Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

Sustainable mobility - strengths and weaknesses of electromobility in smart cities

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Acknowledgement:
Co-financed by the Minister of Science under the "Regional Excellence Initiative".

How to cite this article:
Wang, Z., Tundys, B. and Pokorska, A. (2024). Performance of the gold asset class compared to indices since the end of the Bretton Woods system. *Acta Montanica Slovaca*, Volume 29 (4), 960-977

DOI:
https://doi.org/10.46544/AMS.v29i4.15

Abstract
Sustainable mobility is the goal of modern cities. The following article explores this issue. A SWOT analysis was carried out using the Delphi study. The result of this study shows how and what kind of electromobility strategy is being used in the largest Polish cities. The article analyses the strengths, weaknesses, opportunities and threats associated with implementing electromobility as part of a smart city and sustainable mobility. It shows how modern cities can be combined with the efficient use of not only renewable but also non-renewable fossil resources. These urban solutions aim to save materials and use energy (of various kinds) efficiently and will, therefore, positively impact the environment. In addition to expert research, available strategic documents on which the local government units base their activities (for instance, mobility policies and analyses of strategic documents - expert interviews were conducted on this basis) were used to create the SWOT matrix. SWOT analysis and descriptive statistics were used for the research. The aim of the study was to analyze the strengths, weaknesses, opportunities and threats to the implementation of electromobility strategies in cities, with a particular focus on the assumptions and requirements of smart cities. Considerations include a discussion of effective approaches to sustainable urban development using electromobility principles and future trends.

Keywords
Sustainable mobility, SWOT analysis, electromobility, smart cities, Delphi study, renewable and non-renewable resources, energy, sustainable development, eco-development, electrical energy.

Introduction

Electromobility integrates new electric-powered transport technologies with its innovative solutions, contributes to reducing the carbon footprint, and encourages the promotion of sustainable mobility. It is well known that electromobility in cities currently relies on fossil sources, so its development and use should be planned in such a way that it includes an efficient and modern extraction industry. These urban solutions aim to save materials and use energy (of various kinds) efficiently and will, therefore, positively impact the environment. Although it is often, it is not fully defined. Both narrow and broad approaches to defining electromobility can be noticed. Authors (Grauers et al., 2013) define electromobility as a road transport system based on vehicles powered by electricity, some of which are capable of self-generation and others of using an external energy source, usually coming from the grid. According to (Mataczynski, 2018), electromobility is transportation carried out by electrically powered wheeled vehicles powered by electricity stored in a battery pack. Janczewski (2017) and Ngcobo et al. (2024) recognize electromobility as a concept that assumes ecological, emission-free electric cars instead of cars powered by fossil fuels. Authors (Bartłomiejczyk & Kołacz, 2020, p. 22; Połom, 2021; Fernández, 2021) note that the introduction of electric cars is a major sign of the development of electromobility and sustainable transport in cities. Sustainable mobility is not only about electric cars but also about individual transport. It encompasses various issues, including the powering of vehicles with alternative fuels, hybrid vehicles, hydrogen or CNG vehicles, various types of public transport vehicles, heavy goods vehicles, and individual transport vehicles. The context of the article considers only the element related to individual motorization (a narrow approach in the literature on the subject). This is a limitation, but at the same time, it is an introduction to the broader research that the authors will carry out in the next stages of research on electromobility.

Electromobility is one of the cornerstones of the smart city strategy. Ongoing activities and investments in the area of electromobility have the potential not only to reduce emissions but to support other smart city opportunities for new solutions for mobility, energy consumption, public services, residential and commercial buildings, wider urban systems, citizen engagement and behavioural change, including the creation of new attitudes (https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/sustainable-urban-mobility/electric-vehicles-smart, 05.09.2023).

Cities occupy only 3% of the Earth's surface while generating more than 70% of carbon emissions and consuming 75% of global energy (https://www.iea.org/reports/world-energy-outlook-2020, 08.08.2023). The data clearly show that only the use of sustainable mobility, including transport, is key to preserving the quality of life on the planet. The ever-increasing number of vehicles using only low-emission fuels. In 2022, were sold about 7.8 million units electric cars worldwide, roughly 10 percent of the total new car market, (https://elektrowoz.pl/auta/samochody-elektryczne-w-2022-roku-stanowily-juz-10-procent-aut-nowych-szybko-idzie-1-tesla-2-byd-3-volkswagen-ag/, 16.03.2023). As well as the age of the fleet, the noise it causes and the intrusion of land are all worsening the quality of the environment. This is due to the unsustainable mobility policy that has been pursued to date. (Carteni et al., 2020). City managers are developing and implementing various strategies, including electromobility and smart city concepts, to mitigate the identified problems. Changing the mix of vehicles in use and switching from traditionally powered to electric vehicles is becoming extremely helpful in this context. By definition, electric vehicles are more environmentally friendly, especially in urban areas, and thus support sustainable mobility. Selecting and adapting a mobility strategy is not easy. It must be a well-thought-out concept tailored to the specific characteristics, level of development, and nature of the city, as well as its economic situation, the wealth of its inhabitants, and their level of environmental awareness and need to implement sustainable development. The existence of many types and kinds of electric vehicles on the market and the degree to which the smart city concept is being implemented in a given city are also important.

The aim of this paper is to analyze the strengths, weaknesses, opportunities and threats of implementing electromobility strategies in cities, with a particular focus on the assumptions and requirements of smart cities. Therefore, analyses should be carried out, including assessments of actions taken and the scope of proposed electromobility strategies - using, among others, Strength, Weaknesses, Opportunities, and Threats (SWOT) analysis (Babar et al., 2021). Considerations include discussing an effective approach to sustainable urban development using electromobility principles and trends using a SWOT matrix. Trends and developments in European economies indicate that there is a definite acceleration in the implementation of electromobility and the number of electric cars. Realizing the associated benefits of smart cities requires coordinated action in terms of the organization and management of the network, the technology used, consumer service or the types of products offered to the market. Identifying electromobility's strengths and weaknesses can contribute to more effective implementation of smart city strategies and concepts. The following research thesis accompanies the implementation of the objectives:

H1: tailored to the nature of the city and its specifics, the electromobility strategy (supported by the conducted SWOT analysis) influences effective and efficiently implemented sustainable urban development

H2: The development of electromobility infrastructure has an impact on faster implementation of the smart city concept in cities.

The SWOT analysis methodology was developed based on an expert interview using elements of the Delphi method. Using the SWOT method, we propose different strategies for implementing sustainable mobility in the transport field, correlating them with the degree of progress in the implementation of the smart city strategy. In the next section, we present a discussion of the limitations of our considerations, and the article finishes with conclusions and recommendations for future solutions and implementations.

Literature review

Sustainable mobility and smart city

Sustainable mobility is a tool to reduce the negative externalities caused by transport in environmental, economic and social terms (Cascetta et al., 2015; Nevado Gil et al., 2020). It can be used to support smart city initiatives (Wolniak, 2024).

The smart city encompasses many elements. However, in the context of the deliberations, the most important are those related to transport mobility. These will, therefore, include solutions that support sustainable mobility with environmental, economic and socially responsible measures. Certainly, solutions supporting smart city e-mobility include ITS (Intelligent Transport Systems), offering advanced technologies to provide drivers with timely, necessary and real-time information and services to reduce congestion and increase road capacity (An et al., 2011). Solutions can be considered, the purpose of which is to link vehicles, both among themselves and with the road infrastructure, in order to increase traffic safety and efficiency (Botte et al., 2019; Mačiulytė-Šniukienė et al., 2023). In the context of the smart city, urban transport plays a major role in offering a MaaS (Mobility as a Services) solution, which, through the use of mobile communication technology and smartphones, supports not only the smart city but also sustainable urban mobility (Jittrapirom et al., 2017).

The term smart city includes issues related to sustainable mobility and electromobility in transport. In the urban context, electromobility is identified as an alternative way of powering vehicles, including electrically powered vehicles (Hájnik et al., 2021). Smart city encompasses the construction of cities is achieved through the intensive use of ICT to monitor and control six main areas of smart city: economy, human capital, mobility management, environment and quality of life that enable safe, sustainable and efficient city management and improved social, environmental and economic performance (Keshavarzi et al., 2021; Sharifi, 2020; da Silva et al., 2022). In recent discussions, ICT support has been linked to the increasing importance of urban beneficiaries' participation in the implementation of solutions. Technology and infrastructure are elements that are supposed to increase the satisfaction of citizens and contribute to improving their quality of life. Cities must, using their potential, implement creative development strategies, be open to innovation, and at the same time, be flexible and resilient, reacting quickly and adapting to a changing environment. This is not possible without the support of citizens and increasing their participation in decision-making (Tundys et al., 2020). The most important element in the governance of contemporary cities is the ability to coordinate the ubiquitous networked infrastructure in modern urban units. It enables political agility and social development by implementing activities, concepts, no ideas that can support the promotion of sustainable urban development (De Marco & Mangano, 2021).

The use of electric vehicles in city logistics and smart city concepts is not a new concept.

Both in terms of goods distribution (Pelletier et al., 2016), in the context of the development of the smart city and sustainable mobility, addressing the role of city logistics and sustainable mobility in relation to generating economic, social and environmental value, taking advantage of relevant transformation and market trends is addressed in the work (Tang & Veelenturf, 2019). The transport aspect is considered in various contexts and configurations, ranging from the topic of electric vehicle route selection (Schiffer et al., 2019), reducing negative impacts and externalities emitted by urban freight transport (Allen et al., 2018) up to solutions relating to the speed of vehicles and their load and the possibility of recharging the battery during operation on the chosen route (Liu et al., 2018), up to solutions using alternative means of transport automatically loaded during visits to customers, for example, so as not to lose the efficiency of the implemented solution and system (Cortés-Murcia et al., 2019). In addition, the use and support of the concept of electric passenger cars used by individual users should be mentioned in the development of electromobility in urban areas.

Electromobility as a strategy for the smart cities

Through technological innovation, the transport sector is rapidly transforming and adapting to the requirements of sustainable mobility, which is becoming part of it. The broad market for electromobility products and services is a very fast-growing area of the economy, both nationally and globally, and it is developing for several reasons (Tab. 1).

Tab 1. Rationale for the development of electromobility

Social	striving to improve the quality of life
Political-legal	determined by applicable EU directives and national laws and resolutions
Technical and technological	resulting from the ability to run vehicles on electricity
Economy	striving to rationalize urban transport costs
Business	related to supporting national capacity in building strong players along the electromobility value chain
Transport	subordinated to the need to improve traffic conditions
Ecological	which are an expression of the desire to protect the environment
Operational	related to the vulnerability of public transport to the implementation of electromobility

Source: author's elaboration on the basis of (Szumska & Witkowski, 2018).

The indicated premises can serve as the basis for broader analyses, including SWOT, and be the foundation for creating an electromobility strategy in support of the smart city.

The main determinants of the development of electromobility include the need for a systematic increase in requirements for vehicle combustion standards, the ever-increasing price of oil, the limited availability of this raw material and its origin in politically unstable areas. In addition, the growing public environmental awareness, supported and promoted by broad environmental organizations, is very important. Another premise for the development of electromobility is the increasing availability of electric car models and the gradual equalization of their prices compared to traditional vehicles (Polskie Stowarzyszenie Paliw Alternatywnych, 2022).

A fundamental aspect of sustainable urban mobility is the continuous creation of formal and technical frameworks under economically, socially and environmentally balanced urban processes, and one of the measures is the increase in the share of electric vehicles in the city's transportation service, economy and residents. The energy transition, which is progressing on a global scale, driven by the development of new technologies, environmental and climate protection policies, as well as the desire to reduce import dependence on fossil fuels(Lu et al., 2024), is leading to the transformation of the economic structure, affecting more industries, by increasing energy efficiency, reducing external costs while improving the quality of life.

In the short term, cities and countries can continue to implement, enforce and tighten regulatory measures such as CO_2 and fuel consumption standards and mandates for increased use and promotion of electric vehicles. Taxing gasoline and diesel at rates that reflect their impact on the environment and human health can increase government revenue, reduce negative environmental impacts, and consequently accelerate the development of electromobility and fully implement electromobility strategies (Axsen, Plötz & Wolinetz, 2020; Ewelina & Grysa, 2021; Pietrzak & Pietrzak, 2021; Chenet et al., 2021; Meireles et al., 2021).

Relating considerations to the use of electric vehicles and achieving the full potential for reducing carbon emissions, fundamental progress is needed in decarbonizing electricity generation, integrating electric vehicles into power systems, building charging infrastructure, and advancing sustainable battery production and recycling, in line with emerging regulations and successively higher requirements (Alvarez Guerrero et al., 2021, Danese et al., 2022; Li & Jenn, 2022; Hossain et al., 2022; Pickett et al., 2021).

The indicated premises can serve as the basis for broader analyses, including SWOT, and be the foundation for creating an electromobility strategy in support of the smart city (Tundys & Wiśniewski, 2023; Brzeziński & Wyrwicka, 2022; Połom, 2021).

The main determinants of the development of electromobility include the need for a systematic increase in requirements for vehicle combustion standards, the ever-increasing price of oil, the limited availability of this raw material and its origin in politically unstable areas (Skowrońska-Szmer & Kowalska-Pyzalska, 2021). In addition, the growing environmental awareness of the public, supported and promoted by broad environmental organizations, is very important (Kolz & Schwartz, 2017; Hacker et al., 2009).

A fundamental aspect of sustainable urban mobility is the continuous creation of formal and technical frameworks under economically, socially and environmentally balanced urban processes. One of the measures of sustainable urban mobility is the increase in the share of electric vehicles in the city's transportation service, economy and residents (Angelidou et al., 2022). The energy transition, which is progressing on a global scale, driven by the development of new technologies, environmental and climate protection policies, as well as the desire to reduce import dependence on fossil fuels, is leading to the transformation of the economic structure, affecting more industries, by increasing energy efficiency, reducing external costs while improving the quality of life (György et al., 2017).

Electromobility strategies, by definition, support the broader electromobility policy of sustainable development of urban transport and mobility created by decision-makers, demanded by users of urban space and residents (Motowidlak, 2022; Vovk et al., 2024). The main aspects and elements of the indicated strategies include the development of infrastructure for charging and fuelling alternative fuels; replacement and modernization of vehicles with high emissions to low- and zero-emission vehicles; promotion and support of alternative modes of transport; use of low-emission vehicles by public administration to the greatest possible extent; equipping public buildings with adequate infrastructure supporting electromobility, including charging stations; introduction of appropriate tax regulations supporting users of electric vehicles; development of supporting infrastructure, including a system of bicycle paths or development of systems facilitating transport within the city (for instance, passenger information, which are elements of a broader electromobility policy) (Dzikuć et al., 2021).

The term smart city (Albino et al., 2015) refers not only to changes taking place in the city but also to changes taking place in the city and refers to many other economic areas, such as energy, environmental engineering and protection, transport engineering, knowledge and innovation management, social sciences, e-government or transport and city logistics.

The electromobility market encompasses the implementation of innovative solutions to specific market segments, covering and supporting, inter alia, smart management of public and private electric vehicle fleets, smart city logistics, smart electrification of public transport, development of the autonomous vehicle sector, development of an integrated electromobility infrastructure, support through smart electromobility solutions of multimodal e-mobility services (Połom & Wiśniewski, 2021; Guzik et al., 2021; Bartłomiejczyk & Połom, 2021).

At the same time, sustainable mobility is intelligent mobility that goes beyond moving people around and even reducing emissions from road transport to integrate transport and energy systems. Its tenets relate to providing users with a better travel experience, improving transport and traffic safety while increasing the energy efficiency of both vehicles and cities themselves, and harnessing the huge potential of electric vehicles for energy storage through vehicle-to-grid (V2G) technology (https://smart-cities-marketplace.ec.europa.eu/news-and-events/news/2019/intelligent-mobility-safer-greener-smarter-cities, 05.09.2022) as well as having a positive impact on people's quality of life and health (Gallo & Marinelli, 2020). It has been proven that using electric vehicles helps reduce particulate and CO_2 emissions and, therefore, improves air quality, reducing respiratory, visual and cardiovascular diseases in urban beneficiaries. Noise pollution is also reduced as electric vehicles are quiet (Pallonetto, 2023, p. 465-486; Mojumder et al., 2022; Longo et al., 2018; Zagrajek et al., 2021).

Green industry and smart city

Green management concepts, such as Green Supply Chain Management (GSCM), are increasingly being integrated into various industrial sectors to enhance environmental sustainability. GSCM practices have been shown to improve sustainable performance by reducing waste and emissions in the manufacturing industry. Ahmad, A., Ikram, A., Rehan, M. F., & Ahmad, A. (2022). Going green: Impact of green supply chain management practices on sustainability performance. Frontiers in Psychology, 13, 973676. An important aspect of smart city solutions is industrial ecology, which has emerged as a concept in response to growing public concern about the industry's environmental impact, emphasizing the need for sustainable industrial development. (Richards, Deanna J., ed. The industrial green game: Implications for environmental design and management. National Academies Press, 1997.). The integration of green management and organizational innovation has been explored to understand their relationship and the role of environmental turbulence in influencing these dynamics. Such developments are highly influential in shaping smart city relationships and concepts, including electromobility (Zhou, Y., Shu, C., Jiang, W., & Gao, S. (2019). Green management, firm innovations, and environmental turbulence. Business Strategy and the Environment, 28(4)). The integration of green concepts within smart cities has significant implications for various industrial sectors. Smart city initiatives can enhance urban green development through industrial structure optimization and green technology innovation. (Zhang, Y., Liu, Y., Zhao, J., & Wang, J. (2023). Smart city construction and urban green development: empirical evidence from China. Scientific Reports, 13(1), 17366.) The convergence of smart city and green development strategies has been empirically shown to promote urban industry structure upgrading and improve green efficiency. (Yan, Z., Sun, Z., Shi, R., & Zhao, M. (2023). Smart city and green development: Empirical evidence from the perspective of green technological innovation. Technological Forecasting and Social Change, 191, 122507.) The development of green and smart cities, underpinned by clean energy and information technology, provides a framework for efficient and intelligent industrial operations. The implementation of smart city policies has been found to positively influence corporate green technology innovation, suggesting a beneficial interaction between urban planning and industrial advancement (Guo, C., Wang, Y., Hu, Y., Wu, Y., & Lai, X. (2024). Does smart city policy improve corporate green technology innovation? Evidence from Chinese listed companies. Journal of Environmental Planning and Management, 67(6)). The integration of nature-based solutions and smart city aspects has led to the development of data platforms that assess the role of such solutions in urban health and well-being, reflecting a multidisciplinary approach that encompasses industrial considerations (Kolokotsa, D., Lilli, A., Tsekeri, E., Gobakis, K., Katsiokalis, M., Mania, A., ... & Bisello, A. (2023). The intersection of the green and the smart city: a data platform for health and well-being through nature-based solutions. Smart Cities, 7(1).). Green and smart cities are founded on clean energy and advanced information technologies, serving as a cornerstone for efficient and intelligent urban development as well as green ecological transformation. They form the basis for sustainable social and economic progress and represent an inevitable trend in urban evolution.

Research methods

To answer the research questions and thesis and justify the novelty of the considerations and discussion carried out, the authors used SWOT analysis (H1) and documentary analysis, using descriptive statistics referring to H2. The SWOT analysis methodology was developed based on an expert interview using elements of the Delphi method.

The research process that served as the basis for writing the reflections took place in the following steps. The research problem was identified, followed by the research questions and the thesis. The justification of the thesis and the research undertaken was done on the basis of the available literature on the subject, which was critically analyzed. At the same time, it was decided to use primary and secondary data in the research process, and the research methodology was based on expert analysis, the results of which were used to perform a SWOT analysis. The expert analysis was performed using a structured quasi-delphi interview. The research was based on a structured interview with a panel of experts (conducted - 1 part by telephone, the second part with online criteria, and a total of 3 rounds of research were conducted). The actual analysis and research covered selected cities in Poland at the end of 2020. The motorization index was used as a criterion for selecting the research objects (Beiderbeck et al., 2021; Devaney & Henchion, 2018). This method was chosen not only to reach a research consensus but to be able to provide a basis for creating a SWOT matrix and then determining the ranks of the individual criteria. This method is used in various scientific disciplines (Dalkey & Helmer, 1963). The result of the research thus conducted was extended by transforming individual opinions into a group consensus, which can then be combined with scenario analysis and provide a new perspective, which was done in the work (Lei et al., 2023). The respondents were representatives of the self-governing authorities of selected Polish cities (the 10 largest cities in terms of population were selected for analysis), who deal with aspects of electromobility, implementation of sustainable development strategies, zero-emission and urban mobility on a daily basis. On the basis of the interviews and participatory research, criteria used for the SWOT analysis were constructed (Kowalska-Pyzalska et al., 2020; Voukkali & Zorpas, 2022; Bouraima et al., 2020). In the second step, the surveyed experts were asked to prioritize the individual criteria. On this basis, using statistical analysis methods and their own expert knowledge, rankings and individual tables were created to illustrate the implementation of urban mobility strategies. Both methods are used in research relating to transport, electromobility and urban mobility, and smart cities (Melander et al., 2019; Zimmermann et al., 2012; Melander et al., 2022, p. 108; Sá et al., 2022; Li et al., 2022; Rongen et al., 2023; Kumar & Lobine, 2023).

Quantitative data were obtained from the reports and strategy documents of the cities, which allowed the selected strategies to be assessed in the context of the SWOT analysis. The quantitative research carried out after obtaining the required secondary data and the results of the surveys allowed the correlation of the figures and the links between the smart city assumptions and the electromobility strategy and the verification of the research questions posed in the article.

The empirical analysis was based on a SWOT analysis, which indicated what kind of strategies cities are undertaking or should undertake in order to implement the concepts of sustainable mobility and smart city support, referring to aspects of transport, namely electromobility. It is a method that facilitates decision-making processes, carried out either as an interview or brainstorming technique. For the analyses, both the interview technique (to identify input factors) and the brainstorming technique were used to establish the relevant relationships that allowed strategies to be identified. The ease of performing the research with this method and the relevance of the results allows for a transparent and systematic initial review, identifying the relevant criteria and their validity in order to support the decision-making process (Nikolaou & Evangelinos, 2010, p. 226-234; Helms & Nixon, 2010, concerning the implementation of electromobility strategies and support for smart city concepts. The simplicity of the method also carries disadvantages related to excessive subjectivity and qualitative bias (Shahba et al., 2017). Application of multi-attribute decision-making methods in SWOT analysis of mine waste management (Ghazinoory et al., 2011) or the lack of a consolidated theoretical basis for electromobility research using this method. However, it can be successfully treated as a basis indicating directions for developing an electromobility strategy with a link to the smart city strategy. In order to avoid excessive subjectivity in the strategy-building process, in addition to the interviews used, desk research and a review of the literature and previous studies using SWOT analysis in similar research were relied upon. The analysis results, including the proposed strategies, include discussion and brainstorming in the context of combining strengths and weaknesses, smart city requirements, compensating for weaknesses, and neutralizing threats. In addition, the individual elements of the SWOT analysis were done according to specific and selected criteria, which are not only related to sustainable development and its assumptions but also in line with the smart city concept.

The research process and its underpinnings are shown in Figure 1.

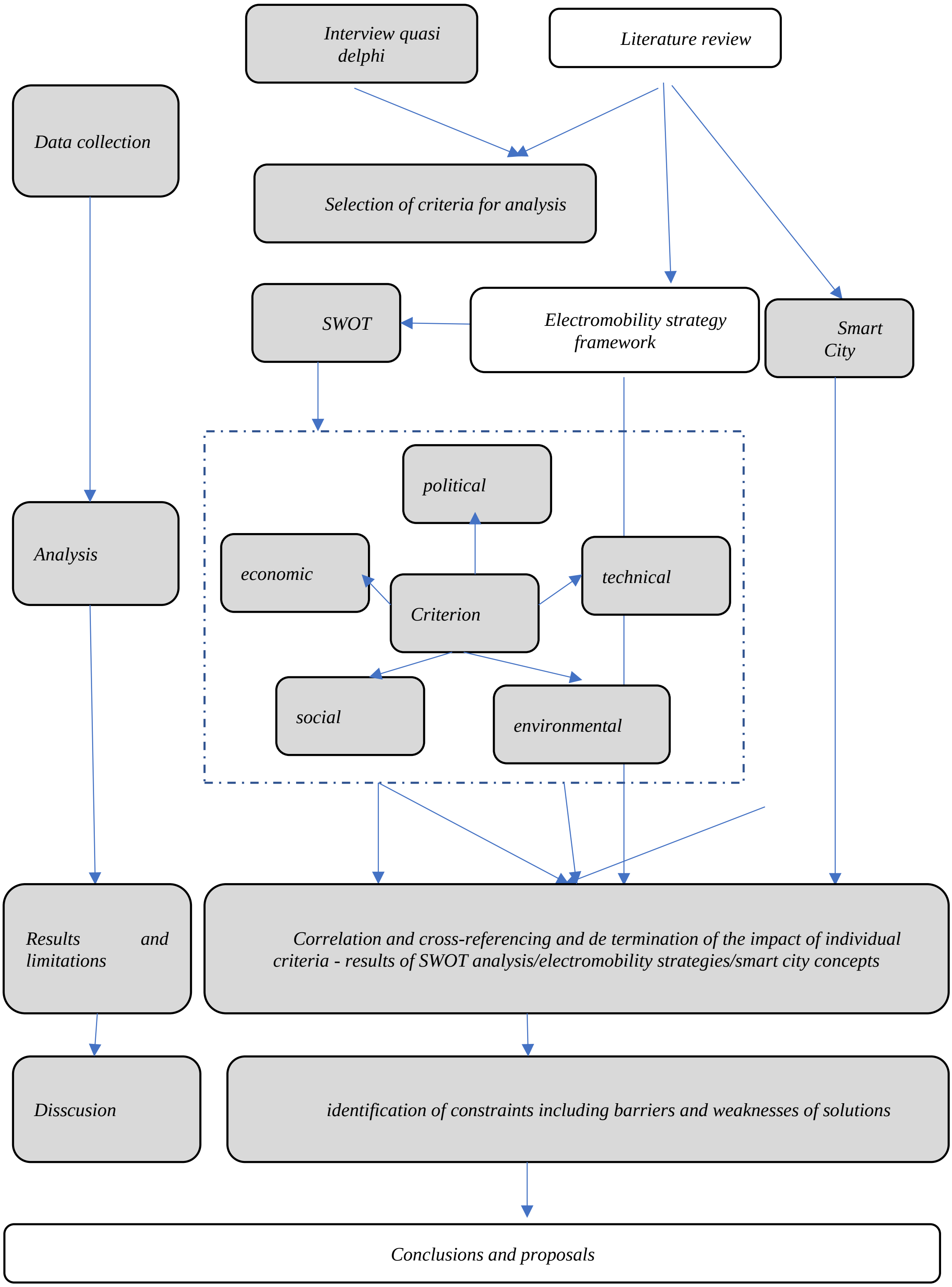

Fig 1. The research process.
Source: own elaboration.

Research results

Analyses of electromobility can be considered from different points of view. Some researchers use cost-benefit analysis for this purpose (Carteni & Henke, 2017; Cartenì, 2018) part relates to analysis using management tools (Kowalska-Pyzalska et al., 2020). The analysis of empirical research related to electromobility strategies implemented in different cities in Poland using the quasi-Delphi method is presented in Tab. 2.

Tab 2. SWOT analysis of the implementation of the e-cars mobility in the electromobility strategies in the city

SWOT Analysis						
	Strengths		*Weigh*	*Weaknesses*		*Weigh*
City (internal aspects)	*Implemented part of the smart city concept and promotion and implementation of sustainable mobility (and sustainable development principles)*	*S1*	*0,2*	*The need to set aside sites for infrastructure, the initial lack of infrastructure and the cost of maintaining it*	*W1*	*0,3*
	Investments in infrastructure development	*S2*	*0,2*	*Local shortages of power reserves and grid capacity*	*W2*	*0,2*
	Increasing range of vehicles offered by manufacturers	*S3*	*0,1*	*Lack of knowledge about electromobility among residents, lack of mechanisms to disseminate knowledge*	*W3*	*0,1*
	Improved quality of life for residents (less air pollution, less noise) - environmental benefits and more efficient and optimal energy consumption	*S4*	*0,2*	*Lack of support for users (concessions, parking spaces, free charging)*	*W4*	*0,2*
	Changing transportation preferences – modal shift	*S5*	*0,3*	*Limited driving range of electric vehicles and long charging times (weaknesses of the new technology)*	*W5*	*0,2*
	Opportunities		*Weigh*	*Threats*		*Weigh*
Environment (external aspects)	*A component of the state's environmental policy - an opportunity to support initiatives*	*O1*	*0,1*	*High cost of implementing the concept*	*T1*	*0,2*
	Ability to combine projects with the concepts of City Logistics and smart cities	*O2*	*0,1*	*Lack of regulation on charging standards and insufficient technologies for recycling used vehicles (especially batteries)*	*T2*	*0,2*
	Ability to optimize power consumption	*O3*	*0,3*	*Negative environmental impact during production and use (traditional energy sources)*	*T3*	*0,1*
	Protecting the environment and increasing environmental awareness	*O4*	*0,2*	*High purchase costs*	*T4*	*0,2*
	Creating new service development and technology development	*O5*	*0,3*	*Underdeveloped and stressed electricity grid and market uncertainty (regarding electromobility as well as energy)*	*T5*	*0,3*

Source: own elaboration.

On the basis of interviews and surveys on the implementation of electromobility strategies, weaknesses, strengths, opportunities, and threats were identified in each category, including emerging factors and elements. The weights of each factor were then determined based on in-depth interviews conducted with local government employees, the literature on the subject and expert knowledge.

The SWOT and TOWS analysis results are presented in Tab. 4.

Tab 4. Results of the analysis SWOT/TOWS

Combination	*SWOT*		*TOWS*		*Summary statement*	
	Product of interaction	*Sum of products*	*Product of interaction*	*Sum of products*	*Product of interaction*	*Sum of products*
Strengths/ Opportunities	*27*	*2,8*	*44*	*8,5*	*71*	*11,3*
Strengths/ Threats	*34*	*6,8*	*42*	*8,7*	*76*	*15,2*
Weaknesses/ Opportunities	*24*	*4,7*	*40*	*7,7*	*64*	*12,4*
Weaknesses / Threats	***36***	***7,8***	***42***	***8,4***	***78***	***16,2***

Source: own elaboration.

Electromobility strategies present many challenges as well as opportunities. They can be considered in the context of aspects of sustainable development, as well as technological and political aspects, which play an extremely important role in promoting and implementing as well as disseminating the strategy among the population. Poland's urban electromobility strategy has many weaknesses. Also, the external environment is not conducive to its development. Through their policies and actions, the state and functioning authorities should try to change this situation.

The electromobility strategy in Poland is defensive. It contradicts the European Union documents, which is caused by the low amount of charging infrastructure, too little support from government and organizational authorities, poor promotion of electromobility and little support in the form of subsidies. For the electromobility strategy in Poland to become offensive, actions should be changed to support electromobility. Actions taken should be more offensive in relation to its promotion and support at every level, as well as consistent with EU policy.

The challenges facing the development of electromobility strategies in cities in Poland are presented in Tab. 5.

Tab 5. The challenges of electromobility

THE CHALLENGES OF ELECTROMOBILITY			***LINKS TO ELECTROMOBILITY***	***REFLECTED IN THE ELECTROMOBILITY STRATEGY***
Environmental (Cev)	*Cev1* *Cev2* *Cev3*	*Difficult access to oil deposits* *Depletion of the world's natural resources of raw materials* *Ensuring access to environmentally neutral energy resources to support electromobility strategies*	++ ++	
Economical (Ce)	*Ce1* *Ce2* *Ce3* *Ce4*	*Viewing electric vehicles as a technology available to everyone, not just a select few (cost)* *Reducing the cost of acquiring vehicles* *Fiscal preferences for users of electromobility resources and concepts (electric cars, public transportation)* *Energy costs (vehicle charging)*	++ ++ ++ ++	
Social (Cs)	*Cs1* *Cs2* *Cs3*	*Changing people's conviction that producing an electric vehicle is much more burdensome to the environment than producing the same class of conventional vehicle* *Changing people's perception of electric vehicles as a technology that is too expensive and immature under current economic development conditions* *Reducing vehicle charging times*	+ + ++	
Political (Cp)	*Cp1* *Cp2*	*Energy supply - flexibility of systems and local energy accumulation* *Coordination of the electromobility system with plans for the expansion of national electricity grids at the local and national level , i.e. garbage trucks, snowplowers, plows*	+ ++	
Technical/technological (Ct)	*Ct1* *Ct2* *Ct3* *Ct4* *Ct5* *Ct6* *Ct7* *Ct8*	*Excessive weight of electric vehicles, especially batteries,* *Lack of full recovery (electro-waste generated at the end of its life cycle)* *Insufficient range of electric cars*		

	Ct9 *Ct10*	*Limited range of available vehicle type* *Uneven growth in power demand across areas (urbanized and rural)* *Cost of upgrading the power grid* *Long lead time and complexity of installation* *Preparation of the power grid to accommodate a significant number of consumers at one time* *Integration of vehicle with smart grid systems with home energy management* *Ability to secure suitable locations for charging points with appropriate technical requirements and limited land availability in the city*		
		Opportunities		
Environmental (Oev)	*Oev1* *Oev2* *Oev3* *Oev4* *Oev5*	*Reduce particulate matter and CO_2 emissions,* *Increased environmental awareness* *Impeded access to oil deposits* *Reduction in the world's natural resources of raw materials* *Gradual introduction and increase of electric vehicles in the fleet of specialized municipal vehicles*		
Economical (Oe)	*Oe1* *Oe2* *Oe3* *Oe4* *Oe5* *Oe6* *Oe7*	*Funding instruments to enable the development of the electric vehicle market and new accompanying services* *Financing a system of financial incentives to stimulate demand for electric vehicles* *Funding the process of minimizing the total cost of owning and operating an electric vehicle* *Tightening emission standards* *Reducing the VAT rate on EVs* *Abolishing excise taxes on EVs* *Reducing the cost of infrastructure construction (experience, economies of scale)*		
Social (Os)	*Os1* *Os2* *Os3* *Os4* *Os5*	*Gaining trust from the public* *Learning charging techniques* *Gaining support among local governments* *Adapting the potential of the traditional automotive industry for the development of electromobility,* *Cooperation of automotive concerns for the continued development of the sector*	+ + + + +	
Political (Op)	*Op1* *Op2* *Op3*	*Common pro-environmental policy* *Independence of countries from* *Non-renewable and hard-to-reach energy sources* *Implementation of the principle of sustainable development in more activities*	+ ++ +	+ + +

		and projects (better effects, synergy)		
Technical/technological (Ot)	*Ot1* *Ot2*	*Construction of new linear infrastructure* *Changing the structure and upgrading the fleet (municipal vehicles and public transport)*	+ +	++ ++
	Strengths			
Environmental (Sev)	*Sev1*	*Improving air quality, which leads to a reduction in respiratory, visual and cardiovascular diseases, reduction of noise pollution*	+	+
Economical (Se)	*Se1*	*The use of electricity is cheaper than traditional power sources*	++	+
Social (Ss)	*Ss1* *Ss2* *Ss3*	*Preferential parking spaces* *No parking fees* *Development of new forms of mobility*	++ ++ ++	++ ++ +
Political (Sp)	*Sp1* *Sp2* *Sp3*	*Innovative and forward-thinking approach* *Keeping up with global trends* *Fitting into the global policy of sustainable development*	+ + +	++ ++ ++
Technical/technological (St)	*St1*	*Innovative, eco-friendly solutions*	+	+

Source: own elaboration.

Tab. 6 indicates the references of each electromobility challenge to the electromobility strategy in cities in Poland.

Tab 6. Overview of links between electromobility challenges and electromobility strategy

THE CHALLENGES OF ELECTROMOBILITY	***LINKS TO ELECTROMOBILITY***	***REFLECTED IN THE ELECTROMOBILITY STRATEGY***
Cev1	++	
Cev2		
Cev3	++	
Ce1	++	
Ce2	++	
Ce3	++	
Ce4	++	
Cs1	+	
Cs2	+	
Cs3	++	
Cp1	+	
Cp2	++	
Ct1	+	
Ct2	+	
Ct3	++	
Ct4	+	
Ct5	++	
Ct6	++	
Ct7	++	
Ct8	++	
Ct9	+	
Ct10	++	
Oev1	++	++
Oev2	+	
Oev3	++	
Oev4	+	
Oev5	+	
Oe1	++	
Oe2	++	
Oe3	++	

Oe4	++	
Oe5	++	
Oe6	++	
Oe7	+	
Os1	+	
Os2	+	
Os3	+	
Os4	+	
Os5	+	
Op1	+	+
Op2	++	+
Op3	+	+
Ot1	+	++
Ot2	+	++
Sev1	+	+
Se1	++	+
Ss1	++	++
Ss2	++	++
Ss3	++	+
Sp1	+	++
Sp2	+	++
Sp3	+	++
St1	+	+

Source: own elaboration.

The electromobility strategy in Poland has too few real references to electromobility to develop at the assumed pace, especially in the category of opportunities, there is a small number of them. A more holistic and coherent approach is needed for it to have a chance to develop.

Discussion and novelty

A novelty and contribution to the development of the discipline is the use of strategies developed by cities in order to analyze the strengths, weaknesses of actions taken, barriers and opportunities provided by the implementation of electromobility strategies, with a particular focus on electromobility. The originality of the considerations and their novelty lies in using expert knowledge to identify the real strengths and weaknesses of electromobility. Until now, the issues have not been presented in this way. Identifying strategies can have practical implications, especially in a management context, providing guidance particularly for local authorities. Understanding the factors and aspects of electromobility according to their respective strengths and weaknesses can be the basis for future actions and their extension to other transport-related areas. To contextualize the discussion presented in this study, existing literature on electromobility highlights several complementary insights. For instance, according to **Geels et al. (2012) (**Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. Journal of transport geography, 24, 471-482**.)**, the transition to sustainable transport systems requires a multi-level perspective that incorporates technological innovation, societal readiness, and infrastructure development. This aligns with the study's emphasis on using strategies and expert knowledge to identify strengths and weaknesses but broadens the view by suggesting a more systemic approach that includes multiple stakeholders and transport modes. Additionally, **Buehler and Pucher (2021)** (Buehler, R., & Pucher, J. (2021). COVID-19 impacts on cycling, 2019–2020. Transport Reviews, 41(4), 393-400.) emphasize the role of supportive policies and financial incentives in overcoming barriers to electromobility adoption. While the analyzed text identifies strengths and weaknesses based on expert insights within Polish cities, this broader perspective highlights the importance of aligning local strategies with national and global frameworks for policy coherence.

A major limitation of the study is that only individual motorization was considered. This approach is because this is an initial study of electromobility strategies and an indication of the strengths and weaknesses of solutions already being implemented, which are linked to available data on individual electromobility. This is a major limitation, but subsequent studies and research considerations will already include further transport modes and considerations in order to show a holistic view of the subject matter. The study's recognition of limitations, particularly its focus on individual motorization, is echoed in **Canzler and Knie (2016) (**Canzler, W., & Knie, A.

(2016). Mobility in the age of digital modernity: why the private car is losing its significance, intermodal transport is winning and why digitalization is the key. Applied Mobilities, 1(1), 56-67), who argue for an integrated approach that includes public transport and shared mobility solutions to achieve a comprehensive understanding of electromobility's potential. Future expansions of this research could benefit from incorporating these dimensions to provide a holistic analysis, as suggested by these authors.

Furthermore, **Sovacool et al. (2018)** (Sovacool, B. K., Kester, J., Noel, L., & de Rubens, G. Z. (2018). The demographics of decarbonizing transport: The influence of gender, education, occupation, age, and household size on electric mobility preferences in the Nordic region. Global Environmental Change, 52, 86-100.) discuss the complexity of achieving socially acceptable and ecologically sustainable electromobility, advocating for interdisciplinary methodologies. This resonates with the text's conclusion about the need for multifaceted research methods but underscores the importance of cross-sectoral collaboration in designing viable strategies.

There is no doubt that the issue of electromobility is as important as it is complex. On the one hand, there are limitations and adversities to its development on many levels, and on the other hand, especially in the current political and economic situation on the national and international arena, this solution has great potential to mitigate the effects of the crisis. The complexity of electromobility brings with it the need to look for new, supportive solutions. Developing a socially acceptable, economically justifiable and ecologically safe strategy requires understanding the current problems of market functioning and applying a range of research methods.

Based on expert research, the authors have made a detailed analysis of the implementation of electromobility strategies in Polish cities, taking into account the conditions of Polish cities and their weaknesses and strengths. The analysis can be relevant to agglomeration managers and to point them in the direction of improvement, so that the further development of electromobility strategies is more effective.

Conclusions

The inadequacy of current city management processes is due to their inherent complexity. A study of city management processes, supported by a systems approach, shows that there is a need to improve the efficiency and speed of decision-making linked to necessary improvements in this complex and constantly changing environment (De Almeida & Muse, 2020). In this place, the results of the study are presented using a SWOT analysis, which was used to determine the state of implementation and to define electromobility strategies being implemented in Polish cities. The results consist of using Strengths, Weaknesses, Opportunities, and Threats (SWOT) and a database of figures to draw conclusions and proposals for the future for implementing smart city electromobility concepts. Finally, the importance of integrating smart city solution technologies in implementing the proposed methodology and ultimately in increasing citizen participation and improving the quality of life in cities is demonstrated.

Decision-making processes for implementing and promoting electromobility should be eco-rational, operating in the best possible way, and sustainable in each area (i.e., social, economic and environmental) (Cartenì, 2014). Often, the measures taken do not quite meet the requirements of rationality, although they are sustainable. That is, they do not work in the best possible way (Carteni et al., 2020). Policies need to be properly designed and implemented, using the appropriate management tools, utilizing smart city and city logistics tools and solutions in such a way that they are integrated and produce positive results while achieving several goals (reducing congestion, emissions, and costs). Thus, they make analyses, using SWOT, for example, and pointing out the various strategies necessary for implementation while at the same time relying on the constant pursuit of improving the existing situation. It is possible to successfully implement an electromobility strategy that will support sustainable urban development and smart cities. These fundamentals and assumptions will translate into a policy of investment in new infrastructure solutions and faster implementation of smart concepts in cities, including the development of an electromobility strategy through the development of its infrastructure.

In fact, an electric vehicle has zero impact only in the local area, as it does not pollute the areas it travels on with harmful substances, but unfortunately, the environmental impact resulting from the production of electricity needed to power the vehicle is far from zero. The potential of electromobility is local zero-emission, especially in cities with high population density, making the technology useful for urban mobility.

E-mobility is useful within the framework of new forms of mobility, which emphasize the latter's strengths, i.e. zero local emissions, reducing its weaknesses, i.e. high purchase price and limited autonomy. Possible areas of e-mobility application under MaaS are (i)micromobility; (ii) shared mobility; (iii) urban electric bus fleet; (iv) urban freight distribution. Rapid development of charging infrastructure is not possible without expansion of existing infrastructure and construction of fast charging networks (Marino & Marufuzzaman, 2020), so the indicated strategies should be supported by infrastructure measures.

Undoubtedly, the issue of electromobility is as important as it is complex. All the more so because, on the one hand, there are limitations and adversities to its development occurring on many levels, and on the other hand, especially in the current political and economic situation in the national and international arena, this solution has great potential to mitigate the perceived effects of the crisis. The complexity of the issue of electromobility brings with it the need to look for new solutions that support it. Policies must be properly designed and implemented, using appropriate management tools, smart city and city logistics tools, and solutions in such a way that they are integrated and have positive effects while achieving several objectives (reducing congestion, emissions, and costs). Thus, they make analyses, using, for example, SWOT, and pointing out the various strategies necessary for implementation while at the same time relying on the constant pursuit of improving the existing situation. It is possible to successfully implement an electromobility strategy that will support sustainable urban development and smart cities. These fundamentals and assumptions will translate into a policy of investment in new infrastructure solutions and faster implementation of smart concepts in cities, including the development of an electromobility strategy through the development of its infrastructure.

In future research work, the authors will focus on further investigating the level of implementation of electromobility strategies in cities in Poland, including a comparison of metropolises in Europe in the structure of the work. Future work in this area must focus on solutions for individual motoring and linking electromobility solutions to public transport and freight transport. Preliminary work on the implementation of electromobility in both areas is already underway. They are certainly more advanced in the use of alternatively powered vehicles in public transport than in freight transport, but both areas are equally important. Another important element is linking electromobility with smart city strategies and their integration as an integral part of the concept. An important factor in development is also the need for cooperation and integration of strategic documents with reality. Creating strategies without supporting infrastructure (for instance, charging stations) will not have the desired effect. As can be seen, this topic has many research possibilities and practical implications.

In summary, the study contributes valuable insights specific to the Polish context, complementing broader academic discussions on electromobility's systemic challenges and opportunities. The research could align more closely with established international frameworks and literature by addressing the limitations and expanding its scope to include diverse transport modes and stakeholder perspectives. Production resources, closed-loop design, in-house research and development) make up the development of new innovative sustainable technologies that will contribute to material savings and efficient energy use, thus having a positive impact on the environment and can be used in smart cities. Verification of the developed model confirmed its usefulness in conducting data analysis for decision support purposes.

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