the report "Our Common Future", also known as the Brundtland report [40]. This report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [41]. The Brundtland report emphasised that meeting the needs of people and future generations is achievable by maintaining a balance between economic growth, social equality, and environmental stewardship. Thus, it highlighted the three main aspects of sustainable development: the economy, society, and the environment, later referred to as the triple bottom line [40,42–45]. Subsequently, the institutional dimension has emerged as a new aspect essential for implementing sustainable development policies [46,47].

Since 1987, global, international, national, and local legislation has addressed sustainable development. The concept of "sustainability" is emphasised in nearly every sector of the economy [48]. Since the early 1990s, authorities have also integrated this concept into urban development strategies. Implementing the principles of sustainable development in cities is challenging due to the concentration of various activities and the intricate relationships among stakeholders in this environment. Nevertheless, cities are the focal points where the principles of sustainable development need to be urgently applied [49].

The smart city concept provides a solution for implementing sustainable development principles in urban strategies. By making cities "smarter", we can mitigate the harmful effects of urbanisation and enhance the quality of life without harming the environment [38]. A smart city is a technologically advanced space that integrates information, people, and other urban elements using innovative technologies. The primary objective of a smart city is to establish a sustainable, eco-friendly, innovative, and competitive environment that enhances the well-being of its residents [50,51]. Therefore, this approach aims to restructure the functioning of urban socio-technical systems, making them the central agents of transformation in sustainable development [52].

2.1.2. The Importance of Energy Conservation in the City

As drivers of economic development in countries and regions, urban areas consume a vast amount of resources and contribute significantly to environmental pollution. Specific challenges faced by cities include substantial energy consumption [53]. Global electricity consumption is estimated to increase by an average of 3% annually [54]. Therefore, achieving energy conservation necessitates finding alternative approaches to urban development while overcoming extensive economic growth. It is crucial to emphasise that energy conservation promotes energy security and facilitates the reduction of CO_2 emissions into the environment [55]. Thus, it represents an important topic from an environmental protection standpoint. Numerous scholars emphasise the need to transition towards sustainable development by employing intelligent and digital solutions that enhance energy efficiency [56,57]. However, the issue of energy conservation is also evident in smart cities, as the extensive use of interconnected devices for autonomous city management results in high energy consumption [58,59]. Nonetheless, using digital solutions can enhance the energy efficiency of cities and optimise energy usage [14,55].

As emphasised by Marrero et al., energy conservation is the primary factor driving sustainable solutions in urban areas [60]. Therefore, numerous technologies and solutions have been developed to reduce energy consumption. One example is implementing an intelligent street lighting control system based on the Internet of Things (IoT) [54,61–63]. This solution enables immediate energy cost reductions of up to 35% and, with proper long-term implementation, reduces total consumption costs by up to 42% [64].

Another example is the use of smart grid technologies, which focus on providing sustainable and high-quality electricity [65]. Smart energy systems, integrating smart grids and buildings, enable real-time and effective energy management [66]. By employing smart grids, cities ensure a flexible energy supply, allowing them to fulfil their functions while enhancing operational efficiency [67].

Renewable energy sources (RES) represent a crucial aspect of energy conservation, significantly reducing pollutant emissions and enhancing residents' quality of life [68]. Using RES in the power system solves many problems, such as dependence on oil, environmental issues, and the volatility of energy prices. Renewable energy sources such as hydropower, solar power, wind energy, and bioenergy, supported by modern energy storage solutions [69,70], can fulfil a substantial portion of the electricity demand in smart cities [71].

Nowadays, consumers are also involved in the energy creation process, making it bi-directional by simultaneously taking on the role of energy producers [72]. This is fostered through the rapid development of private solar PV installations [73] and the introduction of innovative technologies favouring renewable energy production, such as piezo-electric systems [74] and hybrid cars using regenerative braking [75].

2.1.3. Energy-Conserving Technologies Related to Urban Mobility

Mobility and economic growth are closely intertwined [5]. Urban mobility, understood as "the freedom to move between specific locations in urban areas using the available transport network and transport services" [76] (p. 17), constitutes a crucial element in the functioning and development of cities [77,78]. It facilitates access to various goods, fosters broader connections, and enhances global awareness [5,9]. Furthermore, it enables access to essential services such as healthcare, education, and employment [79]. Thus, urban mobility holds immense significance for economic development and citizens' daily lives [32]. Despite its numerous advantages, mobility is responsible for a substantial increase in greenhouse gas emissions, consumes vast amounts of energy, and stands as one of the most polluting sectors [79,80]. The transport sector alone is estimated to account for 20% of global energy consumption [81]. Mobility also contributes to air pollution, adversely impacting urban residents' health. Traditional mobility negatively affects the following aspects [5]:

- Climate: It increases energy consumption and carbon dioxide emissions, consequently influencing climate change.
- Environment and Health: The rise in city congestion results in poor air quality, negatively affecting public health.
- Economic: Traffic congestion and time wastage lead to increased fuel costs.

Therefore, developing an effective mobility management strategy is a primary challenge for modern cities [82]. Sustainable mobility is the desired model for every smart city, providing a solution to urban mobility challenges [79]. Sustainable mobility positively impacts various transport aspects, such as reducing traffic congestion and optimising routes with minimal environmental impact [83]. Additionally, smart mobility involves the exploration of sustainable and innovative eco-friendly solutions, along with the integration of renewable energy sources in public transportation [84].

Energy conservation plays an exceedingly vital role in urban mobility. Chen et al. highlight that cities can achieve energy savings through changes in user behaviour, which can be implemented in three ways: reducing the number of trips, adopting less energy-intensive modes of travel, and minimising energy consumption per kilometre by attaining higher speeds and reducing the number of stops [81].

Cities themselves undertake various initiatives aimed at curbing excessive energy consumption in transportation. An example of such an initiative is investing in intelligent transport systems (ITSs) [85]. ITSs employ data collection and analysis to establish intelligent mobility management systems [86]. Modern information technologies in transport systems enable real-time transport information retrieval [87]. Furthermore, ITSs facilitate traffic control, creating low-emission zones, enhanced safety measures, and increased transport system efficiency [35].

Another example lies in promoting vehicles powered by eco-friendly fuels such as hydrogen, hybrid, and electric vehicles [86]. Introducing ecological transport systems contributes to advancements in renewable energy source utilisation. An increasing number of cities opt for eco-friendly public transportation, such as electric buses. Additionally, alternative means of transport like electric scooters and skateboards have gained popularity, encouraging citizens to embrace such solutions, particularly during peak hours when traffic congestion makes reaching destinations challenging [88].

Utilising new technologies in traditional transport, such as cars, significantly reduces energy consumption. This involves the development of mobile applications that users can download to cater to various needs like parking, bike sharing, carsharing, and carpooling [35].

Two phenomena will drive the evolution of smart mobility in the forthcoming years. The first is the adoption of robots, such as drones, for goods transportation. The second is the transition towards Mobility as a Service (MaaS), where people's mobility revolves around on-demand services. New technologies such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), and big data will play a crucial role in these areas [83].

2.2. Attitudes and Behaviours of Generation Z

2.2.1. Generation Z's Attitudes toward Sustainability

According to the framework adopted in the literature, Generation Z comprises people born between 1995 and 2010 [89]. Although different in many respects, young people born in this timeframe grew up in similar environmental conditions, and therefore, there are several features cited as those that constitute their characteristics as a single generation that is internally homogeneous, yet different from other generations [90]. Among such environmental conditions, the technological, economic, social and ecological spheres are often mentioned [91]. In the first area, it is worth emphasising that this is the first generation referred to as 'Digital Natives', i.e., brought up in the constant presence of modern, internet-based ICT technologies and the devices using them, including computers, as well as, increasingly, mobile devices [92,93]. The economic sphere represents a source of significant opportunities and challenges due to phenomena such as globalisation, economic crises or job instability [94]. Additionally, the social sphere, through the trends that dominated it while they were growing up, significantly impacted their attitudes and behaviours. Trends such as the increasing importance of diversity, social stratification and growing social movements are worth noting here [95,96]. The ecological sphere has also had a powerful impact on young people, further increased by the development of technologies providing them unprecedented access to information [97,98]. Several negative phenomena related to pollution, environmental disasters, or the negative impact of rapid technological and economic development on the ecological sphere, as well as threats related to the COVID-19 epidemic, have translated into young people's perception of the importance of this sphere of human activity on Earth [99].

Among the characteristics of the representatives of Generation Z, attitudes and behaviour in technology and sustainability are of extraordinary importance. Young people seem to be characterised by a level of awareness and a sense of responsibility for the fate of the Earth and future generations that is unparalleled in older generations [100]. A deep concern for the environment characterises them, and according to them, phenomena such as climate change and global warming, as well as developing clean and renewable energy, stopping pollution, recycling, reducing emissions, protecting wildlife, using fewer resources, reducing oil dependency, reducing waste, eliminating pesticides, and reusing resources are of particular importance [90,98,101]. Such concerns translate into many of their attitudes and behaviours manifested in different areas of daily life. They are more inclined toward environmentally friendly behaviour. They support sourcing energy from renewable sources [102–104], but also support sustainable consumption, including sharing and seeking to reduce resource consumption [105]. They consider environmental friendliness in their purchasing decisions and are more willing to pay a premium for sustainability [90,106,107], e.g., in the areas of food [108,109] or clothing [110–112]. They care about minimising waste generation (e.g., through minimal plastic and zero waste) [113–116], but also responsibly dealing with the waste generated [117–120].

2.2.2. Energy Conservation Attitudes and Behaviours of Generation Z

Energy literacy is a concept identified in the literature as a basis for analysing the energy conservation behaviour of people and households. According to its authors, DeWaters and Powers, this concept "encompasses broad content knowledge as well as affective and behavioural characteristics, will empower people to make appropriate energy-related choices and embrace changes in the way we harness and consume energy" [121]. The authors define such literacy based on knowledge, attitudes and behaviour.

Quite a few studies describe the knowledge and attitudes of Generation Z representatives towards conserving energy [104,122–124]. As mentioned earlier, they have broad access to information sources on the Internet, which has become their primary source of knowledge and allows them to acquire the necessary information at any time [125,126].

Attitudes and behaviours toward sustainable energy use are also an increasingly important element of the curriculum in their education. Sustainable attitudes and behaviours of young people are evident within the two areas adopted as the basis for research in this article, namely the drive to reduce energy consumption in everyday life, including urban travel. Young people now have a vast range of ways to access various information thanks to the development of ICT and mass media [90]. They are aware of the increasing threat posed by climate change, have knowledge of its causes and, due to the environmental sensitivity that characterises them, try to adopt attitudes and behaviours that encourage responsible energy procurement and use [127]. Young people present favourable attitudes and intentions to use renewable energy sources such as solar, geothermal, wind and bioenergy and support organisations that invest in this area [103,104,128]. Such attitudes are an intrinsic characteristic of Generation Z [98]. In this respect, too, the specific features of young people favour the emergence of higher levels of energy literacy. Therefore, representatives of Generation Z should display the necessary knowledge and attitudes to implement behaviours directed toward sustainable acquisition and energy consumption. It is worth noting here, however, that although research indicates that a translation of attitudes into behaviour does exist [129], a significant attitude–behaviour gap may also sometimes emerge, characterising those who declare their concern for energy conservation [130,131].

They make responsible purchases, considering in their decisions not only functional characteristics but also the environmental impact of products [106,107]. As some studies indicate, spill over effects between sustainability-oriented behaviours in the different spheres of everyday life are possible. Thus, attitudes and behaviours toward, e.g., responsible purchasing and responsible waste management may also be translated into behaviour related to conserving energy [132,133]. Among the representatives of Generation Z, there are already people who are establishing their own families and households, so their needs are changing along with the family's growing needs. They translate their pro-environmental norms and values into purchasing behaviour by choosing home appliances and light sources that provide energy-conserving opportunities and reduce greenhouse gas emissions [134,135]. Technologies such as Q.R. codes or smart tags enable them to obtain real-time information about each product's environmental impact, thus enabling them to make informed product choices [136]. They also support the development of a circular economy, where the idea to reduce, reuse and recycle materials in production, distribution and consumption processes as much as possible is promoted [116]. They therefore try to minimise the amount of waste produced in the context of, for example, plastic pollution [101,120]. Young people also recognise the need to segregate and responsibly deal with waste and e-waste [115,137,138]. However, according to some studies, their level of knowledge about the principles of behaviour is sometimes moderate [119].

The energy literacy approach identifies the extent of people's energy efficiency based on their knowledge, attitudes and behaviour. However, all of these elements can also be analysed from the perspective of the individual phases of the model describing the process-based Life Cycle Assessment (LCA) as Input, Utilisation and Output. This approach has been used, among others, to assess the environmental impact of specific products or services [139]. However, it can be adapted quite simply to analyse energy conservation behaviour. This is because they concern the sustainable ways of obtaining energy, e.g., from renewable sources, but also the selection and purchase of products regarding their future energy consumption (Inputs) [134,135]. An extensive range of behaviours is related to how energy is used and energy-conserving behaviour, such as switching off lights and appliances (Utilisation) [140]. However, energy-use behaviours do not end with the use of devices, as the ways in which they are disposed of is also a critical issue related to sustainable behaviours as the Output phase of LCA [138].

2.2.3. Mobility Attitudes and Behaviours of Generation Z

A crucial area concerning energy conservation among young people is their mobility and, therefore, their choice of mode of daily travel within the city. The number of available transportation modes is increasing along with technological advances, both in environmentally friendly energy sources and in supporting new ICT solutions. However, certain social and demographic phenomena are causing a change in the needs and behaviour of young urban dwellers and significantly impacting the increase in their popularity. Hence, new solutions are emerging in addition to traditional modes of commuting such as own vehicle, walking or conventional public transportation. Cities that aim to develop sustainably are trying to introduce new vehicles using environmentally friendly energy sources, such as electric or hydrogen vehicles, which reduce GHG and CO_2 emissions [141,142]. Driven by ecology in their lives, young people are aware of the impact of vehicle traffic on air pollution and climate change and therefore view these types of solutions positively [143]. At the same time, the availability of ICT supporting the use of the available means of transportation in the city makes them more comfortable. The various applications available to make it easier to check schedules, pay for tickets, or plan the entire route make young people more likely to choose public transport [144]. With rising car, fuel and insurance prices, public transportation is becoming an attractive alternative for getting around town. Hence the phenomena observed in many countries of declining driver's licenses or car ownership among young people [145–147].

Some sociocultural trends also foster the change in urban travel habits. One of these is the aforementioned sustainable consumption. Young people are less and less driven by the need to own things, which is no longer an important source of social status. There is therefore, as mentioned before, a product-to-service shift in young people's behaviour, referred to as MaaS (Mobility as a Service), which enables more efficient use of resources with respect to mobility services and public transport [146]. Thus, sharing services such as carsharing, bike sharing, and ridesharing are emerging [148,149].

A characteristic of representatives of Generation Z is also their strong online presence. They use the Internet as an essential medium for carrying out a wide range of activities related to both work and social relationships. The emergence of the COVID-19 pandemic only intensified these trends. These preferences have a significant impact on reducing the need for physical movement in urban spaces.

The increasing range of tasks carried out remotely and changes in leisure patterns in favour of online contact is reducing the need to travel longer distances, which has contributed to the development of the micro-mobility phenomenon, which refers to getting around town using "a range of personal light, low-speed vehicles such as electric bikes, e-scooters, and hoverboards, [that] are propelled by an electric motor, [and] others, e.g., conventional bicycles, skates, skateboards, and standing scooters, are solely powered by human energy" [150]. These vehicles provide access to transportation hubs with low economic and environmental impacts, while saving time by avoiding traffic jams, speeding up short-distance travel, and not requiring a driving license [150]. Sharing access to these types of vehicles also allows for additional impacts from sustainable consumption [149].

3. Materials and Methods

3.1. Objective, Hypotheses and Research Methods

The main objective of this study is to identify the relationship and impact of Generation Z's Energy Conserving Behaviours (BEH)—divided into two categories, i.e., Energy Conserving Behaviours (BEH_EN) and Mobility Behaviours (BEH_MOB)—on the assessment of the importance of energy-efficient Sustainable Mobility Solutions in Transport (SMS_TRANS). We classified the young people's energy-conserving behaviours according to the process-based Life Cycle Assessment in Input, Utilisation and Output [151]. In addition, we classified the behaviours in the context of urban mobility according to the energy intensity of the means of transportation studied as: high (HI), medium (MED) and low (LOW). To achieve this research goal, the authors formulated nine hypotheses concerning the two research questions.

The first question, related to the BEH_EN area, is as follows: Do energy-conserving sustainable behaviours in terms of obtaining electrical appliances and their use and disposal affect the assessment of the importance of energy-efficient mobility solutions available in the city?

Research hypotheses related to BEH_EN:

Hypothesis 1$_{\mathbf{(INA)}}$. *Those more likely to obtain energy from renewable sources rate more highly the importance of the availability of energy-efficient transportation solutions in the city*.

Hypothesis 2$_{\mathbf{(INB)}}$. *People who are more likely to purchase energy-efficient light sources and electrical appliances rate more highly the importance of the availability of energy-efficient transportation solutions in the city.*

Hypothesis 3$_{\mathbf{(US1)}}$. *People more likely to care about saving energy by turning off lights rate the importance of the availability of energy-efficient transportation solutions in the city more highly.*

Hypothesis 4$_{\mathbf{(US2)}}$. *People who are more likely to conserve energy by switching off unused electrical appliances from the outlet rate more highly the importance of the availability of energy-efficient transportation solutions in the city.*

Hypothesis 5$_{\mathbf{(OUT)}}$. *People who are more likely to care about disposing of electro-waste in appropriate places rate more highly the importance of the availability of energy-efficient transportation solutions in the city.*

The second question, related to the BEH_MOB area, is as follows: Do energy-related mobility behaviours resulting from the choice of means of transportation for getting around affect the assessment of the importance of the availability of energy-efficient mobility solutions in the city?

Research hypotheses relating to BEH_MOB:

Hypothesis 6$_{\mathbf{(HI)}}$. *People more likely to travel around the city by private car rate more highly the importance of the availability of energy-efficient transportation solutions in the city.*

Hypothesis 7$_{\mathbf{(MED)}}$. *People who travel more often by public transportation rate more highly the importance of the availability of energy-efficient transportation solutions in the city.*

Hypothesis 8$_{\mathbf{(LOWA)}}$. *People who walk more often in the city rate the importance of the availability of energy-efficient transportation solutions in the city more highly.*

Hypothesis 9$_{\mathbf{(LOWB)}}$. *People who are more likely to travel around the city by bicycle or scooter rate more highly the importance of the availability of energy-efficient transportation solutions in the city.*

The research model is presented in graphical form in Figure 1.

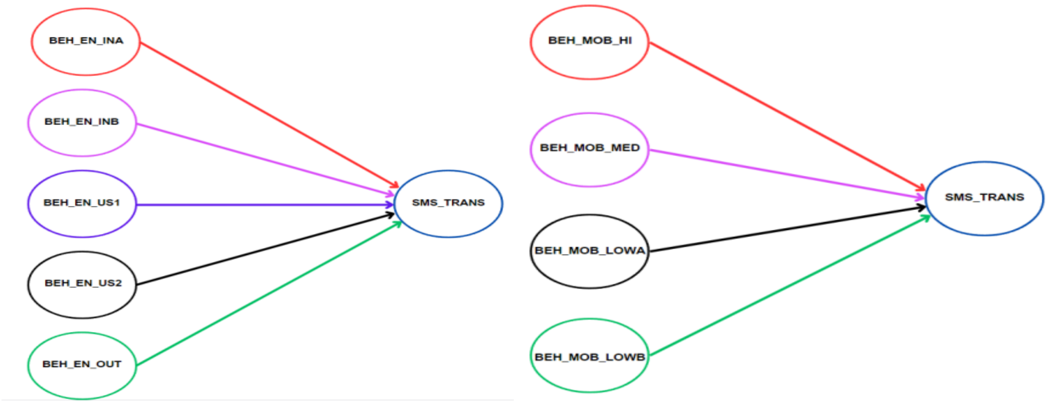

Figure 1. Graphic presentation of the research model. Source: own elaboration.

Based on the selected bibliographic items discussed in the Literature Review, a questionnaire was developed that included questions relating to three research areas, i.e., energy-conserving behaviours [106,122,127,152–156], energy-related mobility behaviours [148,149,157] and energy-efficient mobility solutions–transportation [9,79,158]. The last part of the questionnaire included questions about respondents—gender, level of study, place of residence, and phase in household life. The correctness of the construction of the questionnaire was verified in a pilot study.

The specifics of the research conducted on respondents' behaviours made it possible to use the R. Likert scale based on the ranking of variables that is often used in social research [159]. The following response scale was adopted in the energy-conserving behaviour sand energy-related mobility behaviours question: 1—never; 2—rarely; 3—often; 4—very often; 5—always. Respondents could evaluate transportation solutions in the third research area using the following scale: 1—completely irrelevant; 2—rather irrelevant; 3—neither relevant nor irrelevant; 4—rather relevant; 5—very relevant.

The adopted research objective determined the need to include the three abovementioned subject areas, which were described using the multivariate characteristics dedicated to them (Appendix A—Table A1). Energy-conserving behaviours (BEH_EN) were described on the basis of five variables (EN(INA(IN1),INB(IN2,IN3),US1,US2,OUT)), energy-related mobility behaviours (BEH_MOB) on the basis off our variables (MOB(HI,MED,LOWA (LOW1),LOWB (LOW2,LOW3,LOW4))), and energy-efficient mobility solutions–transportation (SMS_TRANS) on the basis of seven variables (ST(ST1,ST2. . .ST7)), which were subjected to individual and synthetic analysis based on the aggregated ST variable in the analytical part. The validity of the selection of variables and their composition was verified by scale reliability analysis. The determined values of Cronbach's alpha allow us to consider the set of SMS_TRANS as consistent, which in turn provides the basis for using a single aggregated ST explanatory variable in the analysis. The value of the test statistic 0.768 confirms the high reliability level. Two composite variables meeting the reliability criterion were used for explanatory variables: INB (0.704) and LOWB (0.601).

Verification of the research hypotheses embedded in the empirical material required the use of specific statistical tools. In the research process, first, a qualitative analysis was carried out for the three study areas using measures of central tendency. It was followed by a correlation analysis performed using Pearson's classic chi-square independence test. The statistical metrics that were used to determine the strength of the relationship included the symmetric measures Cramer's V and the Contingency Coefficient. The normalisation of the data, giving them a quantitative character, conditioned the possibility of examining the correlation using Pearson's test and the directionality of the analysed relationships based on simple and multiple linear regression results. In social research, the use of mixed analytical methods is considered the most effective solution [160], since such analysis allows the rejection of uncertain results. The statistical analysis was performed using the IBM SPSS Statistics version 27.

3.2. Demographic Profile of the Respondents

The research sample consisted of students from various universities in Lublin (Poland), living in the city and neighbouring towns, who travel around Lublin using multiple means of transportation. Lublin is a large academic centre due to the presence of 65,000 students who study there each year.

Lublin is a city in south-eastern Poland and is the capital of Lublin Voivodeship. Lublin is home to 340,000 inhabitants and covers an area of 147.4 square kilometres [161]. A network of urban transport, rail, and air connections connects Lublin to other parts of the country and the world. Urban transport in Lublin comprises 72 lines, including 13 trolleybuses. There are five park and ride car parks and 44 public car charging points in the city. As for bicycle infrastructure, there are 92 Lublin Urban Bike stations of and more than 180 km of cycle paths in the city. Two companies that rent electric scooters by the minute operate in the city (Bolt, Hopp). Carsharing (Panek) and big car sharing (City Bee) are available in the city. Shuttle services such as Bolt, Uber and Free Now are also in operation. Vehicles such as buses, taxis and electric cars can use dedicated lanes in some areas of the city (14.7 km in total). The city is working towards sustainable development and green transport, investing in a zero-emission public transport fleet.

The survey, conducted in March–June 2022 using the CAWI method [162], involved 490 people, and thus met the minimum sample size criterion for the general population, with an assumed error of 5%. All the respondents were 19–24 years old and were full-time students. Appendix A (Table A2) presents a detailed description of the respondents.

4. Results

The analysis indicates the presence of statistically significant correlations, including cause-and-effect, for the adopted research areas and the variables describing them. The following Results section will describe the detailed results of the realised study.

Measures of central tendency determined for the explanatory variables indicate the diverse nature of behaviour in each area. Due to the peculiarities of each area studied, they will be analysed separately.

The descriptive statistics in Table 1 indicate that the behaviour reflected by the variables included in the BEH_EN area varied. There was leftward asymmetry in the IN2 and OUT variables and rightward asymmetry in the US2 variable. For the remaining variables, the evaluation was not explicit. The US1 variable obtained the highest mean (4.26) and the lowest IN1 (2.95). The results obtained for the other variables ranged from 3.40 to 3.91. For the variable US1, more than half of the respondents indicated the highest possible answer. This response was also dominant for the variables IN2 and OUT.

Table 1. Measures of central tendency of the BEH_EN variable.

	Energy Non-Conserving Respondents		Energy Conserving Respondents		
Variable	**No.**	**(%)**	**Mean**	**Median**	**Dominant**
IN1	86	17.6	2.95	3	2
IN2	14	2.9	3.91	4	5
IN3	14	2.9	3.40	3	4
US1	2	0.4	4.26	5	5
US2	49	10.0	3.34	3	2
OUT	41	8.4	3.55	4	5

In the case of the BEH_MOB variable, indications of the intensity of frequency of use applied only to a fraction of respondents, and the number of respondents varied significantly in relation to the various means represented by the variables in this area. The remaining respondents indicated that they never used the means in question to get around the city. The number of non-users varied significantly from 6 people (1.2%) for LOW1 or 32 (6.5%) for MED, through a moderate number for HI (112 people), to an extensive group for LOW2 (267 people—54.5%) and LOW4 (279 people—56.9%). In contrast, the highest number of indications was for LOW3 (332—67.8%). Due to these discrepancies and the fact that lack of use unambiguously means lack of frequency, measures of central tendency were applied only to the frequency ratings of the remaining people (users). The measures of central tendency indicate that the frequency of use was not very high for any of the indicated means of travel (Table 2). Users assigned the highest average frequency to the variables LOW1 (3.39) and MED (3.29). A slightly lower score was given to the HI variable (2.91). The lowest average frequency of use was for the variables LOW3 (2.41), LOW4 (2.26) and LOW2 (2.13). None of the surveyed variables received a median or dominant score at the highest level on the scale. Low scores also dominated four of the six variables analysed (HI, LOW2, LOW3, LOW4). An unambiguous determination of asymmetry was not possible for any of the variables. The distributions of the results obtained were close to being a symmetrical distribution.

Table 2. Measures of central tendency of the BEH_MOB variable.

	Non-Users		Users		
Variable	**No.**	**(%)**	**Mean**	**Median**	**Dominant**
HI	112	22.9	2.91	2	2
MED	32	6.5	3.29	3	4
LOW1	6	1.2	3.39	4	4
LOW2	267	54.5	2.13	2	2
LOW3	332	67.8	2.41	2	2
LOW4	279	56.9	2.26	2	2

The descriptive statistics presented in Table 3 indicate a relatively high level of evaluation for the relevance of the indicated solutions described with the help of the variables in the SMS_TRANS area. Most of the variables received average ratings above 4.0, including SMS_TRANS4 (4.39), SMS_TRANS1 (4.33), SMS_TRANS5 (4.16), SMS_TRANS3 (4.11) and SMS_TRANS7 (4.09). The remaining variables were rated at average values of 3.69 (SMS_TRANS2) and 3.58 (SMS_TRANS6). For two variables (SMS_TRANS1 and SMS_TRANS4), more than half of the respondents' indications were for the highest possible rating, and were the dominant rating. The distributions of the obtained results were close to a symmetrical distribution for all variables.

Table 3. Measures of central tendency of the SMS_TRANS variable.

Variable	Mean	Median	Dominant
SMS_TRANS1	4.33	5	5
SMS_TRANS2	3.69	4	4
SMS_TRANS3	4.11	4	4
SMS_TRANS4	4.39	5	5
SMS_TRANS5	4.16	4	4
SMS_TRANS6	3.58	4	4
SMS_TRANS7	4.09	4	4

4.1. Energy-Conserving Behaviours (BEH_EN)

The first set of predictors of SMS_TRANS covered the BEH_EN area. Analysis of the results indicates that at the level of the individual independent variables, it is possible to demonstrate the existence of an effect of BEH_EN on SMS_TRANS. The chi-square independence test returned values indicating the presence of statistically significant relationships between some of the pairs tabulated (Table 4). The strength of the identified relationships is low. It was not possible to confirm a statistically significant association of ST2 with any of the variables describing BEH_EN.

Table 4. BEH_EN vs. SMS_TRANS—chi-square tests results.

Variable	Chi-Square Tests		Symmetric Measures	
	Value	***p*** *	**Cramer's V**	**Contingency Coefficient**
IN2 × ST1	36.498	0.002	0.136	0.263
IN3 × ST1	65.714	<0.001	0.183	0.344
US1 × ST1	50.247	<0.001	0.160	0.305
US2 × ST1	28.444	0.028	0.120	0.234
OUT × ST1	69.969	<0.001	0.189	0.353
IN3 × ST3	39.249	0.001	0.142	0.272
IN2 × ST4	28.821	0.025	0.121	0.236
US1 × ST4	37.308	0.002	0.138	0.266
OUT × ST4	36.560	0.002	0.137	0.263
US1 × ST5	50.247	<0.001	0.160	0.305
IN1 × ST6	28.727	0.026	0.121	0.235
OUT × ST6	27.791	0.033	0.119	0.323
US2 × ST7	28.330	0.029	0.120	0.234

* Asymptotic significance (two-sided). Effect significant at $p < 0.05$. Only statistically significant relationships are indicated in the table.

The correlations identified by the chi-square test are partially confirmed by the Pearson's correlation coefficient values (Table 5). At the same time, other correlations were identified. The obtained results indicate an indistinct and average strength of the relationship. It should be noted that this time, in the case of the ST5 variable, no relationship turned out to be statistically significant. However, in the case of the aggregated ST variable, the correlation with each explanatory variable was confirmed, and the results obtained indicate relatively stronger relationships compared to individual relationships.

The results of simple linear regression indicate that each of the predictors included in the analysis had a significant effect on the aggregate ST variable (Table 6). The results obtained are in line with the Pearson's correlation analysis. Apart from the individual impact of each BEH_EN component on SMS_TRANS, the results of the multiple regression did not conclusively confirm the existence of an aggregate effect of all predictors on the ST variable. Despite the positive verification of the entire model by means of an ANOVA test, the criterion of statistical validity was not met by two variables. The final form of the causal model was reduced to three dependent variables using a backward stepwise regression procedure. The first to be eliminated was the variable US2, due to failure to meet the criterion derived from the *t*-test. In the next step, the INB variable was eliminated due to the presence of high collinearity with the other predictors. Both variables have the lowest relative quality of fit for simple models. R Square values indicate high and very high qualities of fit for all models. The highest quality of fit was found for the multivariate model. The final model also met the criterion for the absence of first-order autocorrelation at the 0.01 significance level, as verified by the Durbin–Watson test. The exclusion of the phenomenon of autocorrelation was not confirmed for individual regressors in simple models. Given the peculiarities of the studied dataset and the scope of the conducted analysis, which is static in nature, the results of the Durbin–Watson test do not warrant rejection of the results as being statistically insignificant.

Table 5. BEH_EN vs. SMS_TRANS—Pearson's correlation results.

Variable Coefficient (*p*)	INA	INB	US1	US2	OUT
ST1	0.115 *	0.220 **	0.138 **	0.088	0.247 **
	0.011	<0.001	0.002	0.051	<0.001
ST2	0.058	0.105 *	0.038	−0.004	0.028
	0.197	0.020	0.407	0.927	0.529
ST3	0.142 **	0.126 **	0.080	−0.033	0.033
	0.002	0.005	0.076	0.461	0.472
ST4	0.082	0.174 **	0.094 *	0.014	0.143 **
	0.069	<0.001	0.038	0.764	0.001
ST5	−0.023	0.016	0.026	−0.049	−0.044
	0.619	0.722	0.570	0.275	0.327
ST6	0.137 **	0.114 *	0.022	0.128 **	0.117 **
	0.002	0.012	0.622	0.005	0.009
ST7	0.048	0.133 **	0.048	0.053	0.064
	0.294	0.003	0.292	0.246	0.160
ST	0.190 **	0.306 **	0.161 **	0.115 *	0.408 **
	<0.001	<0.001	<0.001	0.011	<0.001

** Correlation is significant at the 0.01 level (two-tailed). * Correlation is significant at the 0.05 level (two-tailed).

Table 6. BEH_EN → SMS_TRANS—linear regression results.

Variable	R Square	Durbin–Watson	ANOVA	
			F	*p* *
INA	0.832	1.608	2429.207	<0.001
INB	0.933	1.863	6778.486	<0.001
US1	0.946	1.796	8507.278	0.001
US2	0.847	1.665	2712.491	<0.001
OUT	0.887	1.610	3829.800	<0.001
INB, US1, OUT	0.960	1.863	3890.297	0.001

Coefficients						
Variable	(1) Unstandardised (2) Standardised		*t*-Test		Collinearity Statistics	
	1	2	t	*p* *	Tolerance	VIF
INA	1.275	0.912	49.287	<0.001	-	-
INB	1.041	0.966	82.332	<0.001	-	-
US1	0.896	0.972	92.235	<0.001	-	-
US2	1.097	0.920	52.082	<0.001	-	-
OUT	1.051	0.942	61.885	<0.001	-	-
INB	0.197	0.141	6.480	<0.001	0.174	5.750
US1	0.585	0.635	23.343	<0.001	0.111	8.987
OUT	0.254	0.227	8.819	<0.001	0.124	8.088

* Acceptable level: $p < 0.05$. Only statistically significant relationships are indicated in the table. (1) and (2) refer to the column titles below—column entitled 1 contains values for a non-standardized variable, while column entitled 2—values for a standarised variable.

The results obtained therefore confirm the correct choice of explanatory variables in relation to the explanatory variable.

The correlation and regression analysis results indicate that all BEH_EN aggregates hada statistically significant effect on SMS_TRANS. On an individual basis, the INA variable hadthe greatest impact on the value of the ST variable (1.275), and the US1 variable hadthe least (0.896). At the same time, these are not significant differences. This relationship wasnot confirmed by the combined model, in which the INA variable didnot appear. The final form of the multiple regression model shows that the US1 variable (0.585) hadthe strongest effect on the ST explanatory variable.

In summary, all components of BEH_EN were found to be statistically correlated with SMS_TRANS, but in different areas of the dependent variable and with varying relationship strengths. Regardless of the identified differences, the study's results provide support for hypotheses 1–5 (Table 7).

Table 7. Verification of research hypotheses 1–5.

Symbol	Content of the Hypothesis	Hypothesis Verification
$H1_{(INA)}$	Those more likely to obtain energy from renewable sources rate the importance of energy-efficient transportation solutions in the city more highly.	Supported
$H2_{(INB)}$	Those more likely to purchase energy-efficient light sources and electrical appliances rate the importance of energy-efficient transportation solutions in the city more highly.	Supported
$H3_{(US1)}$	Those more likely to care about saving energy by turning off lights rate the importance of energy-efficient transportation solutions in the city more highly.	Supported
$H4_{(US2)}$	People who are more likely to save energy by switching off unused electrical appliances from the outlet rate the importance of energy-efficient transportation solutions in the city more highly.	Supported
$H5_{(OUT)}$	Those more likely to take care of the disposal of electro-waste in appropriate places rate the importance of energy-efficient transportation solutions in the city more highly.	Supported

Source: own elaboration.

Analysis of the obtained results allows us to confirm that energy-conserving behaviours in the acquisition of electrical appliances, as well as their use and disposal, have a statistically significant and positive impact on the assessment of the importance of the availability of energy-efficient mobility solutions in the city.

4.2. *Energy-Related Mobility Behaviours (BEH_MOB)*

The second set of SMS_TRANS predictors covered the BEH_MOB area. The presence of statistically significant relationships between the SMS_TRANS and BEH_MOB variables constituting the aggregates was confirmed by the results of the chi-square independence test (Table 8).

Table 8. BEH_MOB vs. SMS_TRANS—chi-square test results.

Variable	Chi-Square Test		Symmetric Measures	
	Value	*p* *	Cramer's V	Contingency Coefficient
HI × ST1	69.969	<0.001	0.189	0.353
MED × ST1	73.309	<0.001	0.193	0.361
LOW1 × ST1	38.539	0.008	0.140	0.270
LOW1 × ST2	37.728	0.010	0.139	0.267
LOW2 × ST2	26.866	0.043	0.152	0.290
LOW3 × ST2	45.094	0.001	0.160	0.305
LOW1 × ST3	32.277	0.040	0.128	0.249
LOW4 × ST3	61.540	<0.001	0.177	0.334
MED × ST4	63.448	<0.001	0.180	0.339
LOW1 × ST5	45.055	0.001	0.152	0.290

Table 8. *Cont.*

Variable	Chi-Square Test		Symmetric Measures	
	Value	p *	Cramer's V	Contingency Coefficient
LOW3 × ST5	45.028	0.001	0.152	0.290
MED × ST6	57.002	<0.001	0.171	0.323
LOW1 × ST6	36.482	0.013	0.136	0.263
LOW3 × ST7	119.766	<0.001	0.247	0.443

* Asymptotic significance (two-sided). Effect significant at $p < 0.05$. Only statistically significant relationships are indicated in the table.

The correlation analysis did not confirm all of the relationships determined by the chi-square independence test (Table 9). At the same time, other correlations were identified. Not all components of BEH_MOB proved to be statistically correlated with the ST aggregate variable. The relationship was not confirmed in the case of the HI variable. Moreover, for this variable, the correlation with the ST1 aggregate was negative and statistically significant. However, the strength of this relationship was very small. At the same time, it should be noted that the Pearson's correlation coefficient was negative in four pairs of ST aggregates with the HI variable. The lack of statistical significance of most of these relationships certainly translates into a lack of correlation between HI and the ST composite variable. Similarly, as in the case of BEH_EN in the ST5 aggregate area, the determined Pearson's correlation coefficients indicate the absence of a statistically significant relationship with all BEH_MOB components.

Table 9. BEH_MOB vs. SMS_TRANS—Pearson's correlation results.

Variable Coefficient (p)	HI	MED	LOWA	LOWB
ST1	−0.097 *	0.280 **	0.151 **	0.044
	0.033	<0.001	<0.001	0.327
ST2	0.107 *	0.062	0.004	0.097 *
	0.018	0.168	0.935	0.033
ST3	−0.025	0.176 **	0.060	0.163 **
	0.583	<0.001	0.188	<0.001
ST4	−0.018	0.203 **	0.075	0.111 *
	0.686	<0.001	0.096	0.014
ST5	0.042	0.088	0.042	0.028
	0.352	0.051	0.358	0.543
ST6	−0.065	0.136 **	0.063	0.064
	0.148	0.003	0.162	0.157
ST7	0.089 *	0.106 *	0.013	0.089 *
	0.049	0.019	0.778	0.049
ST	0.016	0.241 **	0.100*	0.144 **
	0.731	<0.001	0.027	0.001

** Correlation is significant at the 0.01 level (two-tailed). * Correlation is significant at the 0.05 level (two-tailed).

Regression analysis based on simple models did not provide a basis for excluding individual predictors of SMA_TRANS (Table 10). The results obtained are in partial agreement with the analysis of Pearson's correlation. The results of simple regression confirmed the existence of a statistically significant effect of all BEH_MOB components on the ST variable, and the results of multivariable regression confirmed the existence of a combined effect of all predictors on the ST variable. The positive verification of the multivariate model by means of an ANOVA test is covered by the individual variables' assessments of their statistical significance (t-test) and lack of collinearity (collinearity statistics). The R Square values indicate average, high and very high qualities of fit for all regression functions. The highest level of fit was found for the multivariate model. The initial model, which was also the final model, also met the criterion for the absence of first-order autocorrelation at the 0.01 significance level (Durbin–Watson test).

Table 10. BEH_MOB → SMS_TRANS—linear regression results.

Variable	R Square		Durbin–Watson		ANOVA	
					F	*p* *
HI	0.603		1.132		743.760	<0.001
MED	0.832		1.503		2418.968	<0.001
LOWA	0.894		1.869		4141.094	<0.001
LOWB	0.469		0.922		431.239	<0.001
HI, MED, LOWA, LOWB	0.951		1.976		2375.553	0.001
Coefficients						
Variable	[1] Unstandardised [2] Standardised		*t*-Test		Collinearity Statistics	
	1	2	t	*p* *	Tolerance	VIF
HI	1.193	0.777	27.272	<0.001	-	-
MED	1.111	0.912	49.183	<0.001	-	-
LOWA	1.089	0.946	64.351	<0.001	-	-
LOWB	2.609	0.685	20.766	<0.001	-	-
HI	0.365	0.238	16.635	<0.001	0.491	2.037
MED	0.397	0.326	14.187	<0.001	0.189	5.285
LOWA	0.526	0.457	18.423	<0.001	0.163	6.143
LOWB	0.206	0.054	3.969	<0.001	0.538	1.857

* Acceptable level: $p < 0.05$. Only statistically significant relationships are indicated in the table. [1] and [2] refer to the column titles below—column entitled 1 contains values for a non-standardized variable, while column entitled 2—values for a standarised variable.

The results confirm the correct choice of explanatory variables in relation to the explained variable and confirm the existence of a statistically significant effect of BEH_MOB on SMS_TRANS.

The results obtained by means of correlation and regression analysis indicate that not all components of BEH_MOB had a statistically significant effect on the ST variable, which ultimately allows positive verification of hypotheses 7–9 (Table 11). In the case of hypothesis $H6_{(HI)}$, the results obtained do not warrant its acceptance due to the discrepancies in interpretation when applying different research tools.

Table 11. Verification of research hypotheses 6–9.

Symbol	Content of the Hypothesis	Hypothesis Verification
$H6_{(HI)}$	Those more likely to travel around the city by private car rate more highly the importance of the availability of energy-efficient transportation solutions in the city	Not supported
$H7_{(MED)}$	People who travel more often by public transportation rate more highly the importance of the availability of energy-efficient transportation solutions in the city	Supported
$H8_{(LOWA)}$	People who walk more often in the city rate more highly the importance of the availability of energy-efficient transportation solutions in the city	Supported
$H9_{(LOWB)}$	Those more likely to travel around the city by bicycle or scooter rate more highly the importance of the availability of energy-efficient transportation solutions in the city	Supported

Source: own elaboration.

On an individual basis, the variable LOWB (2.609) had the greatest and LOWA (1.089) had the smallest impact on the value of the ST variable.

Analysis of the results allows us to confirm that energy-related mobility behaviours resulting from the choice of specific modes of transportation in the city, such as public transportation, bicycle, scooter and walking, have a statistically significant and positive impact on the assessment of the importance of energy-conserving mobility solutions. This relationship was not confirmed when respondents moved around the city by private car.

5. Discussion

Assuming that an assessment of the relevance of energy-efficient urban transport solutions is a manifestation of a positive attitude toward sustainable city mobility, we can conclude that our study confirms that there are statistically significant relationships between the areas of energy-conserving behaviour and the choice of means of urban travel of young people and their attitudes toward the development of a sustainable transport system in a city. These results are consistent with those in other studies available in the literature.

The energy-conserving behaviour of young people is a manifestation of this generation's characteristic pro-environmental attitude. Representatives of Generation Z pursue pro-environmental values in their purchases and are willing to choose sustainable products even if they have to pay more for them [90,106,107]. Our study results confirm the propensity of young people to do so.

Many authors point out that young people's pro-environmental attitudes often do not translate into their real-world behaviour [4], which the results obtained in our study seem to confirm, albeit only partially. The confirmation is only partial, as the area of the surveyed young people's involvement in taking care to turn off the lights in the room received a very high average score in our survey, the highest in the entire area concerning energy-conserving behaviours. However, the behaviour in the area of turning off appliances and not leaving them on standby received a much lower rating, which is consistent with other studies available in the literature. As the literature analysis indicates, this type of action is generally less visible in young people's behaviours due to factors such as discomfort associated with the need to break certain habits, to be constantly aware of their everyday activities in this context, or finally to put more effort into the implementation of such energy-conserving behaviours [122,130,163].

Although collectively, all of the energy-conserving oriented behaviours we investigated significantly influenced their attitudes toward energy-efficient urban transportation solutions, this relationship was particularly evident for the purchase of energy-efficient light sources and appliances, which correlated significantly with almost all types of sustainable transportation solutions analysed. Thus, it seems that, following the studies available in the literature, young people who declare adherence to pro-environmental values are also willing to make sustainable purchases in this area [134,135,164]. These findings are also consistent with research indicating that the level of awareness among young people about the need to save energy is high [165].

The described ways of getting around the city are not disconnected and are often used interchangeably [5]. The highest frequency, according to the results obtained in our study, was for walking, which confirms results available in the literature [166]. The second most frequently used mode of mobility was public transportation. In most studies, public transportation is a frequently used form of transportation. However, its popularity depends on factors such as the density of the transportation networkand the convenience and quality of transportation [167,168], as well as factors that are more subjective in evaluation, such as perception of benefits (environmental, reduction of traffic congestion, traveller's comfort, shortening of travel time) [169], friendly, helpful and polite customer service [143], or perceived safety [170]. Our research confirms this transportation mode's popularity among the study group.

Less than half of the people surveyed used the other low-energy-consuming means of urban mobility—micro-mobility solutions, such as bicycles (own or city bikes) and scooters. The study results partially confirm the conclusions of the literature analysis on getting around the city using these modes of transportation. As previous studies indicate, getting around the city by micro-mobility allows one to cope with several negative phenomena occurring in cities, such as external transportation costs, traffic congestion, emissions, parking and car accidents [171,172]. However, their use is associated with several constraints related to safety (accidents), limitations of use (inability to carry luggage or share trips with others, and a lack of protection from weather conditions), and factors of a technical nature (breakdowns, rental difficulties, charging problems) [150,171–173]. Our survey results indicate that although the percentage of users for all modes of micro-mobility studied is relatively low, scooters are the least popular means of urban travel. Since the survey results in the literature are inconclusive, this confirms some of the available findings [171,174] while contradicting others [149,175]. The question arises as to whether a relationship in which the use of bicycles is much more popular is the target situation, or whether this mode of transportation, which is still in its early stages of development, is just beginning to build its popularity. However, it is undoubtedly a slower process than described in studies from other parts of the world, such as the United States, might suggest [176].

Travelling around town in a private car is a mobility mode that deserves particular attention. We couldn't confirm the positive relationship between the car mobility variable and the attitude toward energy-conserving solutions in the city's transportation. This finding, however, is not much of a surprise, given that numerous studies have proved that private car owners often have a different attitude toward environmental issues than non-owners, as presented, for example, in studies concerning attitudes toward the introduction of administrative solutions for reducing exhaust pollution, such as the congestion charges applied in various cities around the world [177–180]. In the case of our study, due to inconsistent results obtained using two different statistical methods, we were unable to show whether there was a statistically significant relationship between driving one's own car and one's evaluation of transportation solutions that in volvelow-emission vehicles, carsharing, or the availability of car charging stations.

Except for private cars, all other forms of urban mobility were significantly related among young people to their attitudes toward energy-efficient urban transportation solutions. However, moving on foot stands out from the other modes of travel. For this variable, the only solution linked in a statistically significant way was low-emission vehicles in urban transport. Such a relationship is also not surprising. Indeed, people on foot are at high risk of exposure to traffic pollutants that directly threaten their health and significantly affect their years of life expectancy (YLE) [181,182]. Hence, it is understandable that this variable was particularly important to them.

6. Conclusions and Limitations

In today's world, energy-conserving behaviour is fundamental, especially with respect to mobility. Awareness of this problem should be significant, especially among young people, who will be a large group of energy consumers in the future.

Representatives of Generation Z prefer change and are constantly on the move, which may translate into their increased need to move around, contributing to the excessive energy intensity of transportation processes. The energy security of future generations may depend on their awareness of the need to save energy.

The authors' main research objective was to identify the relationship between and impact of Generation Z's sustainability behaviours, divided into two categories, i.e., energy-consereving and mobility behaviours, on assessing the importance of the availability of energy-efficient transportation solutions in the city.

Based on the results of this study, it can be concluded that energy-conserving sustainable behaviours in terms of obtaining electric devices, and their use and disposal, as well as energy-related mobility behaviours resulting from the choice of specific modes of transportation for moving around the city, such as by public transportation, bicycle, scooter, orwalking, have a statistically significant and positive impact on the assessment of the importance of energy-efficient mobility solutions. This relationship was not statistically confirmed among respondents who moved around the city by private car. The study results enabled the authors to achieve their set goal, verifying the formulated research hypotheses and filling the identified research gap.

However, the results presented have some limitations. First, it should be remembered that various factors may be relevant to Generation Z's disclosure of certain behaviours. One of them is the issue of young people's autonomy. Their decisions, particularly their purchasing decisions, can be influenced by their parents, with whom they may live [140]. In the case of the study described here, this issue may be particularly relevant, given that dependents accounted for 58.9% of the sample. Unless they invest in them themselves, they may also have limited options in terms of renewable energy sources, such as photovoltaics [104]. Another factor that may influence their transportation behaviour is the distance they travel each day and the availability of convenient connections on public transportation [171,183–185].

The second type of limitation is related to the research sample, which was not fully representative of the entire population of Generation Z. This is because it consisted of representatives of universities located in one city in Poland.

The energy-conserving behaviour of the younger generation is a topic that requires in-depth research in the future. Therefore, the results can serve as inspiration for other researchers to conduct analyses in various other fields of study.

The study's conclusions may be useful to Gen Z city transport users, who can build on them to increase their commitment to environmentally friendly mobility in the city. This effect can be achieved by improving energy literacy levels and building young people's awareness of sustainable mobility. However, it seems crucial to translate the resulting attitudes into their behaviour and habits.

At the same time, the results described in this article can be used by administrative authorities in cities as a guideline for how and to what extent to implement energy-conserving solutions in urban transportation, as well as to plan and promote appropriate mobility activities tailored to the attitudes and behaviours of representatives of Generation Z.

The examples above of the potential audience for these research results constitute only a fraction of the potential stakeholders who may be affected by them. It is worth noting that, among them, it is possible to identify entities such as, e.g., universities, which are co-responsible for the education of young people, or transport companies, which, by adapting their offer to the needs and expectations of the representatives of generation Z, may influence their preferences regarding responsible urban mobility. In conclusion, ensuring the effectiveness of energy-conserving sustainable mobility measures depends on the joint commitment of all stakeholders.

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Appendix A

Table A1. Items, indicators of items, and variables used in the research.

General Item Symbol	Item Name/ Detailed Item Symbol	Answers/Variables
BEH	**SUSTAINABLE BEHAVIOURS**	
BEH_EN	***ENERGY-CONSERVING BEHAVIOURS***	
Input (IN)	Energy sources and electrical devices purchases	
INA	Renewable sources	
	IN1	I get energy from renewable sources.
INB	Electrical equipment	
	IN2	I buy energy-saving bulbs.
	IN3	I buy energy-saving appliances.
Utilisation (US)	Use of electrical appliances	
	US1	I take notice of lights that areleft on.
	US2	When I am not using electronic devices, I unplug them and do not leave them on standby.
Output (OUT)	Disposal of electrical equipment	
	OUT	I deliver electro-waste to specialised e-waste collection points.
BEH_MOB	***ENERGY-RELATED MOBILITY BEHAVIOURS***	
High (HI).	High-energy-consuming means of transportation	
	HI	Private car
Medium (MED)	Medium-energy-consuming means of transportation	
	MED	Public transport
Low (LOW)	Low-energy-consuming means of transportation	
LOWA	Low-energy-consuming means of transportation (On foot)	
	LOW1	On foot
LOWB	Low-energy-consuming means of transportation (City bicycle, Private bicycle, Scooter)	
	LOW2	City bicycle
	LOW3	Private bicycle
	LOW4	Scooter
SMS	**ENERGY-EFFICIENT SUSTAINABLE MOBILITY SOLUTIONS**	
SMS_TRANS	***TRANSPORTATION***	
	ST1	Low-emission vehicles (electric, trolleybuses, ecological city fuel)
	ST2	Car rental (Carsharing, e.g., Panek)
	ST3	Scooter rental
	ST4	City bike rental
	ST5	Cabs (including Bolt and Uber)
	ST6	Carpooling (commuting together by car)
	ST7	Charging stations for electric cars

Source: own elaboration.

Table A2. Sample structure.

Group	Number of Respondents	Percentage
	Total	
-	490	100.0
	Gender	
Women	256	52.2
Men	234	47.8
	Phase in household life cycle	
My parents support me	289	58.9
Single-person household (Single)	159	32.4
A marriage (partnership) without children	34	6.9
A marriage (partnership) with young children	8	1.6

Table A2. *Cont.*

Group	Number of Respondents	Percentage
	Level of study	
First-degree studies (B.A.)	274	55.8
Second-degree studies (MA)	207	42.2
5-year Masters course	9	1.8
	Registration of residence (number of inhabitants)	
Lublin	123	25.1
rural area	196	39.9
urban area, up to 15,000	55	11.2
urban area, up to 150,000	96	19.6
urban area, up to 300,000	17	3.5
urban area, over 300,000 (other than Lublin)	3	0.6

Source: own elaboration.

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