

PROSPECTS FOR THE DEVELOPMENT OF SMART CITIES IN POLAND AND THE QUALITY OF LIFE OF RESIDENTS

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Purpose: This article addresses the crucial issue of smart city development in Polish cities. The main goal of the article is to analyze the prospects for technological development and sustainable management in the context of building smart cities in Poland, as well as to assess their impact on the quality of life of residents. Urban space and the growing importance of technology in civilizational development indicate the need to adapt to global trends in this area.

Design/methodology/approach: The aim of this work was achieved through theoretical and practical analysis. The article analyzes the results of the conducted research and compares the author's own research with national studies on the presented topic. The results presented in this work illustrate the image of Polish cities striving to become smart cities of the future.

Findings: The results of the conducted research enabled the identification of key directions for technological development and the implementation of solutions in Polish cities that contribute most to improving the quality of life of their residents. The observed trend in implementing the smart city concept, aimed at improving the efficiency of urban spaces, allows for the definition of priorities for implementing innovative tools and systems that support everyday urban life. The analysis of the research material enabled an assessment of the impact of modern technologies on the development of smart cities and their role in shaping a more sustainable and friendly urban environment.

Research limitations/implications: The topic discussed in this article is important and timely, and therefore research in this area should be published. However, research opportunities are limited, and significant changes occur year by year. Therefore, there is a need to conduct further studies and expand their scope. The author plans to continue this research, which will allow for deeper knowledge of the subject in the future.

Practical implications: The information presented in this article has significant economic and commercial impact due to the directions it outlines. Both individual companies and the overall development of businesses in Poland should consider the need to improve the quality of life for citizens. The article presents options for implementing actions that consumers believe are important to them. The solutions identified can help determine the direction of business development. Entrepreneurs can learn about the demand for products and initiatives and what practical changes need to be implemented. They can use this knowledge to increase competitiveness and acquire new customers.

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Social implications: The presented research will influence public awareness of smart cities. At the same time, city residents will learn about the benefits of implementing technological solutions that will improve their lives and functioning in cities. Participants will learn about the state's capabilities in the areas of smart cities, environmental protection, and what actions they can implement in their immediate surroundings. The article will allow them to assess their own attitudes toward smart city solutions.

Originality/value: The added value of the article is the opportunity to learn about technological solutions that improve the quality of life for city residents within the smart city concept. The topics presented are current and relevant to all residents of Polish cities from the perspective of their development.

Keywords: technologies, smart cities, quality of life, sustainable management.

Category of the paper: Research paper.

1. Introduction

Contemporary cities, as centers of social, economic, and cultural life, are facing increasing pressure resulting from the development of urbanization processes, climate change, and growing expectations of residents regarding quality of life (Kar et al., 2019). In response to these challenges, the concept of smart cities is evolving. It integrates advanced information and communication technologies, sustainable resource management, and innovative models of urban space organization (Bokhari, Myeong, 2022). The development of smart cities is based on the interaction between technological advancement and strategic management aimed at sustainable development (Giuliodori et al., 2023). The key objective of these efforts is to improve the functionality and efficiency of cities while enhancing residents' quality of life and minimizing negative environmental impacts. The idea of smart cities in Poland is gaining increasing importance in the context of urban development strategies, particularly in areas such as mobility, energy management, security, environmental protection, and access to public services. Crucial to this process is both the development of digital infrastructure and the implementation of sustainable development principles, which together form the foundation for more functional, user-friendly, and crisis-resilient cities (Wahyuddin, Wibowo, 2021; Ancillai, 2023). The aim of this paper is to analyze the development prospects of technology and sustainable management in the context of building smart cities in Poland, as well as to assess their impact on residents' quality of life.

2. The concept of the smart city

The smart city represents an interdisciplinary approach to the sustainable development of urban areas, combining elements of technology, urban planning, public administration, and social sciences (Makiela et al., 2022; Borda et al., 2021). In the literature, the term has not been clearly defined, which is why today, under the umbrella of "smart city", a variety of different concepts are encompassed (Attaran, Kheibari, Bahrepour, 2022; Gracias et al., 2023). These concepts share a common goal: the need for a holistic approach to urban modernization that takes into account technological, social, economic, and environmental factors (Shams et al., 2020; Joss et al., 2019; Attaran et al., 2022). In this context, a smart city is not only a space equipped with modern infrastructure, but above all an environment that fosters social innovation, flexible governance, and the ability to adapt to changing external conditions (Nureen et al., 2023; DeJong, Joss, Taeihagh, 2024). The essence of the smart city concept lies in the use of modern technologies - particularly information and communication technologies (ICT) - to improve residents' quality of life, the efficiency of public services, and the sustainable management of urban resources (Alahi et al., 2023). An important aspect of the smart city is also the support of a low-emission economy, the promotion of efficient use of natural resources, and the development of green infrastructure (Hui, 2023). From the perspective of public administration, a smart city is also a data-driven organizational model, where decisions are made based on the analysis of information gathered from various sources -such as sensors, monitoring systems, digital platforms, and interactions between citizens and institutions (Ortega-Fernández, 2020). The transition to this model requires system integration, data interoperability, and addressing challenges related to information security and user privacy (Yin, Zhu, 2020; Xia et al., 2024). A smart city can be viewed as a complex system in which six key components are integrated (Figure 1):

- smart governance, which uses digital technologies and data analysis to efficiently manage urban infrastructure, resources, and services, thereby improving residents' quality of life (Ripoll González, Gale, 2023);
- smart economy, which efficiently leverages technology and data to optimize economic processes, improve resource efficiency, and implement innovation within the city (Sha, Taeihagh, De Jong, 2024);
- smart mobility, meaning an integrated and optimized approach to transportation that utilizes digital technologies and data analysis to improve the efficiency, safety, and sustainability of transport systems (Fontaine, Minner, Schiffer, 2023);
- smart environment, defined as an area that uses advanced technologies to monitor and manage natural resources, improve air and water quality, and ensure the efficient use of energy (Debnath, Sarkar, 2023);

- smart citizens, who are a key element in the functioning of smart cities. While technology and infrastructure are important, it is informed, engaged, and active citizens who determine the success of the smart city concept (Deng, Fei, 2023; Calzada et al., 2021);
- smart living, a lifestyle supported by modern technologies, sustainable development, and active citizen participation. It refers to everyday life in a city that responds to people's needs by utilizing data, automation, and digital tools (Caragliu, Del Bo, 2023).

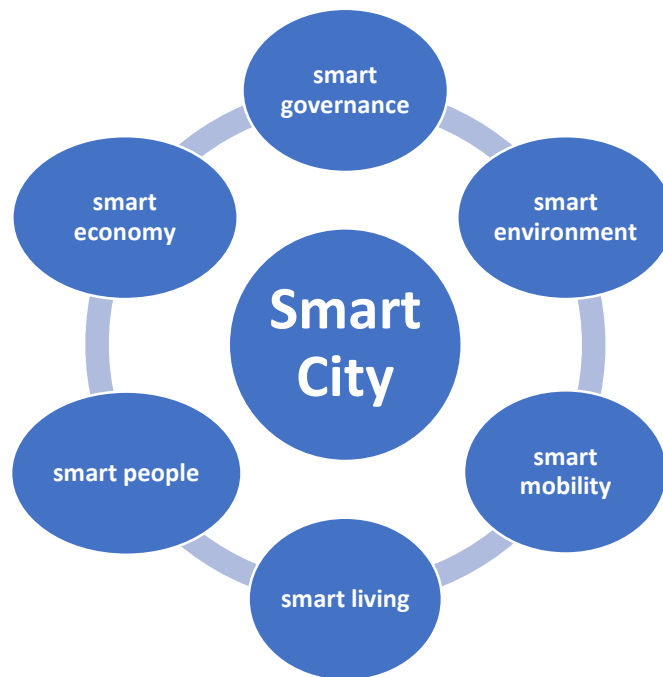


Figure 1. Smart City Factors Model.

Source: Own elaboration based on Kim, 2022.

All of the factors mentioned above are essential to achieving smart city status. Today's technological and informational capabilities enable the rapid transmission of large volumes of data, allowing for quick processing and the implementation of appropriate solutions (Kourtit, Nijkamp, 2021). The most significant benefits of smart cities include, among others (Jiang et al., 2021):

- improvement in residents' quality of life through better access to services, as well as increased transparency and efficiency of administration by leveraging data access and digitizing administrative processes that enhance the transparency and effectiveness of public offices,
- greater safety thanks to monitoring and traffic analysis systems that enable early detection of threats,
- sustainable urban development through efficient resource use, cost reduction, cleaner air, and environmental protection,
- increased city competitiveness by attracting investors and tourists, contributing to economic development and city promotion,

- financial savings through optimizing resource consumption and more efficient city management, resulting in cost savings for both the city and its residents,
- more efficient transportation through the reduction of traffic congestion and delays, thanks to smart traffic management and optimization of vehicle flow (Kmiecik, Wierzbicka, 2024),
- increased comfort and convenience of travel, thanks to easy access to transportation information and the ability to choose optimal routes,
- greater citizen participation through active involvement in decision-making and urban life (Giela, 2023).

The implementation of smart city management requires the involvement of multiple stakeholders - primarily city authorities, businesses, residents, as well as research and educational institutions (Figure 2). The role of city authorities is to develop an appropriate strategy using available technologies and to ensure proper funding. Research and educational institutions should support the development of this strategy and facilitate the implementation of innovative technologies and solutions. Meanwhile, businesses should develop and deploy innovative solutions in which residents actively participate and from which they directly benefit.

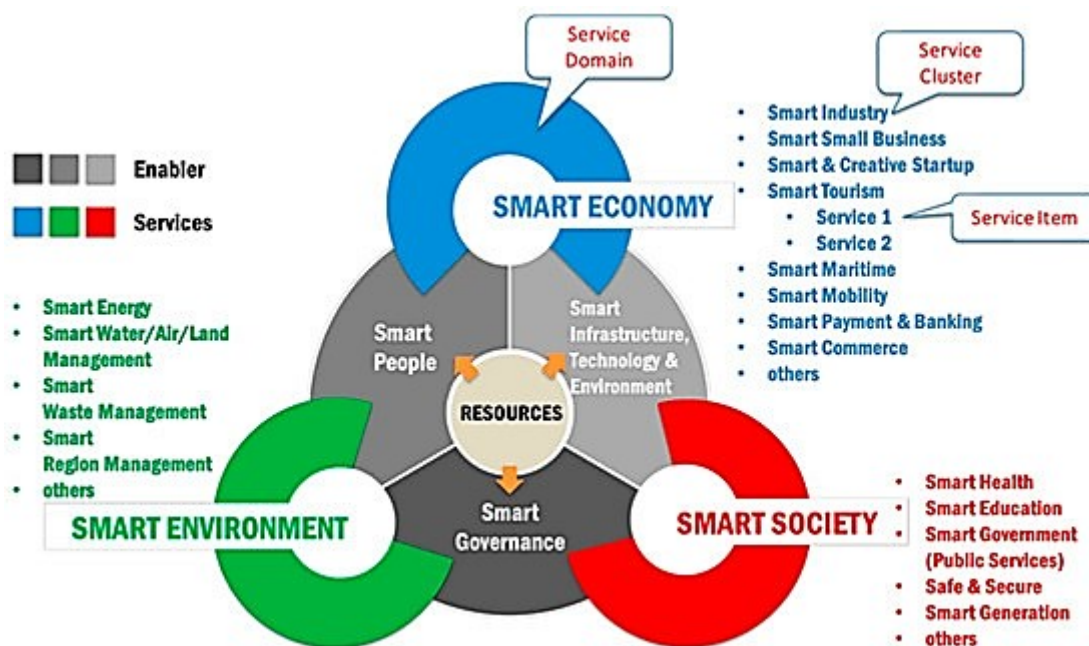


Figure 2. Smart City Model.

Source: Kézai, Szabolcs, Mihály, 2020, pp. 1477-1494.

The involvement of all stakeholders - especially citizens - in the sharing economy would lead to the creation of an effective system in which everything functions as intended and is fully utilized to support the operation of the city (Curtis, Mont, 2022; Masik et al., 2021). City authorities should have well-considered development directions. The strategy should be prepared not only in terms of the problems faced by residents but also with regard to the city's

revenues and planned investments. A city focused on tourism will pursue different development paths than one whose growth is based on the creation of large logistics centers. The implemented concept should take into account all essential elements and needs of a smart city.

3. Polish cities and the smart city concept

The development of the smart city concept in Poland, similarly to global trends, has undergone an evolution. Initially, these were primarily technology-driven initiatives focused on the implementation of modern infrastructure and IT systems. Over time, they have shifted toward a more holistic approach, where the overarching goal is to improve residents' quality of life through the integration of technology, sustainable development, and social participation (Masik, Sagan, Scott, 2021). In Poland, the smart city concept is increasingly being applied in large and medium-sized cities. Although many Polish cities have implemented systems that align with smart city strategies, a comprehensive integration of these systems is still lacking (Roman, 2018). The solutions being implemented cover various areas: from the digitalization of public services, through sustainable transport and energy efficiency, to social participation (Curtis, Mont, 2022). For the purpose of the analysis, seven cities were selected that meet the criteria of smart cities: Warsaw, Gdansk, Wroclaw, Poznan, Cracow, Lodz, and Rzeszow. Although all of the analyzed cities declare their commitment to implementing the smart city concept, the scope and pace of these efforts vary (Table 1).

Table 1.
Comparison of Smart City Areas in Selected Polish Cities

City	Key Areas	Notable Smart City Solutions	Grading	Level of Advancement
Warsaw	Smart governance, smart mobility, open data	Open Data of the Capital City of Warsaw, Veturilo (city bike system), participatory budgeting apps, smart lighting	10 points	High (comprehensive and integrated actions across multiple sectors)
Gdansk	Smart environment, smart governance	"Gdansk Without Plastic" initiative, Tristar traffic management system, participatory urban planning	9 points	High (innovative approach to environment and governance)
Wroclaw	Smart mobility, smart living, smart infrastructure	Wroclaw City Card, Urban Lab, Intelligent Transport System (ITS), Wroclaw 360° app	9 points	High (strong focus on residents and quality of life)
Poznan	Smart people, smart services	Smart City Poznan, digital urban services platform, digital education, spatial information system	7 points	Medium (advanced development of digital infrastructure and competencies)
Cracow	Smart mobility, smart environment	Smart traffic management, air quality sensors, EcoHarmonogram app	6 points	Medium (fragmented actions, but under development)

Cont. table 1.

Lodz	Smart infrastructure, smart economy	Municipal ICT cluster, downtown revitalization using data, Smart City Lodz	7 points	Medium (high activity in projects, but lack of full integration)
Rzeszow	Smart mobility, smart governance	Smart Rzeszow, ITS, development of e-services, digital city office, smog sensors	6 points	Medium (dynamic development despite the smaller city size)

Source: Own elaboration based on <https://aspolska.pl/raport-zielone-smart-city/>, 25.07.2025; <https://obserwatorium.miasta.pl/wp-content/uploads/2016/08/R28TT-Miasta.pdf>, 25.07.2025; https://archiwum.nist.gov.pl/files/texts/4447_16927740289611.pdf, 23.07.2025; <https://www.pwe.com.pl/pobierz.php?id=1288821611&mode=artykul>, 26.07.2025; <https://www.googleadservices.com>, 25.07.2025; <https://content.knightfrank.com/research/1500/documents/pl/warszawa-w-kierunku-smart-city-april-2018-5463.pdf>, 23.07.2025; https://almine.pl/smart_city_przyklady_polska/, 25.07.2025; <https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.gdansk.pl/smartcity/nowa-wizja>, 26.07.2025.

The cities analyzed above represent different stages and models of transformation towards smart cities. During the analysis of cities, six main criteria were used to determine the level of sophistication of a smart city:

- the scope of implementations, i.e. the number and variety of smart city areas,
- solution integration, i.e. checking whether systems and projects are related to each other and share data,
- innovation of solutions, i.e. the innovative nature of projects on a national scale,
- the scale and range of implementations, whether the activities cover the entire city or only selected districts,
- social participation and participation, whether there is participation of residents in the use of solutions,
- effects and results, i.e. e.g. the number of application users, shortening the travel time.

The grading system is included in a point scale, each of the 6 criteria is assessed on a scale of 0-2 points (0 – no activities, 1 – fragmentary activities, 2 – comprehensive and well-documented activities). The maximum number of points was 12, while the level assignment: High: 9-12 points, Medium: 5-8 points, Low: 0-4 points. The capitals of voivodeships with the largest populations (Warsaw, Wroclaw, Gdansk) are characterized by institutional maturity and a systemic approach to implementing smart solutions. In these cities, integrated urban strategies aligned with the smart city concept, advanced ICT infrastructure, and mechanisms for monitoring the effects of implemented policies are observed. The larger cities possess greater financial, human and technological potential, which translates into the ability to implement more advanced projects. An example is Warsaw, where activities cover a wide range of urban functions: from traffic management to digital collaboration in spatial planning. Rzeszow demonstrates that smaller urban centers can effectively implement smart city solutions based on flexible management structures and operational efficiency. The analysis reveals a varied level of advancement in the digital and managerial transformation of cities, with a dominance

of technology-driven actions often carried out in a fragmented manner. There is a need to create a nationwide system for implementing the smart city concept.

When analyzing the presented topic, one can also refer to the quality of life report, in which all the surveyed cities ranked highly (Table 2). The report covered ten areas influencing quality of life. These include education, work, housing, environment, health, safety, community, leisure, local government, and transport and connectivity.

Table 2.
The Quality of Life Ranking in Polish Cities

City	Ranking position	Number of points
Warsaw	2	98,96
Cracow	3	95,88
Poznan	4	94,52
Rzeszow	5	94,46
Gdansk	6	93,88
Wroclaw	7	91,80
Lodz	24	62,87

Source: Own elaboration based on: www.miasta.pl/aktualnosci/ranking-jakosci-zycia-w-miastach, 23.07.2025.

According to the report, the quality of life in Polish smart cities is rated highly, which is undoubtedly influenced by the technological and informational development of the implemented urban systems.

In reference to the analyzed reports, it was decided to conduct original research on the quality of life of residents in these cities. To ensure transparency and comparability of results, the paper focused on the scoring system in Table 1, which enabled the identification of areas with the highest and intermediate levels of implementation of smart city initiatives. The sample selection was purposeful and took into account factors such as: provincial capital status, having a smart city strategy or equivalent documents, availability of public project data, and geographic diversity (different regions of Poland). The research was conducted using a survey method between January and June 2025. The survey was conducted via the Internet, using the Computer Assisted Web Interview (CAWI) research method, and total of 560 correctly completed questionnaires were obtained. The respondents (560 respondents) were residents of the analyzed cities, i.e.: Warsaw (85 respondents), Gdansk (79 respondents), Wroclaw (84 respondents), Poznan (80 respondents), Kraków (78 respondents), Lodz (82 respondents) and Rzeszow (72 respondents). The study included city residents of various ages, both women and men, characterized by different levels of education and social status. For the analysis of primary and secondary data, MS Excel and the use of basic tools of descriptive statistics were used. Additionally, the results were visualized in the form of figures, focusing on the responses of respondents from the studied cities, to indicate differences in the smart city development profiles of individual cities.

Regarding the most important questions from the survey, the information relevant to the article's topic is presented below. The most interesting aspect of the questions was the respondents' opinion on the quality of life in their place of residence (Figure 3).

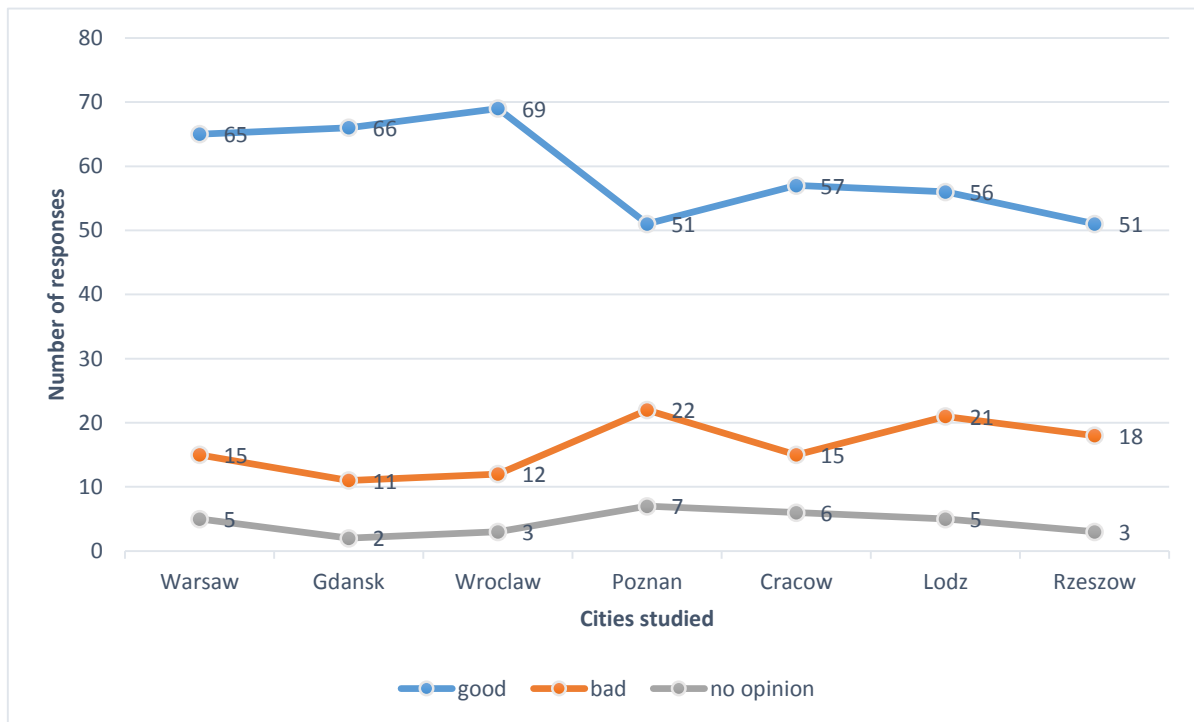


Figure 3. The structure of respondents' answers by city of residence.

Source: Own elaboration based on the survey, n = 560.

The majority of respondents rated the quality of life in the surveyed cities highly, which indicates the proper implementation of concepts that influence residents' satisfaction. Wroclaw received the highest rating, consistently ranking high among the best-rated Polish cities in various rankings.

Another important aspect is the assessment of the level of safety in the city. Respondents evaluated safety based on the following factors: efficiently functioning city surveillance, protection of the city's digital infrastructure, civic cooperation, and the response of relevant services. The responses provided were as follows (Figure 4).

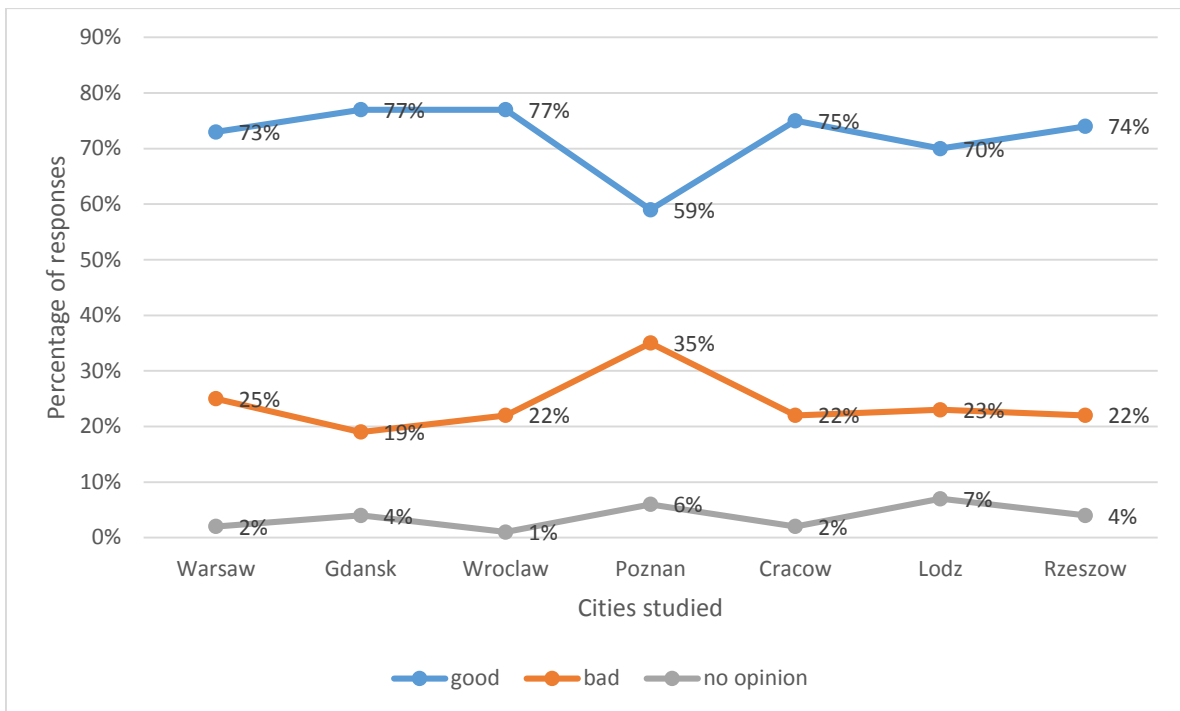


Figure 4. The structure of respondents' answers by city of residence.

Source: Own elaboration based on the survey, n = 560.

A high level of safety in the city is one of the most important issues for many authorities due to actions taken to improve the public perception of this matter. Therefore, the presented data indicating safety at around 70% according to residents' opinions is positive both for city authorities and for visitors to the smart city. Of course, these perceptions are subjective opinions of the respondents, but nonetheless they demonstrate a high level of safety in the surveyed cities, influenced by the implemented technological solutions.

The survey also asked respondents for their opinion on:

- the level of mobility in the city, defined by the organization of transport, including the availability of bicycles, scooters, and car-sharing services,
- the level of implementation of intelligent urban systems utilizing modern technologies, sensor networks, data analytics, and automation,
- the level of technological and informational development in the city through the use of advanced digital technologies, data processing systems, and intelligent management tools that enhance the efficiency of city operations and the quality of life of its residents (Table 3).

Table 3.
Percentage Structure of the Respondents' High-Level Responses

City	Level of mobility in the city	Level of implementation of intelligent urban systems	Level of technological and informational development in the city
Warsaw	69%	76%	80%
Gdansk	80%	77%	82%
Wroclaw	70%	76%	70%
Poznan	57%	74%	49%
Cracow	73%	77%	53%
Lodz	73%	74%	54%
Rzeszow	76%	79%	57%

Source: Own elaboration based on the survey, n = 560.

The table above presents respondents' answers indicating a high level of mobility, implementation of intelligent urban systems, and technological and informational development in all the analyzed cities. The research clearly shows that residents notice the technologies being implemented and are satisfied with their presence. These technologies enable better functioning within the urban space.

In the conducted survey, respondents were asked for their opinion on the level of natural resource management and environmental protection in their place of residence. They were requested to complete the questionnaire considering the following factors: whether they observe efficient resource use, implementation of investments aimed at reducing living costs, cleaner air, and actions contributing to environmental protection (Figure 5).

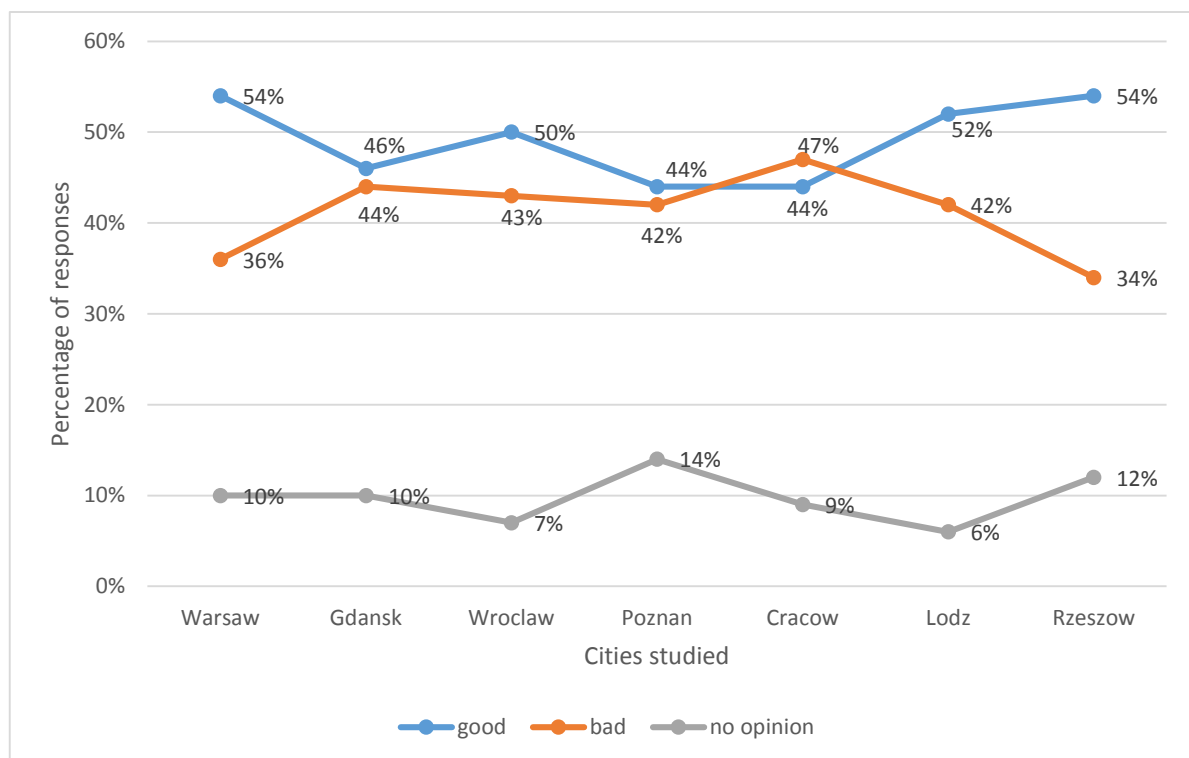


Figure 5. The structure of respondents' answers by city of residence.

Source: Own elaboration based on the survey, n = 560.

Data presented in Figure 5 indicate that residents perceive shortcomings in actions related to environmental protection and the use of natural resources aimed at reducing living costs and caring for the natural environment. The results highlight the need to implement more initiatives in this area. All the surveyed cities must improve this aspect of their functioning to achieve better resident feedback in the future.

Simply living in an urban space or residing in a city listed in smart city rankings is not necessarily an indicator of the best quality of life. However, it is important to remember that all changes and conveniences in smart cities require time to function properly. A high level of awareness among city authorities, businesses, and residents themselves is essential for the effective use of available systems and technologies. Each city strives to be the best for its inhabitants, so the actions taken should be the most beneficial for the specific city.

4. Discussion and Recommendations

Within the smart city concept in Poland, most of the analyzed cities show a predominance of implementing infrastructural and technological solutions. However, social components such as co-management, development of digital competencies, digital education, and inclusion of local communities in decision-making processes are less developed. This imbalance leads to a technocratization of urban development, where residents become merely service recipients rather than active participants in the transformation process. Therefore, it is recommended to implement integrated strategies that combine ICT development with civic education. Such actions will enable the achievement of sustainable outcomes in terms of quality of life and sustainable development.

Poland lacks unified strategic and legal frameworks at the national level that could ensure coordination, interoperability, and the exchange of best practices between cities. This hinders the development of a nationwide smart city system and the effective implementation of innovations. Individual urban initiatives are often isolated projects, dependent on available European Union funds, without linkage to a long-term national vision for smart city development. Establishing a central institution or expert team responsible for coordination, knowledge transfer, and support for smaller local governments could significantly enhance the efficiency of digital transformation in Polish cities.

Despite the existence of municipal open data platforms, their practical use in management and planning remains limited. Data is rarely utilized for analyzing urban trends or dynamic service management and often serves merely an informational role. Transitioning from an informational model to data-driven governance remains one of the key challenges for all analyzed cities. In Poland, it is recommended to establish urban analytics teams within municipal offices and to train staff in GIS data analysis and information management.

A beneficial step would be integrating data from various sectors, such as transport, environment, and public health, as well as implementing predictive systems based on artificial intelligence and forecasting models. These actions could significantly improve the functioning of cities of the future.

In many cities, especially Gdansk, Cracow, and Wroclaw, there is a clear emphasis on combating smog, improving energy efficiency, digitally managing waste, and developing green infrastructure. This indicates that Polish cities recognize the link between technology and sustainable development; however, the scale of these efforts still does not match the magnitude of climate challenges. Respondents in the conducted studies also noticed shortcomings in this area, which is why it is recommended to implement a greater number of initiatives addressing environmental protection aspects.

All conclusions drawn from the analyzed studies, both own and nationwide reports, focus on finding the most beneficial solutions for Polish cities. The implementation of modern technological and communication initiatives across various areas of urban life will enable an improvement in the quality of life in the city.

5. Summary

In summary, based on the presented data and theoretical-practical analyses, it can be concluded that the article's objective has been achieved through the conducted analyses. The conclusions regarding quality of life in smart cities are clear: everyone desires to use available technologies that facilitate functioning in the urban space. Smart city systems help city authorities adapt the city to the needs of its residents. However, it is important to remember that technology can both support society and harm the natural environment. Therefore, a balance must be found between technology and environmental protection. Intelligent solutions in cities require residents' awareness and the ability to effectively use the available tools. Thus, both technology and information campaigns, as well as digital education for residents, are crucial. The presented analyses of reports illustrate the types of initiatives operating in Polish cities. Additionally, the conducted surveys among residents of Polish smart cities confirmed the thesis that the quality of life is perceived as high. Currently, most smart city initiatives are implemented in larger cities due to their financial and human resource capacities. European funds and cooperation between cities within research and development programs play a significant role. In the future, efforts should be made to equalize opportunities for all cities to implement the most important initiatives that enable better functioning and improve the quality of life in a sustainable smart city. The author plans to further explore the topic of management in smart cities and its relationship with the quality of life of residents. This subject remains relevant and aligns with current trends - both national and global.

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