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APPLICATION OF IOT TECHNOLOGY IN PUBLIC TRANSPORT MANAGEMENT IN SMART CITIES

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Purpose: The dynamic development of modern information and communication technologies (ICT) and the increasingly widespread application of the Internet of Things (IoT) concept are one of the key elements in the transformation of modern cities into so-called smart cities. The growing demand for effective, safe, and environmentally friendly solutions in public transport makes IoT particularly important as a tool supporting sustainable development and improving the quality of life of residents. The aim of this article is therefore to examine the level of public awareness, perception of benefits, and potential risks arising from the use of IoT technology in public transport. The aim of the study was also to determine the extent to which respondents recognize the importance of IoT in improving the functioning of public transport, including punctuality, safety, travel comfort, and environmental protection. Another important aspect of the analysis was to identify potential concerns related to privacy and user data security, which is one of the main challenges of modern smart systems. Ultimately, the article aims to provide valuable insights for both practitioners and researchers involved in the field of smart cities. The research results can serve as a source of knowledge for planning and implementing IoT-based solutions in public transport, supporting the decision-making process of local authorities, transport system designers, and institutions responsible for sustainable urban development.

Design/methodology/approach: The research objectives were achieved by using a diagnostic survey method based on an online questionnaire. The approach to the topic is empirical and analytical, based on the theoretical assumptions of the Internet of Things (IoT) concept and its application in public transport in the context of smart city development.

Findings: The study found that most respondents had a positive view of the impact of IoT technology on the quality of public transport, especially in terms of improving safety and punctuality. The analysis of the results also confirmed a high level of public acceptance for the implementation of IoT-based solutions in smart cities.

Originality/value: The article brings a new perspective on the practical application of Internet of Things (IoT) technology in public transport, presenting users' opinions and expectations regarding smart urban solutions. Its value lies in providing up-to-date empirical data that can support local authorities, transport system designers, and researchers working on smart city issues.

Keywords: IoT, Management Smart City, Management Smart Mobility.

Category of the paper: Research paper.

1. Introduction

New technologies and new channels of communication affect not only the real economy and changes in the ways goods are produced and services are provided, but also work, housing, culture, value systems, etc. The transformations are so significant and so rapid that specialists are trying to analyze the consequences of these changes, find patterns, and create new theories. Automation has been around since the last two decades of the 20th century, and its widespread use did not bring about a breakthrough. Fundamental changes were brought about by networking, which was made possible by the digitization of various spheres of economic and non-economic activity. Increased efficiency was of fundamental importance for economic development. Networking broke down the barriers that existed in the traditional management process, in which each economic entity sought to rationalize the use of its resources. A similar development began to take place in the area of local government. This concerns the pursuit of new technological and organizational solutions, known as ICT, in the field of smart city development. Their implementation also has an impact on one of the six main sub-areas, namely smart mobility (Bitkowska, 2018; Łabędzki, 2022). The stages of transforming a city into a smart city, which were presented in Figure 1, are a natural consequence of the evolution of cities.

Figure 1. The evolution of the city towards the smart city concept.
Source: besed on: Dewalska-Opitek, 2014.

The level of interactivity of urban areas is growing in parallel with the awareness of residents. Smart city elements are developing all over the world, including (Qonita, Giyarsih, 2023, pp. 481-483):

- Smart economy.
- Smart environment.
- Smart management.
- Smart living.
- Smart mobility.
- Smart people.

According to this transformation, they aim to transfer new technologies to the world, allowing them to live more comfortably. However, in Poland, the idea of smart cities may seem costly, but in the long term, it allows for significant savings at the local government level. When analyzing citizens' needs, local governments recognize the need to combine public

transport solutions with process management support dictated by the dynamically changing conditions of the urban environment, which cities of the future must meet, resulting from the implementation of adaptive measures (Bitkowska, 2018). More and more local governments recognize the need to implement a process management model that allows for the integration of the strategic and operational levels. There is a necessity to analyze the city's public transport processes, considering the relationship between individual internal and external elements. By definition, urban transport is one of the branches of the economy that most closely follows innovative solutions in the areas of vehicle resources used (including rail, road, and underground). In its efforts, it ensures effective travel for residents in three important relationships:

- home – work – home,
- home – school – home,
- home – destination – home.

In summary, the efficient functioning of public transport is crucial for the daily lives of residents and for the sustainable development of the city. The use of modern technologies, including solutions based on the Internet of Things concept, can contribute to increasing the efficiency of transport systems, improving their accessibility, and the quality of services provided. As a result, public transport becomes not only a means of transportation, but also an important element of a smart and resident-friendly city.

2. Literature review

Currently, there are many definitions of a city. Urban centers and related concepts are classified according to population size, type of functions performed, buildings or regardless of these factors, municipal rights (Manik, 2024, pp. 3-4). Definitions of cities have evolved (Noori, et al., 2025, pp. 14-15). Initially, defensive strongholds with their suburbs or commercial settlements were considered cities. However, cities with their definitions along with the development of civilization, the functions of settlements, their population and the nature of their buildings have changed. Table 1 presents an overview of current definitions of smart city.

Table 1.
Selected definitions of the smart city

Definition	Autor's
The smart city has been proposed as a way to develop sustainable cities by improving efficiency and better optimizing processes in the urban system.	Clement et al., 2023
A smart city is characterized by intelligent, heterogeneous devices that cooperate with each other through the regular exchange of small amounts of data in the context of IoT in an urban area.	Murroni et al., 2023

Cont. table 1.

A smart city is perceived as an agglomeration of cooperating systems, in which each physical system is connected and synergistically integrated with the surrounding urban environment.	Tricomi et al., 2024
Smart cities, which are a modern and efficient model of cities, digital solutions are implemented in various areas. It is embedded in sustainable development, striving for ecosystem balance and a new quality of life for residents.	Wolniak et al., 2024
A smart city is a new approach to urban development that goes beyond traditional models and is based primarily on information technology.	Chen et al., 2024
A smart city is a city structure based on new-generation information technologies and the progressiveness of a knowledge-based society.	Chen et al., 2025

Source: Author's own study.

The term Internet of Things (IoT) was first introduced in 1999 by Kevin Ashton, who described the emerging global architecture of internet-based information services (Mishra et al., 2016, p. 1332). Today, this concept refers to a network connecting devices, applications, and services through the Internet. These elements are equipped with sensors and microprocessors, enabling them to communicate with one another and exchange data in real time. As a result, it becomes possible to create intelligent systems that automatically collect and analyze information, make decisions, and perform specific tasks. IoT technology is applied on many fields, including industry, transportation, healthcare, energy, and agriculture, allowing for process automation, optimization, and the improvement of people's quality of life. Table 2 presents an overview of current definitions of IoT.

Table 2.
Selected definitions of the Internet of Things (IoT)

Definition	Autors
The Internet of Things, a revolutionary and rapidly developing technology that could change the way we interact with our surroundings.	Li et al., 2024
The Internet of Things has revolutionized information technology and sensors in various fields, providing widespread coverage and creating opportunities and challenges in the present day.	Ahakonye et al., 2024
The Internet of Things is gaining popularity, and with the development of technology, the Internet, and big data, the networks created are used in every branch of people's everyday lives.	Sharma et al., 2024
The Internet of Things (IoT) can be defined as a global network infrastructure consisting of connected devices that use detection, communication, networking, and information processing technologies.	Xiaoshao, Antwi-Afari, 2024
The Internet of Things (IoT) enables connection, interaction, and data exchange between a large number of diverse devices, while maintaining security standards.	Ashfra et al., 2025
The Internet of Things (IoT) is a network of connected devices whose task is to communicate and exchange data via the Internet.	Azad et al., 2025

Source: Author's own study.

The Internet of Things (IoT) has been increasing popularity (Kiełtyka, 2019, p. 39), finding wide application within the concept of smart cities. This idea involves the development of solutions such as smart homes, where all components are connected to the Internet and can interact with one another. In most cases, IoT communication relies on wireless technologies, enabling the creation of integrated networks of devices capable of exchanging information (Burg et al., 2018, p. 39).

Such systems allow for the automatic control and monitoring of various elements of everyday life – from waste bins and household appliances to lighting – significantly improving both efficiency and user comfort. The Internet of Things can be defined as a network of physical objects ("things") equipped with electronics, software, sensors, and communication modules that enable them to collect and exchange data. This makes it possible to remotely detect and control objects using the existing network infrastructure. As a result, IoT fosters the direct integration of the physical world with computer systems, enhancing efficiency, accuracy, and delivering tangible economic benefits.

Each device is uniquely identifiable through a built-in address, while still being able to operate within the global Internet infrastructure. According to forecasts, the number of devices connected to IoT was expected to reach nearly 20.7 billion in 2024, with projections indicating growth to 50 billion by 2030 (Law, 2024). Currently, companies developing IoT technologies emphasize that some concepts and solutions can already be implemented, while others remain within the scope of forecasts and long-term visions (Malucha, 2018, pp. 53-54).

The literature review was directly linked to the topic of the article through an analysis of existing research on the application of Internet of Things technology in public transport and the concept of smart cities. The publications cited by the author provided the basis for identifying key research problems and the appropriate selection of variables analyzed in the empirical part. This provides a coherent link between the two parts, generating a uniform background for the research and facilitating the interpretation of the results obtained. This connection also allows the conclusions of the article to be placed in the broader context of current trends and directions in urban transport development.

3. Methods

The study used simple random sampling, which involved randomly selecting respondents without dividing them into strata or using a fixed selection scheme. The sample was selected from the population of city residents using public transport, regardless of gender, age, or professional status. This approach made it possible to obtain a diverse research group, reflecting a cross-section of public transport users. The sampling method used helped to reduce bias and increased the reliability of the results obtained. To achieve the research objectives, the method of direct interviews was adopted and carried out between August and September 2025. This technique made it possible to gather in-depth opinions and individual experiences of respondents regarding the functioning and potential of the Internet of Things (IoT) in public transport. The choice of this method was driven by the need to collect qualitative data that not only reveal the level of public awareness of IoT but also help identify expectations, concerns, and suggestions for the practical implementation of new technologies.

The interviews were organized in a semi-structured format, meaning that the researcher used a pre-prepared set of questions while leaving space for open responses and further exploration of relevant topics. The questions focused on, among others:

- knowledge and understanding of the Internet of Things,
- perceived benefits of its application in public transport (e.g., route optimization, improved punctuality, enhanced safety),
- potential risks and barriers to implementation (e.g., data privacy issues, investment costs, system reliability),
- assessment of the community's readiness to adopt such innovations.

Respondents were selected purposively to include diverse perspectives of public transport users. Participants represented different age groups, occupational backgrounds, and frequencies of using public transport. This approach ensured that the collected opinions reflected a broad cross-section of the community.

The qualitative data were then categorized and subjected to thematic analysis. Based on recurring opinions and themes, the main areas of interest were identified and used to formulate research conclusions. The results were presented in graphical form-through charts, tables, and infographics-which allowed for clear and visually engaging presentation. Such visualization facilitated the comparison of individual categories of responses and provided a quick overview of the dominant trends within the surveyed group.

The combination of interviews and graphical data presentation made it possible to obtain comprehensive insights into public perceptions of the Internet of Things in public transport, as well as to identify factors that may support or hinder the implementation of such solutions in the future.

4. Results

The distribution of respondents' answers regarding their perception of Internet of Things technology in public transport, their level of knowledge about IoT, and their readiness to use smart solutions is presented. The results are presented in tabular form, which allows for a clear presentation of data for the reader. This part of the study is limited to describing the results of the survey, while the interpretation and evaluation are discussed later in the article. The survey was conducted in August–September 2025 on a group of 70 randomly selected respondents. The aim was to obtain opinions on awareness and perception of the applications of the Internet of Things (IoT) in public transport. A diagnostic survey method was used, employing a questionnaire prepared in Microsoft Forms, which enabled efficient data collection and subsequent quantitative and qualitative analysis. The results are presented in Table 3.

Table 3.
Demographic characteristics of respondents

Education	**Results**
Basic	3%
Secondary (technical school, high school)	24%
Higher	70%
Basic vocational	3%
How often do you use public transportation?	**Results**
Every day	40%
Several times a month	21%
Several times a week	16%
Once a week	10%
Rarely/never	13%
How would you rate your knowledge of Internet of Things (IoT) technology?	**Results**
Very good	11%
Good	37%
Low	20%
Average	31%
Age	**Results**
18-24	10%
25-34	26%
34-44	30%
45-54	27%
55-54	6%
>64	1%
Gender	**Results**
Woman	51%
Man	45%
No answer	4%
Age	**Results**
18-24	10%
25-34	26%
34-44	30%
45-54	27%
55-54	6%
>64	1%

Source: Author's own study.

Based on the data presented, it can be seen that a diverse group of respondents took part in the survey, with a majority of them having higher education (70%). The most numerous age groups were people aged 34-44 (30%) and 45-54 (27%), which indicates a predominance of professionally active people who are potentially more likely to use public transport. The majority of participants in the study were women (51%), while men accounted for 45% of the sample. Forty percent of respondents declared that they use public transport regularly, and another 16% use it several times a week, which confirms the importance of public transport in the daily lives of residents. The level of knowledge of Internet of Things technology was most often rated as good (37%) or average (31%), which indicates growing public awareness of modern technological solutions. These results suggest that the respondents have a basic knowledge of IoT, but there is potential for further education and popularization of this topic.

The questionnaire consisted of a personal details section and a set of questions about the level of knowledge about IoT technology, perceived benefits, potential risks, and readiness to use smart transport solutions. Respondents were selected at random, which allowed for a diverse research sample in terms of age, education, and frequency of public transport use. The information obtained forms the basis for drawing conclusions about the social perception of modern technologies in the context of smart city development. The answers to all questions are presented in Table 4.

Table 4.
Research details

Question No.	Name	Results
1	**How do you assess the importance of IoT technology for improving the quality of public transport?**	
	Very large	59%
	Small	10%
	Moderate	31%
2	**Which aspect of IoT application in public transport do you consider the most important?**	**Results**
	Passenger safety	33%
	Traffic flow and punctuality	57%
	Convenience and comfort of travel	10%
3	**To what extent do you think that the introduction of IoT in public transport will contribute to environmental protection?**	**Results**
	To a large extent	44%
	To a small extent	14%
	To a moderate extent	41%
4	**How do you assess the potential risks related to data privacy when using IoT in public transport?**	**Results**
	Very high	33%
	Low	19%
	Moderate	49%
5	**Would you use a mobile application based on IoT that provides information about delays and the location of public transport vehicles?**	**Results**
	Yes	63%
	No	37%
6	**Do you think that the use of IoT can increase passenger safety in public transport?**	**Results**
	Yes	87%
	No	13%
7	**Do you think investing in IoT solutions for public transport should be a priority in smart cities?**	**Results**
	Yes	83%
	No	17%

Source: Author's own study.

Based on the results obtained, it can be concluded that respondents generally assess the importance of Internet of Things (IoT) technology in the context of public transport development positively. As many as 59% of respondents considered that the impact of IoT on improving transport quality is very significant, while 31% assessed it as moderate, which indicates a high level of acceptance for this technology. The most important aspect of IoT application in public transport was considered by the participants to be traffic flow and punctuality (57%), followed by passenger safety (33%).

A significant proportion of respondents (44%) believe that the use of IoT can greatly contribute to environmental protection, mainly through route optimization and reduced emissions. At the same time, respondents also see potential threats – 49% assess the risk of data privacy breaches as moderate, and 33% as very high, which indicates the need for appropriate system security measures.

Most respondents (63%) declare their willingness to use IoT-based mobile applications that provide information about delays and vehicle locations, and as many as 87% believe that these solutions can increase passenger safety. The vast majority of respondents (83%) also emphasize that investing in IoT technologies should be a priority in the smart city development strategy. These results confirm the positive reception of the IoT concept and indicate public support for the implementation of smart solutions in public transport.

5. Discussion

The survey allowed us to determine how public transport users perceive the importance of Internet of Things technology in the context of improving the quality of transport services, safety, and the efficiency of the system. Unlike previous studies, which focused mainly on the technical and organizational aspects of IoT, the analysis provides up-to-date empirical data based on the opinions of end users. The results obtained are largely consistent with the literature on the subject, confirming the importance of IoT for the development of intelligent transport, but they also reveal stronger concerns among respondents about data privacy. It can be concluded that the implementation of IoT solutions requires not only technological development, but also information and education activities. The results of the study confirmed the hypothesis about the positive perception of IoT technology in public transport. In the future, it is planned to expand the study to a larger sample and to deepen the analysis by using qualitative methods, such as individual interviews.

The results obtained are consistent with the findings presented in studies by Zanella et al., who indicate that Internet of Things technologies significantly contribute to improving punctuality and safety in public transport, which is also confirmed in this study (Zanella et al., 2014). Similarly, Bibri emphasizes that IoT is a key element in the development of smart cities, especially in the area of urban mobility and traffic management, which corresponds to the high level of acceptance of investments in such solutions among the respondents (Bibri, 2018).

At the same time, compared to previous studies, respondents' concerns about privacy and data security are more noticeable, which indicates growing public awareness in this area. These differences may result from the dynamic development of digital technologies and the increasingly frequent public debate on the processing of personal data. The results of the study therefore confirm the general trends described in the literature, while providing up-to-date empirical data from the perspective of public transport users.

6. Summary

The implementation of sustainable urban management objectives is increasingly based on the concept of a smart city, in which modern technologies, including the Internet of Things (IoT), play a key role. Implementing this idea requires not only appropriate technological solutions, but also the creation of new organizational structures consisting of qualified and properly trained employees capable of effectively managing complex urban systems.

Economic issues are an important aspect of the implementation process. Local authorities often focus on initial costs, assuming that the expenses associated with the maintenance and development of systems will be passed on to future administrations. However, this approach can lead to a lack of continuity and limit the long-term effectiveness of the solutions implemented. A truly smart city is not created solely through technological investments, but above all through sustainable planning, responsible resource management, and continuous improvement of infrastructure.

According to the smart city concept, all activities should be focused on the needs of residents. Technologies, including IoT-based solutions in public transport, are designed to improve the quality of life, increase the comfort of everyday functioning, and reduce the negative impact of humans on the environment. The effective implementation of intelligent communication systems can contribute to improving urban mobility, reducing traffic jams, optimizing energy consumption, and increasing the safety of public transport users.

Ultimately, creating a smart city requires a long-term strategy based on cooperation between public administration, the private sector, and residents. Only then will technologies such as the Internet of Things be able to fully realize their potential, becoming a tool that supports the development of sustainable, modern, and socially friendly urban spaces.

The development of new technologies and increasingly easy access to information will enable real-time city management in the future. Smart cities leverage the growing potential of information and communication technologies (ICT) to perform tasks that provide authorities with access to effective and modern solutions. Through the use of ICT and advanced data analysis, these cities strive to achieve three key objectives: strengthening social cohesion, supporting sustainable development, and increasing the efficiency of urban space.

These goals can only be achieved through close cooperation between city authorities and residents, as well as through detailed analysis of data obtained from sensors installed in urban infrastructure, such as traffic lights, bus stops, and users' mobile devices. This data forms an integrated information network that allows for continuous monitoring of processes taking place in the city and supports decision-making based on real and up-to-date information.

Smart city systems require constant supervision, and the data they collect should be systematically processed, analyzed, and made available. This process forms the basis for initiating new activities and development projects that lead to an improvement in the quality of life of residents and increase the innovation and efficiency of the city's functioning.

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