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Future Development of an Energy-Efficient Electric Scooter Sharing System Based on a Stakeholder Analysis Method

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Abstract: E-scooters as a new form of mobility are gaining more and more popularity. This popularity results from the flexibility of this mode of transport, but above all from the positive impact on the natural environment through the much higher energy efficiency of an e-scooter compared to a motor vehicle (according to the literature the rate is 2 km per kWh equivalent for a motor vehicle and the range is 90–100 km per kWh in the case of an e-scooter). This paper introduces a discussion on the future development of an energy-efficient electric scooter sharing system based on stakeholder analysis methods. The implementation of the e-scooter sharing system involves linking several areas of human activity, including social activity. This, in turn, relates to the interactions and building of relationships with entities, particularly those influencing the provision of services and their effects. The large number of entities and the complexity of the relations between them make it a challenge both to identify stakeholders in the development of the public e-scooter system and to indicate their roles in shaping the sustainable development strategy for urban mobility. The following study was based on the methodological foundations of stakeholder theory and social network analyses. The main research objective of the article is to identify and assign to different groups the stakeholders influencing the sustainable development of energy-efficient e-scooter sharing systems based on Polish cities. An evaluation was carried out using expert methods with a stakeholder analysis, based on matrix and mapping methods, and with the MACTOR application. Relationships and cooperation suggestions were established for each of the stakeholder groups, which could become an important part of the strategic approach to supporting public transport service providers and organizers, as well as allowing for further reductions in energy consumption in the city by introducing such services on a large scale. The cooperation of the entities participating in the implementation of bike-sharing services can contribute to their greater sustainable development and assurance using the new mobility modes, which consume less energy and at the same time make the city energy-efficient.

Keywords: electric scooter sharing system; electric scooter energy efficiency; stakeholder analysis; MACTOR application; reduction in energy consumption in the city; urban transport

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1. Introduction

An electric scooter is an electrically driven, two-axle vehicle with a steering wheel, without a seat and pedals, which is structurally designed to be moved only by the driver of the vehicle. Electric scooters are powered by a battery that can be charged from any external source of electricity. Since electric scooters do not have a motor, they have become an efficient and energy-saving means of road transport, which does not contribute to environmental pollution, does not emit greenhouse gases, and has a potentially positive impact on transport by reducing the use of private cars, as well as car ownership. In practice, the size of these advantages depends on the specific operating conditions of the electric scooter system services, such as the battery capacity, electric scooter life, or existence and impact of other coexisting e-mobility systems in a given area, both in terms of complementarity and competition. Electric scooters have limited battery capacity and require frequent charging, which means that the operating costs are significantly higher and often hinder the profitability of the service.

Electric scooter systems as a shared micromobility service were established in 2017 when Bird launched its first docking service in Santa Monica, California, USA [1]. Scooter-sharing services allow users to rent e-scooters through their mobile phone (smartphone) for a fee. Today, electric scooter systems are widely used in many cities around the world, mainly in micromobility systems for short trips.

In Poland, e-scooter systems started to operate in 2018, while their significant expansion in many cities occurred in 2019 [2]. According to statistical data provided by SmartRide [3], in June 2022, e-scooter sharing services were available in up to 149 towns in Poland, almost two and a half times more than in 2021. However, in terms of vehicle supply, the e-scooter sharing market increased by 92% during the year to the level of more than 72,000 electric scooters, demonstrating the very dynamic development of this type of system.

Taking into account the entire market of micromobility sharing services in Poland (i.e., shared bicycles, e-scooters, and e-mopeds, with a total supply of nearly 96,000 vehicles), electric scooter rentals account for three-quarters of it (nearly 76%). With each subsequent year, this offering becomes more and more numerous and reaches more and more towns [3]. Hence, it can be concluded that the Polish market for e-scooter systems is actively developing and follows the sustainable development of transport and energy savings.

Furthermore, the dynamic development of shared mobility systems, especially electric scooters, offers new opportunities to move around the city and poses new challenges, especially in dense transport networks with a significant traffic load [4,5]. From the perspective of users, e-scooters are an attractive way to meet their communication needs in sections that are more difficult to cover on foot or even by bicycle [6].

The main research objective of this article is to identify and assign to different groups the stakeholders influencing the sustainable development of e-scooter sharing systems considering Polish cities. The estimations were performed using expert methods with a stakeholder study, based on matrix and mapping methods, and with the MACTOR computer application. Relationships and cooperation suggestions were established for each stakeholder group, which may become an important part of the strategic approach to support public transport service providers and organizers. The cooperation of entities participating in the implementation of bike-sharing services can contribute to their greater sustainable development.

This article consists of six sections. After the introduction section, the second section presents a review of the scientific literature in the field of electric scooters and the implications for urban transport, electric scooter technologies, energy efficiency and energy consumption rates, environmental impacts, predictions of demand, spatial analyses, planning for electric scooters, users, and related injuries. In the Materials and Methods section, the research area and research method based on the MACTOR application are presented. The most important part of the paper is included in the fourth section. In Section 4, the stakeholder analysis results for the Polish e-scooter sharing services are presented, consisting of the identification and characteristics of the stakeholders, the identification of key stakeholders with the mapping method, and finally the key stakeholders' strategic recommendations based on the MACTOR method. Our interpretation of the obtained results is presented in the discussion section. At the end of the paper, the conclusions resulting from the theoretical and research parts of the paper are presented.

2. Scientific Literature Review

The review of the literature indicates that due to the novelty and timeliness of the topic of electric scooter systems, many different types of scientific research on e-scooters and their implications for urban transport can now be found in the literature. Most of the research work comes from the last three years. However, on the other hand, due to the relatively short period of operation of this type of system around the world (since 2017), all of these studies are for the early stage of operation of electric scooter systems, and the number of these studies is incomparably smaller than the numbers of studies dedicated to other forms of transport that have been operating on transport networks for many years. In addition, many issues related to electric scooter systems have been presented superficially, without an in-depth analysis of the problem. This superficiality is often associated with the lack of available data for analyses or the use of small datasets (for example, data on the safety of scooter users are most often analyzed based on data obtained from hospitals, as many road accident recording systems do not include electric scooters; therefore, these events are often not registered in databases [7–9]).

Taking into account research studies dedicated to the evolution of electric scooter systems, separate main research directions can be found. These are:

- Safety matters, accidents, injuries;
- Energy efficiency, environmental impact;
- Electric scooter systems planning, design, and development issues, especially product design, innovations, infrastructure and equipment issues (battery), relocation strategies for shared e-scooters, problem of vandalism;
- Use, market, forecasting the demand for electric scooters, spatial analysis;
- Acceptance and motivation to use electric scooter systems;
- Business models and sharing economy of electric scooter systems;
- Characteristics of system users;
- Use of the system during and after the COVID pandemic in a post-COVID world.

A certain group of studies involve various types of technical reports, which contain reports on the first periods of operation of this form of shared mobility in given areas. These reports present various aspects of the use of electric scooter systems in urban areas and are based on real research samples [10–12].

E-scooter services are convenient to use because the user has the option of unlocking the e-scooter using an application on their smartphone, and after the end of the journey, the toll is automatically charged. Due to this, e-scooter systems are a reliable alternative to other transport options in a given area. However, the effectiveness of e-scooter systems in cities depends on the number of users, i.e., people willing to ride this means of transport. Therefore, it is essential to know the factors that influence the choice of an e-scooter for a trip or a certain stage of a trip. As shown in the work by Karli et al. [13], the behavioral intentions in terms of acceptance and decision to ride an e-scooter are significantly influenced by characteristics such as the expected effort and the price of the service. In turn, Scorrano and Rotaris [14] found that in addition to various financial and technical features of electric scooters, features such as the higher level of environmental care, especially at the local level, positively influenced the choice of electric scooters for travel, while the knowledge of electric scooters does not play a statistically significant role. An interesting study was presented by Liao and Correira [15]. This study involved a search for the personality profile of shared mobility users, including users of e-scooter systems. The results of the study indicated that the current users of electric scooter systems are mainly middle-aged men with relatively high income and education levels. The demand for all common types of e-mobility has many common predictors; such systems appeal to people with similar sociodemographic characteristics and generate higher demand in locations with better transport connectivity and more places of interest. In turn, evaluations of the quality of e-scooter system services carried out in selected cities in Poland indicated that the customer satisfaction levels in individual cities differ [16,17]. Another study indicated that future research in the field of e-scooter systems should be focused on the interactions of users of e-scooters with other road users and pedestrians, and the alignment of policies and practices to integrate e-scooters with transportation planning [18].

Since the popularity of e-scooters is growing year by year, their share in urban spaces is also becoming more and more visible. Many cities have introduced orders to use e-scooters on roads and have banned riding on sidewalks [19]. A natural consequence of road sharing between motor vehicles and users of e-scooters is road incidents involving e-scooters and motor vehicle users. As shown by the latest work in this field (e.g., [20]), although the frequency of injuries by users of electric scooters with motor vehicles is relatively constant, the injuries of users of e-scooter systems resulting from road accidents are becoming characteristic. As demonstrated by Leone et al. [21] in the case of electric scooters, the head, maxillofacial region, and upper and lower extremities are more susceptible to damage than the thoracoabdominal region and the spine. Among these fractures, the nasal area, radius, and tibia are the most affected. Intracranial injuries are rare, but an important cause of disability and possible death. Although most patients are discharged home the same day, these events often require outpatient follow-up and sometimes hospitalization. In turn, Morgan et al. [22], based on the research carried out, concluded that the use of electronic scooters by children is dangerous and can cause serious injury to the musculoskeletal system. These conclusions should be taken into account and should lead to the limitation of the use of e-scooters by children. Therefore, social campaigns play an important role in raising awareness of the existence of risks when using electric scooters, as they may be effective in reducing the injuries caused by riding electric scooters [23].

The issues of road safety and injuries among e-scooter users are still current subjects of research; hence, in the literature on these subjects, you can also find the kinematics of the behaviors of e-scooters and their users in road accidents. Ptak et al. [24], based on an analysis of road accident scenarios involving electric scooters, developed graphs of the linear acceleration of a dummy's head and its size for the scenarios analyzed, together with the kinematics of the scooter's behavior in a road accident.

In turn, Tian et al. [25] analyzed the relationship between the e-scooter structure of the users and the occurrence of road accidents. The results obtained allowed us to conclude that people who often use e-scooters are characterized by an increased risk for all kinds of accidents. Using bike lanes for at least 25% of the time while riding e-scooters has been identified as a protective. In turn, women who rode more frequently on pavements and unpaved surfaces were characterized by an increased risk of injury. These results were partially confirmed in subsequent studies by Nauroth et al. [26]. The results of these studies allowed us to conclude that the electric scooter users who suffered motor vehicle injuries were young and mostly male. The accidents occurred mainly on the street (96.3%) and on public land. Based on their analysis, the authors concluded that as electronic scooters and motorized vehicles increasingly share the road, more attention should be paid to how the two modes of transport interact with each other. Promoting thoughtful regulation and infrastructure changes can help promote safer travel for all road users.

In addition, there are many other areas where e-scooters have been addressed. The positive impact of e-scooters on the natural environment is often emphasized in such work, indicating that the potential to reduce greenhouse gas emissions is highly dependent on the general conditions of a specific use case; for example, it can depend on the service life of the e-scooter and its type [27]. In turn, in [28], a solution for the solar charging of e-scooters was proposed, which also contributed to energy efficiency and had a positive impact on the natural environment, with proposals for new technological solutions towards energy efficiency [29].

A summary of the most important directions for the development of electric scooter systems is presented in Table 1.

The review of the literature made it possible to conclude that the existing literature on the subject raised various issues related to the electric scooter, but so far there are no scientific papers in the literature that have analyzed and classified the stakeholders influencing the development of this type of system. Getting to know stakeholders related to e-scooter systems is important not only because of the future use of e-scooters as an alternative to other forms of urban transport, but also, above all, because of the need to properly shape transport systems in urban areas.

Table 1. Synopsis of the most important directions for the development of electric scooter systems.

Research Group	Year	Key Research Works	Research Location	Data	Research Description	Key Findings
Predicting demand	2019–2021	S. Kim et al. [30]	Seoul, Korea	Trip data	Development of a model to forecast demand for shared use.	The demand for shared e-scooters can be influenced not only by time and weather but also by many regional features and special events.
	2021	S.W. Ham et al. [31]	South Korea	The total number of e-scooters used and the users	A search was conducted for a methodology to predict the demand for electric scooters with high spatial resolution.	A new algorithm for the e-scooter research methodology was formed by establishing the network architecture and correctly considering the unmet demand.
	2021	S. Phithakkitnukoon et al. [32]	Calgary, Canada	Dataset for e-scooter usage	A model was built for predicting the demand for e-scooters without a docking station based on deep learning techniques.	A model was made considering the day of the week or holiday for which various sets of influential features may be utilized.
Energy efficiency	2021	Y. Wang et al. [33]	Gothenburg, Sweden	The geolocation and battery state of charge data for each available scooter	Studies of energy consumption during individual journeys and studies of factors that affect energy consumption.	Using a regression model, a Monte Carlo simulation framework was proposed to estimate the fleet's energy consumption in different scenarios, considering both journey-related energy consumption and idle energy loss. The results indicated that in current practice, 40% of the energy from an e-scooter battery was wasted while idle, mainly due to the relatively low utilization rate (0.83) of e-scooters. If the average utilization rate falls below 0.5, the wasted energy can reach 53%.
	2022	F. Laurent [34]	France	-	Modeling of the operation, replacement, and consumption of electric batteries depending on the depth of discharge.	Equations were established for the optimal cost of a battery replacement, depth of discharge, battery energy capacity, scooter life, and energy consumption rate.
	2021	R. Rettig et al. [35]	Germany	Open data source	Based on vehicle-to-vehicle communication (V2V) and a time-of-flight camera (TOF), automated platooning has been implemented and tested for e-scooters.	The results presented the potential of electronic architectures for e-scooters in the context of safety, security, sustainability, and energy efficiency.
Spatial analysis	2021	A. Hosseinzadeh et al. [36]	Louisville, USA	E-scooter trip data	The study aimed to determine how factors related to demographics, density, diversity, design, urban performance, distance from the subway, and other transport-related variables affect the travel of an e-scooter.	The results of the analysis indicated that factors such as the land use, age distribution, gender distribution, gait rating, and parking rating influenced the density of the e-scooter travel.
	2020	J. Jiao, and S. Bai [37]	Austin, Texas, USA	E-scooter trip data	The journey samples of 1.7 million e-scooter trips were studied.	More trips came from the city center than were completed. Zones with a dense population and more educated residents were interdependent with more e-scooter trips.
	2020	O. Caspi et al. [38]	Austin, Texas, USA	E-scooter trip data	An analysis of the use of e-scooters.	The analysis showed that people use e-scooters almost exclusively in the city center. Commuting to work does not appear to be the main purpose of travel, and the use of e-scooters is associated with areas with high employment rates and areas with cycling infrastructure. People use e-scooter sharing services regardless of the neighborhood affluence, although less affluent areas with high usage rates have large student populations, suggesting that students are using this mode of travel.

Table 1. *Cont.*

Research Group	Year	Key Research Works	Research Location	Data	Research Description	Key Findings
E-scooter technology	2021	R. Ratan et al. [39]	USA	Survey study	The research examined how perceptions of mobile apps, i.e., communication technologies, influence the intent to use e-scooters (i.e., transportation technology), while considering other perceptions specific to e-scooters, such as the usefulness, environmental impact, ease of use, safety, enjoyment, context of use (geographic landscape), and demographic factors (sex and age).	The results indicated that the perceived ease of use of the mobile app is related to the intention to use an e-scooter.
	2020	F. H. Huang [40]	New Taipei, Taiwan	Experimental and survey data	Investigated factors that may influence user acceptance of fully immersive virtual reality versus desktop virtual reality.	The results indicated that the model constructs of expected performance, hedonic motivation, and facilitating conditions are useful predictors of the behavioral intention to use virtual reality systems. Although these factors were significantly higher for fully immersive virtual reality systems, both virtual reality systems can have positive effects on behavioral intentions. Based on these findings, several implications for developers and suggestions for future research were presented.
	2021	B. Azzahra et al. [41]	Jakarta Metropolitan Area, Indonesia	Survey data	The study used the UTAUT2 framework (Universal Principle of Acceptance and Use of Technology 2) to identify and build a quantitative approach to identify factors related to the intention of purchasing an e-scooter.	The use of e-scooters is shaped by seven main factors. They are the expected performance, expected effort, social impact, improvements in fitness, hedonic motivation, price, and habits.
E-scooter planning	2021	Ch. Latinopoulos et al. [7]	Paris, France	An online survey of potential users	Information was collected on the current state of the e-scooter market. A proposal was made for an e-scooter assessment framework that classifies all aspects of interest to planners and decision makers.	The results are intended to provide researchers and stakeholders with insights related to the design of new e-scooter systems or the optimization of the performance of existing ones.
	2020	Ch. Feng et al. [42]	Texas, USA	Origin and destination trip data	The planning and estimation of e-scooter flow patterns were performed without knowing the actual routes taken by e-scooter drivers.	A tool for planning in cities for the emerging joint micromobility services.
	2021	M. Fazio et al. [43]	Catania, Italy	Geographic data	A GIS-based multicriteria analysis to prioritize e-scooter networks focusing on safety, transportation, and land use characteristics.	The methodology was developed to prioritize the road network elements better suited to the needs of the e-scooter, for the design of appropriate infrastructure, and for the planning of the transport network.

Table 1. *Cont.*

Research Group	Year	Key Research Works	Research Location	Data	Research Description	Key Findings
Energy consumption	2021	Y. Wang et al. [33]	Göteborg, Sweden	Geolocation and battery status data for each available scooter	A multi-logarithmic regression model was built to study energy consumption on single trips and factors affecting energy consumption.	Here, 40% of the energy for the electric scooter battery was wasted while idle, mainly due to the relatively low utilization rate (0.83) of the electric scooters. If the average utilization rate falls below 0.5, the wasted energy can reach 53%.
	2021	H. Akova et al. [44]	Turkey	-	A search was conducted for locations of cost-effective charging stations for electric scooters, emphasizing the importance of calculating battery energy consumption as accurately as possible.	For e-scooters, the distance-based energy consumption approach overstates or underestimates the requirements for charging stations and the locations of charging stations.
	2017	S. K. Rechkemmer et al. [45]	Stuttgart, Germany	Theoretical data	A model of an aging e-scooter drivetrain.	The developed models make it possible to evaluate the long-term behavior or aging of the powertrain in realistic driving cycles.
E-scooter users	2020	B. La, and U. Leth [46]	Vienna, Austria	Online survey	An evaluation of socioeconomic profiles and usage patterns of e-scooter users.	E-scooter users are more often young men, well educated, and residents.
	2022	M. Pazzini et al. [47]	Trondheim, Norway	Hidden observer	An analysis of the speed and behavior of e-scooter drivers in a city to support local authorities in managing this mode of transport.	The choice of the type of infrastructure for movement depends mainly on the road environment; often e-scooters users chose a bicycle path to move around.
	2022	K. Kazemzadeh, and F. Sprei [18]	-	Open-source data from e-scooter companies	The quantification of user experiences.	The results confirmed the lack of previous research available in this area and that e-scooters are rarely included with the level of services of other modes of transport.
E-scooter related injuries	2022	F.D. Grill et al. [48]	Germany	Data on victims of electric scooter accidents	An analysis of the frequency and types of injuries sustained in accidents on electric scooters and a comparison of the results with accidents on bicycles.	Helmets were not recorded among e-scooter users. In addition, e-scooter accidents showed higher rates of facial soft tissue injuries, facial fractures, and tooth injuries than cyclists. Accidents among e-scooters usually occurred on weekends.
	2021	J.B. Ciccchino et al. [49]	Washington, USA	Data on adults injured while riding e-scooters	An analysis of the severity of e-scooter rider injuries associated with trip characteristics.	The electric scooter users were the most injured on the pavement (58%) and the road (23%). Furthermore, e-scooter users on the road were approximately twice as likely to be injured as those riding elsewhere. The greater severity of injuries for cyclists injured on the road may reflect higher speeds.
	2021	E.H. Tischler et al. [50]	USA	Electronic database of injuries	An evaluation of orthopedic fracture patterns related to the use of electronic scooters and an evaluation of risk factors related to direct hospital admission.	Fractures of the upper extremities were the most common (25.4%), followed by fractures of the upper arm, metacarpal bones, skull, and related internal organs. The greatest associations with direct admission to the hospital were for fractures of the upper leg and lower trunk and related damage to the internal organs.

3. Materials and Methods

3.1. Research Area

The area of analysis was Poland and the area of influence of the stakeholders was adopted in the investigation. The research was carried out in the cities with the highest density of e-scooters (Figure 1).

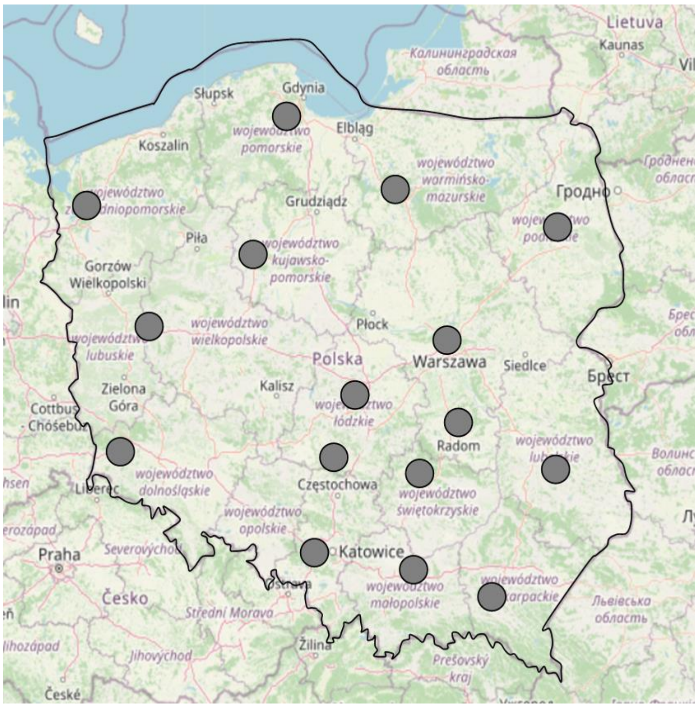

Figure 1. Research area. Source: own research based on Open Street Maps [51]. Note: —cities where the research was conducted.

In the Polish e-scooter system market, four companies handle up to 92% of all rentals. These include Bolt (available in 37 towns) and Lime (available in 42 towns), each with a fleet of approximately 21,000. scooters and 29% market share. Other companies include Tier (approximately 15,000 vehicles in 40 towns and 21% market share) and Dott (more than 10,000 vehicles in 14 towns and 14% market share). The cities in Poland where most e-scooters are located are as follows.

- Warsaw—more than 15,000 vehicles and 21% market share;
- Tricity—over 10,000 vehicles and 14% market share;
- Kraków—more than 7000 vehicles and 10% market share;
- Poznań—nearly 5000 vehicles and 7% market share;
- Wrocław—nearly 4500 vehicles and 6% market share.

The legal regulations on electric scooter mobility were made public in Poland in 2021, which were undoubtedly related to the dissemination of these vehicles. The regulations in this regard are included in the Road Traffic Act [52]. According to this act, people who use electric scooters on public roads are obliged to comply with the general rules of safe road use, which are established in the provisions of the road traffic laws. In addition, the person driving the electric scooter is obliged to use the road for bicycles or the lane for bicycles if they are designated for the direction in which they are moving or intend to turn; they are obliged to exercise extreme caution and give way to pedestrians when using an area for bicycles and pedestrians; they may stop in the bicycle lock next to other drivers of these vehicles, and are obliged to leave it when it is possible to continue driving in the intended direction and take a place on the roadway following the relevant provisions of the road traffic laws. On the other hand, a person driving an electric scooter is prohibited from riding on the road next to another traffic participant; driving without keeping at least one hand on the steering wheel and legs on the footrests; attaching themselves to vehicles, pulling or towing another vehicle; and transporting another person, animal, or cargo.

3.2. Research Methodology

The research on the analysis of the stakeholders of Polish e-scooter services was carried out in three main stages, as presented in Figure 2.

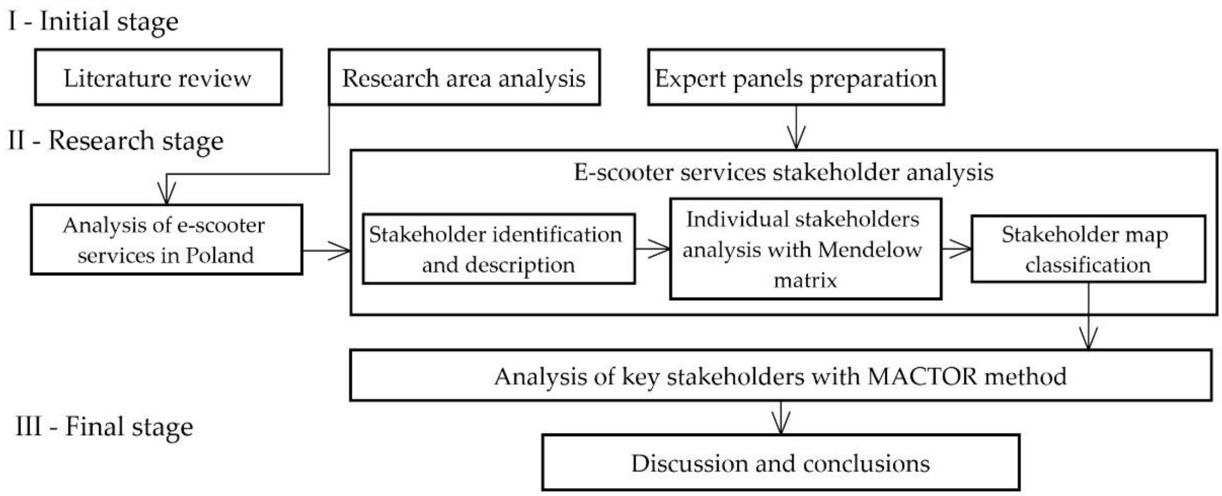

Figure 2. Research stages of the methodology.

Stage I was the initial stage focused on the literature and documents (legal acts, strategies, and program reviews of electric scooters and shared mobility systems in the research area). As a result, the characteristics of the shared mobility users were developed, as well as knowledge of the stakeholder analysis tools and methods. This phase also covered the preparations for expert panels, which included the selection of experts and sending invitations to participate in the research.

Stage II focused on the specific research involving stakeholder analyses of Polish e-scooter sharing services. First, based on the analysis of e-scooter services in Poland a report was prepared, which was then presented to the expert panel. Finally, 17 people representing the industry, scooter users, journalists, infrastructure managers, and people responsible for the expansion of the transport system in the given area participated in the expert panel. A stakeholder analysis was carried out through two expert meetings. At the first meeting, a list of stakeholders was prepared using the brainstorming method. The list was then completed and organized by the authors. At the second meeting, experts were asked to individually judge each stakeholder based on two dimensions: the levels of interest and power. This enabled the authors to group and classify stakeholders with the Medelow matrix mapping method developed in [53]. It allowed the classification of individual stakeholders into one of four groups: key players, subjects, settlers, and the crowd. To understand the strategy and role of each group of stakeholders, the Johnson and Scholes [54] method was adopted.

The stakeholder analysis in the research stage was then enriched with a more detailed study of key stakeholder groups (actors) using the MACTOR method and software. The MACTOR software program was developed by the French Computer Innovation Institute 3IE (Institut d'Innovation Informatique pour l'Entreprise) under the supervision of its conceptual creators, the LIPSOR Prospective Strategic and Organizational Research Laboratory. The MACTOR abbreviation was developed by Godet [55] from the Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations. It is a computer software program that supports the analysis and visualization of an analytical method based on stakeholders' (actors') future behavior. It has been used in studies related to transportation, such as for air transport [56]. The methodology presented in Figure 3 for the stakeholder analysis was based on Godet's MACTOR method conducted in [57].

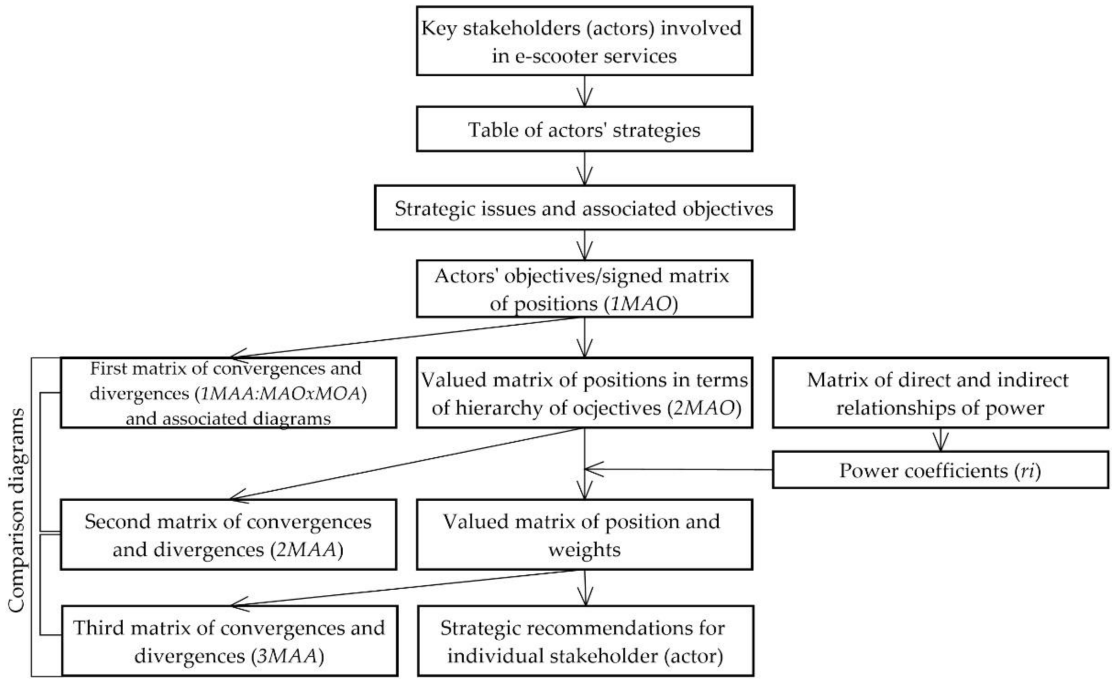

Figure 3. MACTOR method. Source: own research based on [57].

The MACTOR method includes seven phases:

- Phase 1—Building the table of actors (this is done using the mapping method;
- Phase 2—Identifying strategic issues and the related objectives of the actors related to e-scooter sharing services;
- Phase 3—Positioning actors against their objectives by identifying similarities/differences (single positions);
- Phase 4—Prioritizing the objectives for each actor (valued positions);
- Phase 5—Evaluating the power relationships and formulating strategic recommendations for each actor;
- Phase 6—Integrating power relations in the analysis of convergence and divergence between actors;
- Phase 7—Formulating policy recommendations and key issues for the future.

The use of the MACTOR application involves the preparation of two main inputs. The positioning of the actors on issues is achieved using the position matrix (1MAO). The position of each actor on an issue is reflected by its attitude and is quantified as follows: +1 (for); −1 (against); 0 (neutral). The second input reflects the reciprocal influences exerted between the actors and is represented by the influence matrix.

Finally, stage III of the investigation covered a discussion and conclusions. The usefulness of the research we conducted was verified, as well as the limitations resulting from it and the possible future development directions.

4. Stakeholder Analysis of Polish E-Scooter Sharing Services

The stakeholder analysis of Polish e-scooter sharing services is presented in Section 2. It consisted of four main steps: stakeholder identification, stakeholder influence, power influence, and future strategic recommendations for key stakeholders (actors).

4.1. Identification and Characteristics of the Stakeholders

In the first phase of the stakeholder analysis, stakeholders needed to be identified. Groups and individual entities that are related to a different degree with e-scooter sharing services in Poland were considered. The report on e-scooter services in Poland was presented to the experts, and the ideas for the stakeholder list were gathered during the first panel. Later, this was elaborated and organized into the map of interests presented in Figure 4.

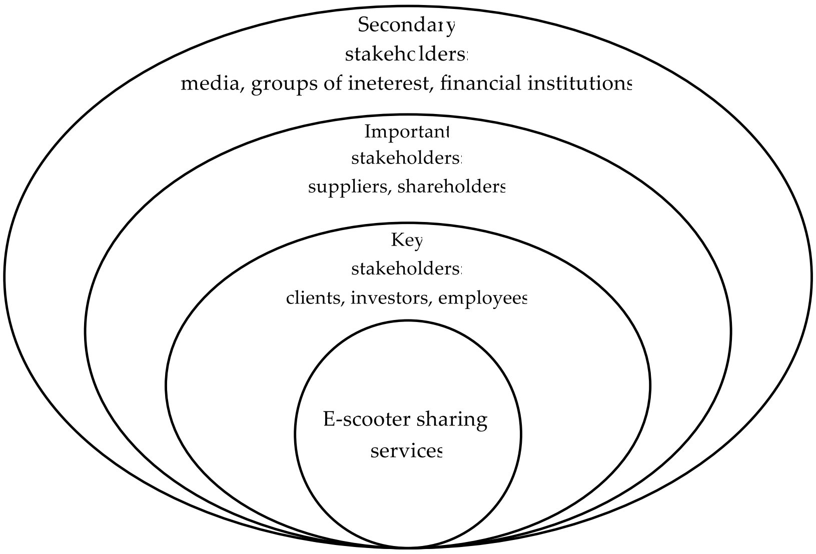

Figure 4. Stakeholder group map for the e-scooter sharing services.

Stakeholders related to e-scooter sharing services can be classified into three groups. The most important stakeholders are those who influence the analyzed services from the inside, i.e., clients of car-sharing services, investors, and employees. Suppliers and shareholders are considered important stakeholder groups. Media representatives, different groups of interest, as well as financial institutions were classified as secondary stakeholders. Twenty-three stakeholders were identified.

The detailed characteristics of the stakeholder groups of e-scooter sharing services are presented in Table 2.

The competitors and customers constitute very important groups of stakeholders, among whom we distinguished both individuals and institutions. Some entities in the group of investors may become a threat to the enterprise because there is a noticeable trend of launching their own sharing services via leasing companies, IT companies, and even banks. The technical support is usually provided by different suppliers and stakeholders.

The dependency on various financial institutions is obvious, but it is also worth emphasizing the influence of the media on the perceptions of e-scooter sharing services.

4.2. Identification of Key Stakeholders with the Mapping Method

The stakeholders varied by type and amount of interest, as well as their power to regulate or influence the e-scooter sharing services in Poland. Therefore, the next step of the research was an analysis of the identified relationships between the stakeholders and the e-scooter services. For this purpose, experts were asked to determine two variables according to the Maslow matrix approach: the impact strength and the probability of involvement on a scale of 0–10. The results are shown on the grid in Figure 5.

Table 2. Characteristics of stakeholder groups of e-scooter sharing services.

Stakeholder Group	Stakeholder Characteristics
Clients	c1—individual clients c2—institutional/business clients c3—municipal guards and other services
Competitors	t1—competitive service operators (bike-sharing and car-sharing operators, etc.) t2—public transport providers
Investors	i1—operators of e-scooter sharing services (Bolt, Lime, Dott, etc.) i2—electronic shared mobility platforms (e.g., FreeNow) i3—administrative representatives
Employees	e1—full- and part-time employees e2—potential employees
Suppliers	s1—e-scooter manufacturers s2—e-scooter spare parts distributors s3—energy supplier s4—e-scooter shared mobility software and hardware suppliers
Shareholders	h1—transportation authorities and policymakers h2—land owners or administrators
Financial institutions	f1—Ministry of Finance f2—National Bank of Poland f3—Polish Financial Supervision Authority
Media	m1—Urban Mobility Association m2—web portals on shared mobility issues m3—non-governmental organizations m4—advertisers

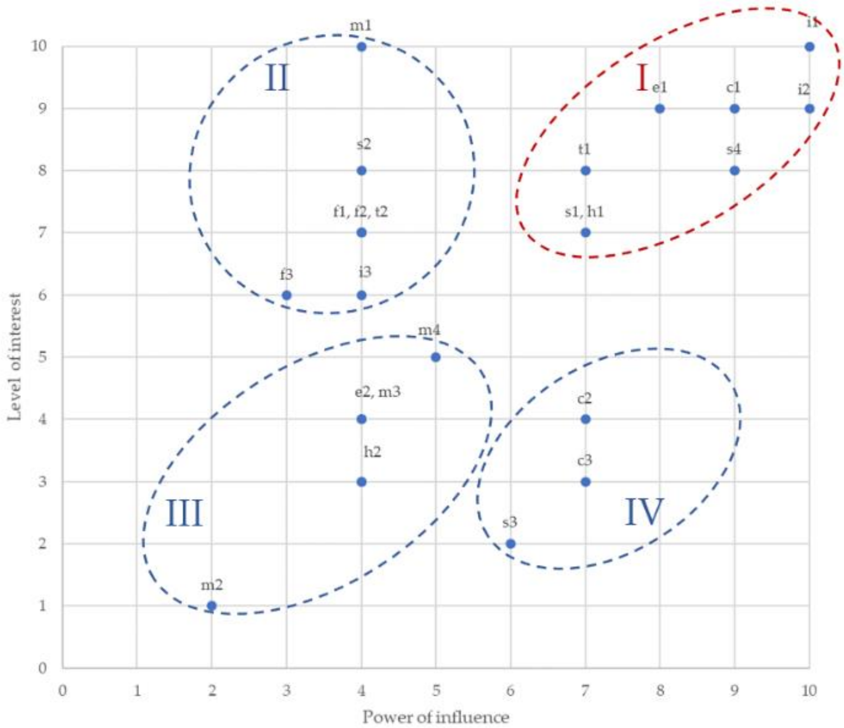

Figure 5. E-scooter sharing service stakeholder relationship matrix of interest versus influence.

The evaluation of the relationships between stakeholders in the e-scooter sharing services allowed us to group them according to the four quadrants of the grid: key players, subjects, context setters, and the crowd. In quadrant I, there were eight stakeholders selected as the most important ones: e-scooter operators (i1), application operators (i2), individual clients (c1), employees (e1), competitive service operators (t1), transportation authorities (h1), e-scooter manufacturers (s1), and hardware and software suppliers (s4).

This is the most important group of entities that should be considered for collaboration. They are particularly interested in the success of e-scooter services, and sometimes business growth may depend upon these key stakeholders.

Field II of the matrix refers to stakeholders qualified as subjects, which include all financial institutions, including the Ministry of Finance (f1), National Bank of Poland (f2) and Polish Financial Supervision Authority (f3), as well as administrative representatives (i3), e-scooter spare parts distributors (s2), the Urban Mobility Association (m1), and public transport providers (t2). The entities presented do not have much influence on the analyzed services, but should be informed on various aspects of a company's operations to maintain the legitimacy of its operations, mainly due to bureaucracy and reporting reasons.

Group III presents stakeholders qualified for the context settlers group, with whom relations are based on maintaining satisfaction. According to the results of the analysis, there are three entities representing the media (m2, m3, m4), potential employees (e2), and land owners or administrators (h2).

In quadrant IV, there are three stakeholders, representing the crowd: municipal guards (c3), who are users of e-scooter services in some Polish cities; institutional clients (c2); and energy suppliers (s3). Relations with them mainly include obtaining products and services needed by the company and maintaining a good image of the company.

4.3. Key Stakeholder Strategic Recommendations Based on MACTOR Method

When selecting the most significant stakeholders from the standpoint of interest and influence, a further analysis focusing on the MACTOR method is necessary to evaluate the balance of power between the actors. The research was narrowed down to eight key stakeholders selected in the previous step. Based on the literature review, 14 objectives were identified to express the strategies of the e-scooter sharing services. The list of actors and their possible objectives is collected in Table 3.

Table 3. Input data for the MACTOR method.

Actors	Objectives
c1—individual clients	o1—ensuring the availability of e-scooters and applications
i1—e-scooter operators	o2—increasing the number of e-scooters
i2—application operators	o3—sharing mobility popularization
e1—employees	o4—maintaining the ease of use
t1—competitive service operators	o5— ensuring the stability of the shared mobility system
s1—e-scooters manufacturers	o6—strengthening public transport
s4—software and hardware suppliers	o7—ensuring transport safety
h1—transportation authorities	o8—establishing the sustainability of the transport system
	o9—increasing the quality of sharing services
	o10—increasing effectiveness of e-scooters sharing system
	o11—stabilizing the regulations related to the operation of e-scooter sharing systems
	o12—integration of shared mobility systems
	o13—traffic reduction
	o14—integration of mobility applications

In the next step of the research, two types of relationship needed to be evaluated: the influence exerted by the actors on each other and the position of each actor regarding the objectives.

The first relationship was built using the matrix of direct influences (*MID*) by setting the measures of the influence of actor i on actor j, as follows:

- 0—If actor i has little or no influence on actor j;
- 1—If actor i can influence in a limited way the operating procedures of e-scooter sharing services of actor j;
- 2—If actor i can influence the success of the e-scooter sharing service projects of actor j;

- 3—If actor *i* can influence the fulfillment of missions related to the e-scooter services of actor *j*;
- 4—If actor *i* can influence the existence of actor *j*.

Based on the influence rules, the measures were established, and the matrix of direct influences (*MID*) for the e-scooter sharing services is presented in Table 4.

Table 4. Matrix of direct influences (*MID*) of the actors in the e-scooter sharing services.

MID	A_1 (c1)	A_2 (i1)	A_3 (i2)	A_4 (e1)	A_5 (t1)	A_6 (s1)	A_7 (s4)	A_8 (h1)	$\sum A_j$
A_1 (c1)	-	3	4	1	4	0	0	2	14
A_2 (i1)	4	-	4	4	1	4	3	1	21
A_3 (i2)	3	3	-	2	0	0	4	0	12
A_4 (e1)	2	4	4	-	2	2	1	1	16
A_5 (t1)	3	3	3	0	-	0	0	3	12
A_6 (s1)	1	4	2	1	0	-	4	0	12
A_7 (s4)	1	4	4	3	0	4	-	0	16
A_8 (h1)	3	3	0	1	3	0	0	-	10
$\sum A_i$	17	24	21	12	10	10	12	7	113

Based on the sum of columns and rows of the matrix contained in the table, it can be concluded that actor i1 (e-scooter operators) is the most influential in the scooter sharing services.

With the MACTOR application, it is also possible to evaluate the indirect relationships between the actors through the matrix of direct and indirect Influences (*MDII*) shown in Figure 6.

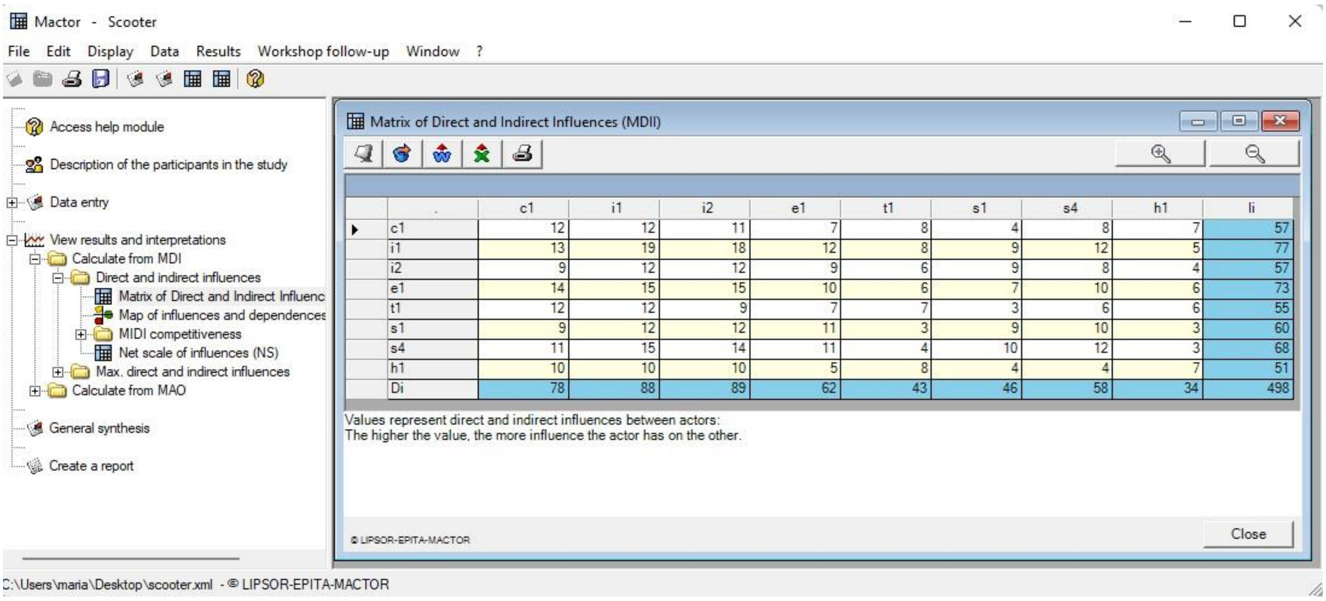

Figure 6. Matrix of direct and indirect influences (*MDII*) of key stakeholders in the MACTOR application.

Two indicators can be calculated from the matrix of direct and indirect influences (*MDII*): I_i, the degree of direct and indirect influence of each actor, and D_i, the degree of direct and indirect dependence of each actor. The values shown represent the direct and indirect influences between actors: the higher the value, the more influence the actor has on the other. In the case of actors sharing e-scooter services, e-scooter operators (i1) are the most influent stakeholders (I_2 = 77), similar to the direct matrix, but application operators (i2) are the most dependent (D3 = 89).

A map of the influence and dependence between actors as a graphic representation of the actors' positions concerning influences and dependencies (direct or indirect, D_i and I_i, respectively) between each other is shown in Figure 7.

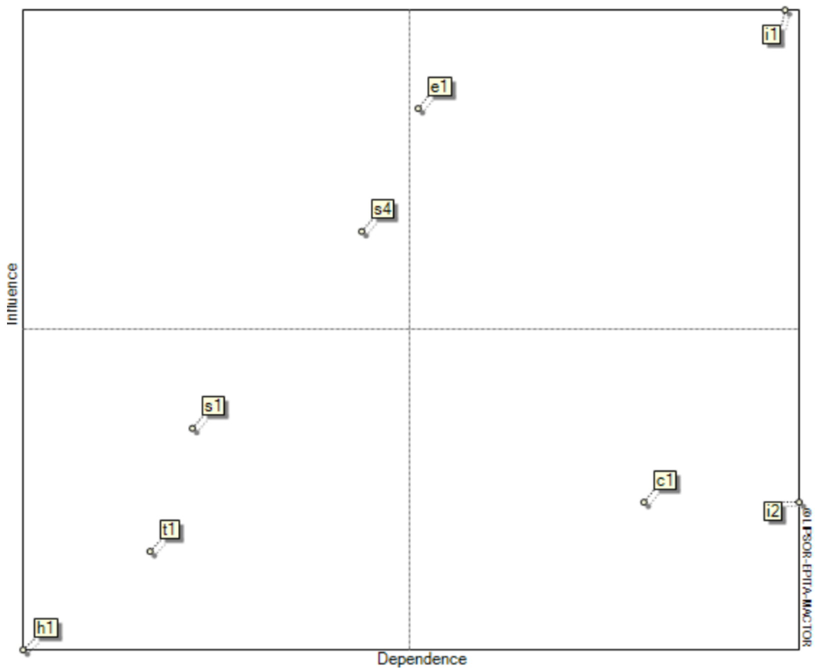

Figure 7. Map of influences and dependencies between actors sharing e-scooter services.

The *MDII* matrix and the map of influences and dependencies also revealed the very weak position of the transportation authorities (h1) regarding the e-scooter sharing services.

Based on the *MDII* indicators, I_i, and D_i, MACTOR enables the calculation of the relation power ratio (r_i) from the following formula [58,59]:

$$r_i = \frac{I_i - MDII_{ii}}{\sum I_i} \frac{I_i}{I_i + D_i} \quad (1)$$

Surprisingly, employees (e1) of the e-scooter sharing services were in a very favorable power balance, with r_4 = 1.3. The actors with the weakest indicators r_1 = 0.7 and r_3 = 0.7 were the most dominated by the system, namely individual clients (c1) and application operators (i2), respectively. The histogram of the relation power ratio for each actor is shown in Figure 8.

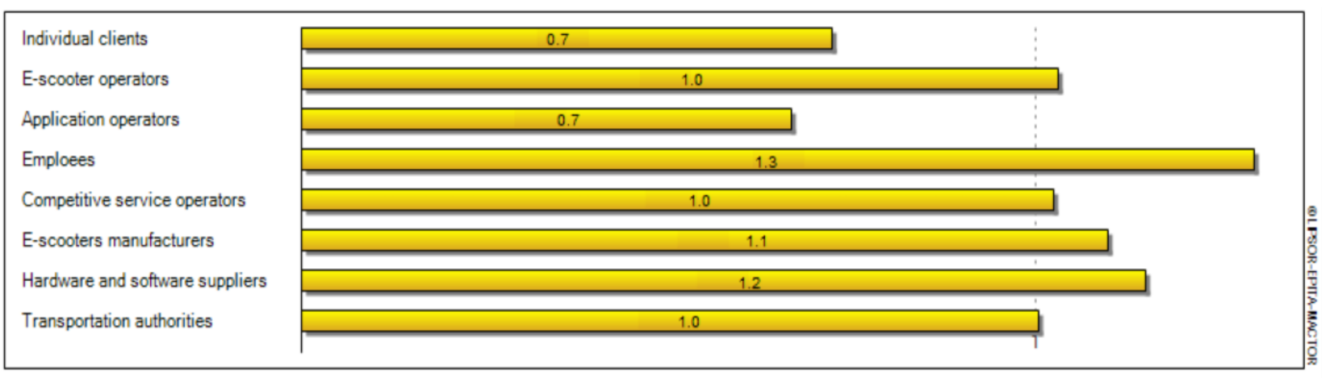

Figure 8. Histogram of the relationship power ratios of the actors.

The MACTOR application also calculates Q_i competitiveness indicators from the matrix of maxima direct and indirect influences (*MMDII*). It determines the maximum level of influence an actor can have on another, either directly or indirectly (through an intermediary actor). The histogram in Figure 9 presents the highest competitiveness ratio

Q_2 = 1.1 for e-scooter operators (i1) and the same value of Q_8 = 1.1 for transportation authorities (t1).

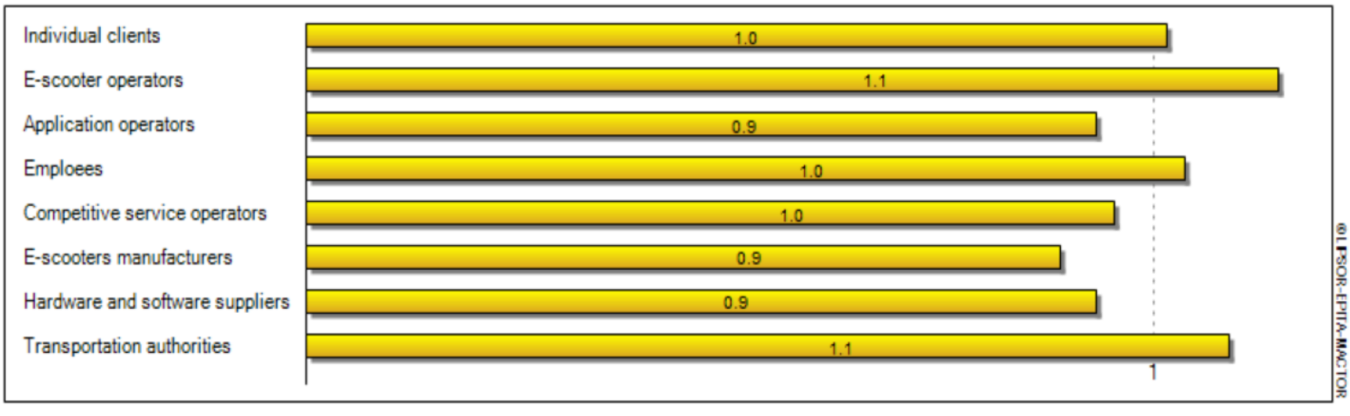

Figure 9. Histogram of the competitiveness indicators of the actors.

The next step of the analysis is to evaluate the objectives and priorities of the objectives for each actor in the valued positions matrix (*2MAO*). This is obtained by estimating the intensity of the objective positioning for each actor. It is based on the simple position matrix (*1MAO*), which shows the valency of each actor concerning every objective (1—likely to achieve the objective; −1—unlikely to achieve the objective; 0—neutral). The *2MAO*, presented in Table 5, reflects the intensity of the validity of the objective on the following value scale:

- 0—If the objective is of little consequence for the actor;
- 1—If the objective jeopardizes the actor's operating procedures or is vital for its operating procedures;
- 2—If the objective jeopardizes the success of the actor's projects or is vital for the success of its projects;
- 3—If the objective jeopardizes the accomplishment of the actor's mission or is indispensable for its missions;
- 4—If the objective jeopardizes the actor's existence or is indispensable for its existence.

Table 5. The valued position matrix (*2MAO*) of e-scooter sharing service actors versus objectives.

2MAO	o1	o2	o3	o4	o5	o6	o7	o8	o9	o10	o11	o12	o13	o14	∑
A_1 (c1)	0	2	1	4	2	−1	4	−1	2	3	2	4	2	4	32
A_2 (i1)	3	3	4	3	4	−3	3	1	4	4	−2	2	2	2	41
A_3 (i2)	4	1	3	4	3	0	0	1	4	4	0	4	0	4	34
A_4 (e1)	1	2	4	1	4	−4	4	3	4	3	4	−2	0	2	38
A_5 (t1)	−4	−4	4	−2	3	−3	3	3	4	−4	3	4	3	3	47
A_6 (s1)	0	4	1	0	0	0	0	1	3	3	0	0	0	0	18
A_7 (s4)	3	1	2	3	0	0	1	1	3	3	0	4	0	4	25
A_8 (h1)	0	1	3	0	3	4	4	4	4	3	4	3	4	1	40
Number of agreements	12	13	24	15	19	4	19	14	28	20	16	21	11	20	
Number of disagreements	−4	−7	0	−2	0	−13	0	−1	0	−6	−4	−2	0	0	
Number of positions	16	20	24	17	19	17	19	15	28	26	20	23	11	20	

The histogram of the MACTOR software shown in Figure 10 graphically presents the results obtained from the valued position matrix (*2MAO*) between the actors and objectives. It represents the objectives of the mobilization process.

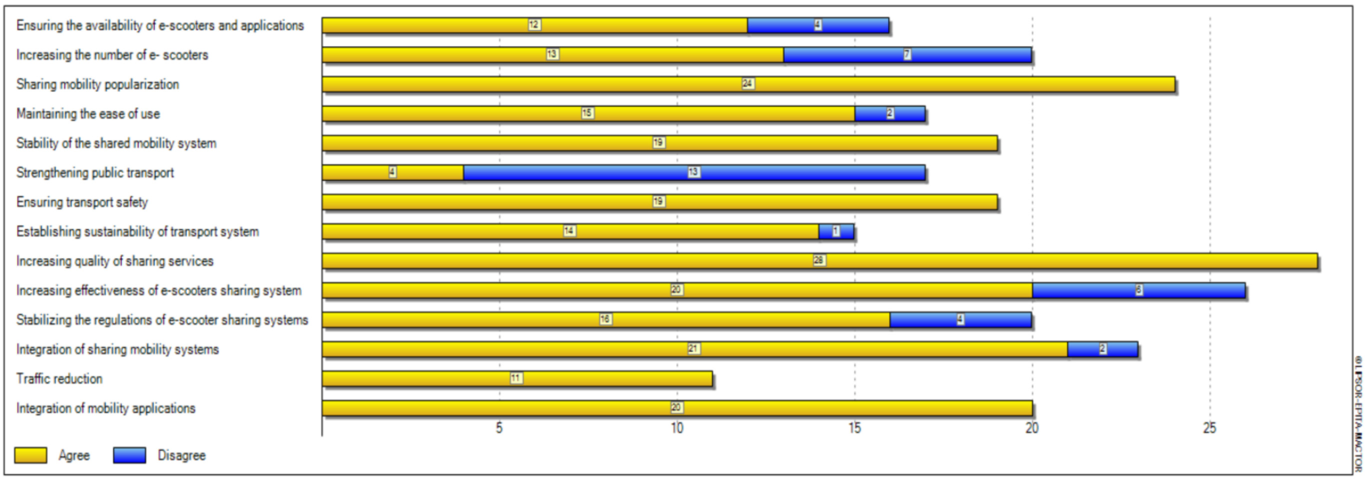

Figure 10. Histogram of the actors' intentions towards e-scooter sharing system objectives.

The results for the final actors and objectives show that o9, which increases the quality of the sharing services, involves the actors the most. The least involvement for the actors is represented by objective o6, which is to improve public transport.

To analyze the balance of power between stakeholders of e-scooter sharing services, an analysis of convergence and divergence between actors can be carried out. The graph of convergences between actors presented in Figure 11a is based on the valued convergence matrix (*2CAA*), related to the valued position matrix (*2MAO*). This calculates the average convergence intensity between two actors when these have the same degree of being for or against the objective. The values in this matrix do not indicate the number of potential alliances, but the intensity of the alliances with the hierarchy (preferences) of objectives of some of the actors. The divergence graph between actors (Figure 11b) represents the valued divergence matrix (*2DAA*). The values in this matrix do not indicate the number of potential conflicts, but rather the conflict intensity with the hierarchy objectives (preferences) of some of the actors.

(**a**)

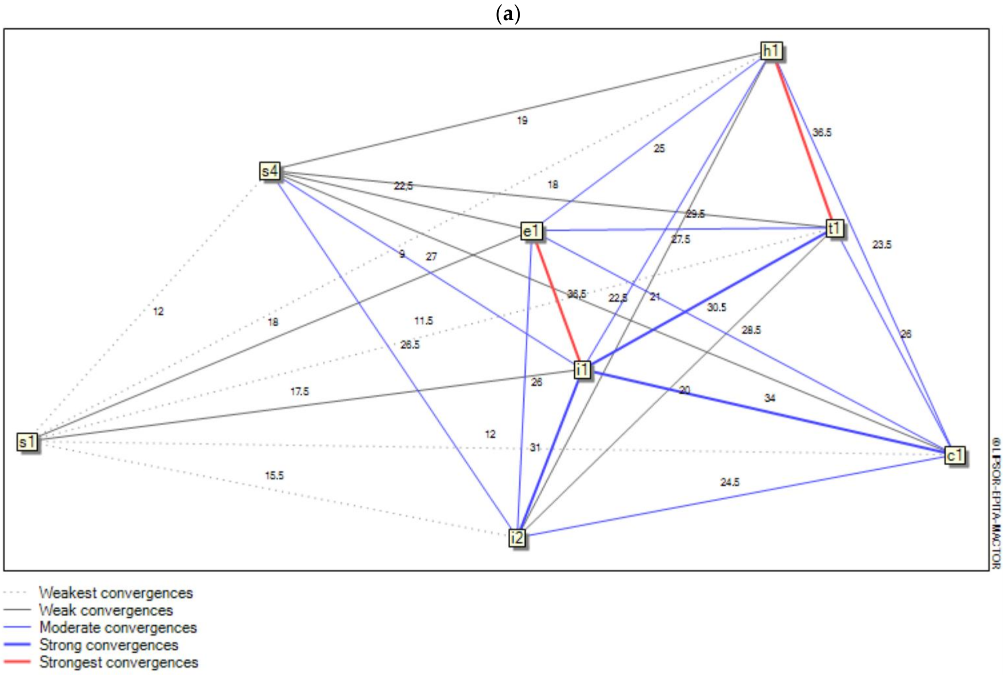

Figure 11. *Cont.*

(b)

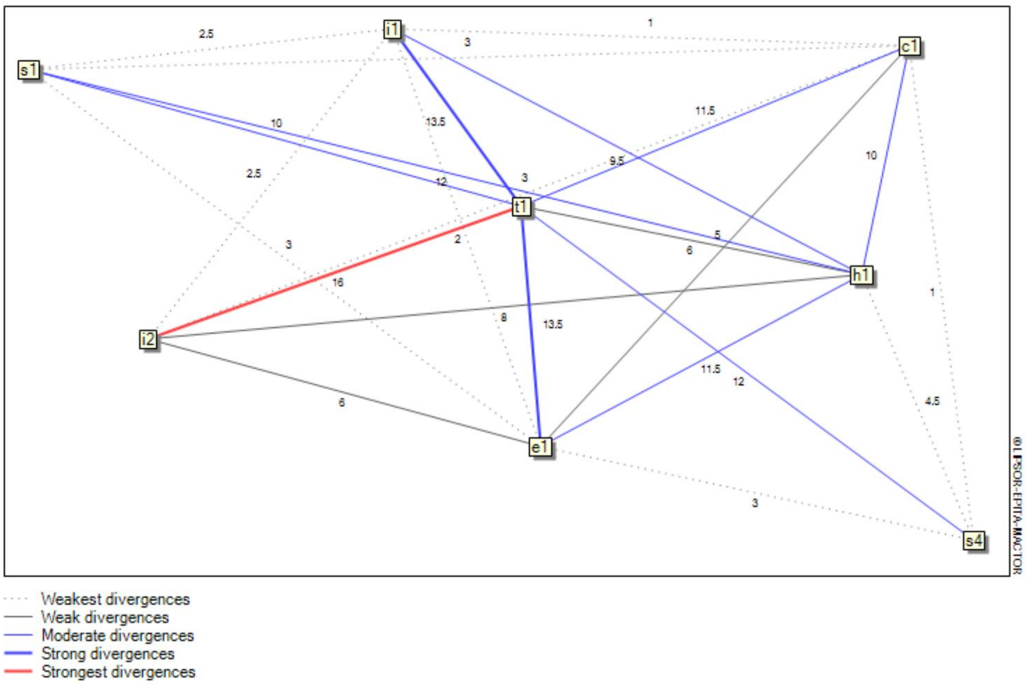

Figure 11. Graphs of the convergence and divergence analyses between the actors: (**a**) graph of convergence between actors; (**b**) graph of divergence between actors.

The convergence and divergence analyses between actors revealed the strongest alliances were between the employees and e-scooter operators (e1–i1), as well as between the transport authorities and competitive service operators (h1–t1). The strongest potential conflict is expected between application operators and competitive service operators (i2–t1), whose attitudes toward the objectives differ.

5. Discussion

The mapping of stakeholders allowed us to identify the key players for e-scooter services in Poland. Despite the use of Maslow's method consisting of the selection of a group of the most important entities from a wide range of stakeholders, this selection approach is still characterized by heterogeneity in terms of the goals and benefits the key stakeholders can offer to the business.

The role of a key stakeholder within the services varies depending on many factors. Civera and Freeman underlined in [60] that the relationships contribute to a new way of thinking that relies on cooperative relationships and mutual and shared responsibilities.

This research highlighted some roles that key stakeholders can assume in the development of e-scooter services. Usually, the responsibilities of key stakeholders may include providing financial support to the business, being interested in current projects or recent developments, helping with business initiatives or assignments, or even contributing during company leadership meetings or planning.

Gonzalez-Feliu et al. in [61] stated that in the development of urban transport systems, the local authorities and public planners traditionally choose and implement different solutions while the other stakeholders react to those choices. Therefore, the transport authorities (h1) were one of the key groups of actors. The stakeholders involved are not several individuals who have different roles, but a group with links and relationships at different decision levels. According to Gonzalez-Feliu and Morana [62], these are transactional, informational, and decisional levels. A transactional type of collaboration is typical in e-scooter services with individual clients (c1) or e-scooter manufacturers (s1). The informational type of relationship is related to the application operators (i2), transportation authorities (h1), or competitive service operators (t1). For the most developed type of collaboration, the decision is related to the employees (e1) and software and hardware suppliers (s4); however, it may also concern other key stakeholders depending on the implemented project and the parties' participation.

A further analysis was performed on the attitudes of the key stakeholders towards the development objectives for the e-scooter sharing services. Fourteen objectives were identified. Increasing the quality of sharing services (o9) was the factor that engendered the most interest from the actors. Standing et al. visualized the levels of participation in the sharing economy for transport [63] and especially considered future transport strategies that consider sharing options that will require government departments and other stakeholders to work cooperatively. According to Kumar et al. [64], one of the most critical factors affecting the quality of ride hailing services is reliability, while the most impactful factor with regard to ride-sharing services is security. In the context of reliability, a stakeholder is a person or entity who receives value from a reliable service. Therefore, building long-term relationships based on joint ventures with the right actors is very important. According to Hamerska et al. [65], three dimensions identified by the authors should be considered in the common projects, namely mobile application functions, device characteristics, and customer service, which are valid aspects for examining the quality of shared micromobility factors in the case of e-scooters.

The key stakeholders in the e-scooter sharing services were least interested in strengthening the objective of public transport (o6). Many authors have focused on the integration of sharing services with public transport in their research. For example, Izdebski and Jacyna [66], Jacyna et al. [67], Barchański et al. [68], and others [69,70] proposed a model for the integration of different transport services in the decision-making process. Usually, researchers treat transport-sharing services as a complement to public transport on short and medium trips. Radzimski and Dzięcielski claimed in [71] that substitutions between sharing and public transport are more likely on long trips. Furthermore, Veeneman in [72] deduced that shared modes can provide both synergetic and competitive relationships with the existing public transport system. However, in both positive and negative business cases, shared modes will operate in a mobility context, with public authorities playing an important role as stakeholders in the regulation and financing of services and infrastructure.

Lindholm and Browne [73] underlined that not only are objectives important in stakeholder partnerships, but also the dissemination of results to maximize the opportunity for identifiable policy impacts. They also proved that the outcomes are not just the physical objects and projects, but equally important are the knowledge exchange and relationship development between participants, since these provide the foundation for the further improvement of the e-scooter sharing services.

Furthermore, an important stage of the investigation was the analysis of the possibilities among the selected partners in the e-scooter sharing services. It allowed the verification of convergences and divergences between actors related to their different attitudes toward the objectives. The strongest alliance possibilities were between the employees and e-scooter operators (e1–i1), as well as between the transport authorities and competitive service operators (h1–t1). The importance of employees in the shared transport system was recognized in the business models for new mobility services by Macioszek and Cieśla [74] and Kao et al. in [75], where special attention was paid to the important dependence of salaries on the total costs of the system, affecting the issues of loyalty and commitment. This alliance is understandable and is characterized by positive synergy that can influence the development of e-scooter sharing services. However, it may be worse in the case of the second alliance, as the cooperation of transport authorities and competitive service operators may lead to coordination in terms of public collective transport, meaning the demand for personalized transport services will weaken. As Lazarus et al. claim in [76], shared automated mobility services offer many opportunities to improve the quality of public transport. In [77], Kamargiani et al. developed an index to evaluate the level of integration of mobility between newly existing mobility services in urban transport. The conclusions state that a higher level of integration is more attractive to travelers.

The strongest potential conflict within the research presented here was anticipated between the application operators and competitive service operators (i2–t1), whose attitudes to the objectives differ. Bıyık [78] proposed a model framework for sharing applications to provide better integration with public transport systems, with a multi-stakeholder scheme also taken into consideration, which was also emphasized in Wróblewski et al. [79–81].

In summary, regardless of the role, it is worth underlining the importance of the continuous participation of key stakeholders, which is essential in sharing services and creating joint value creation. For this reason, they should be constantly informed about current promotions and new e-scooter sharing service extensions. Clients should be encouraged to participate in loyalty programs to maintain a permanent and lasting relationship with the services.

6. Conclusions

The implementation of an e-scooter sharing system involves linking several areas of human activity, including social activity. This, in turn, concerns the interactions and building of relationships with entities, particularly those influencing the provision of services and their effects. The e-scooter services in Poland are characterized by a large number of entities, and the complexity of the relations between them makes it a challenge both to identify stakeholders and to indicate their roles in shaping the sustainable development strategy for urban mobility.

The research purpose of this article was achieved, since the stakeholders influencing the sustainable development of Polish e-scooter sharing systems were identified and assigned to different strategic groups.

Estimations were performed using expert methods with stakeholder analyses, based on matrix and mapping methods, and with the MACTOR computer application.

Firstly, 23 stakeholders were identified into 6 groups: clients, competitors, investors, employees, suppliers, shareholders, financial institutions, and the media. Determining their levels of interest and influence, according to the Maslow matrix approach, allowed the identification of eight stakeholders as the key ones (the actors). Our further research was focused on this group. The attitudes of the key stakeholders regarding the 14 objectives identified allowed them to express their strategies regarding the e-scooter sharing services. The e-scooter operators (o1) were identified as the most influential in the scooter sharing services system; however, the application operators (i2) were classified as the most reliable ones. The highest competitiveness ratios were calculated for e-scooter operators (i1) and transportation authorities (t1).

The attitudes of key stakeholders towards the objectives connected with the development of e-scooter sharing services shows that “increasing the quality of sharing services” (o9) involves actors the most. The least involvement of the actors was represented by the o6 objective, which was “strengthening public transport”. The convergence and divergence analyses between actors revealed the strongest alliances between the employees and e-scooter operators (e1–i1), as well as between the transport authorities and competitive service operators (h1–t1). The strongest potential conflict is anticipated between application operators and competitive service operators (i2–t1).

The key results can be summarized as follows:

- The identification of stakeholders in the sharing of e-scooter services;
- The classification of stakeholders in e-scooter sharing services;
- The identification of key stakeholders and their roles in business creation;
- Understanding convergences and divergence between actors, related to their different attitudes toward the objectives.

Future research may be related to strengthening the cooperation between individual stakeholders and introducing a policy to strengthen the development of e-scooter services by expanding those initiatives that according to research have the highest chance of development.

In addition, based on the review of the literature on the subject presented in the article and the analyses performed, it can be concluded that the actual trends in the electric scooter sharing system include the following future research areas:

- Safety matters, accidents, and injuries;
- Energy efficiency and environmental impact;
- Electric scooter system planning, design, and development issues, especially related to product design, innovations, infrastructure, and equipment issues (battery), as well as relocation strategies for shared electric scooters and problems with vandalism;
- The use of electric scooters, the marketing strategies, and forecasting of the demand for electric scooters, as well as spatial analyses;
- Acceptance and motivation to use electric scooter systems;
- Business models and the sharing economy of electric scooter systems;
- The characteristics of system users;
- The use of the system during and after the COVID pandemic in a post-COVID world.

The Polish market for e-scooter systems is actively developing following the idea of achieving the sustainable development of transport systems and providing energy savings, so it can also be assumed that the further stages of e-scooter system development will, therefore, include market increases in e-scooter sharing and a transition from the use of e-scooters with docking stations to e-scooters without docking stations. Additionally, based on the analyses presented in the article, it can also be concluded that the actual trends in the electric scooter sharing system will be increasingly influenced by the stakeholders indicated in the research part of the article.

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