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Barriers related to the implementation of intelligent transport systems in cities - the Polish local government's perspective

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ABSTRACT

Intelligent transport systems (ITS) are undoubtedly an opportunity for the sustainable development of smart cities today. ITS is based on advanced transport technologies that help minimise the emission of harmful substances to the environment. Smart mobility and ITS are related to the use of ICT. The implementation of technologically advanced ITS is associated with several benefits, barriers and difficulties. However, transport, ITS and smart mobility (as a component of a smart city) are indicated as the most desirable option for sustainable urban transport systems. The article aims to identify barriers related to the implementation of ITS in cities from the point of view of people responsible for the organisation of urban transport representing the local government of selected voivodship cities in Poland. The goal formulated in this way allowed to identify the following research question: what are the problems and barriers of implementing ITS in the city from the local government's perspective? To achieve the paper's aim, the author based their analysis on a qualitative technique of collecting empirical data. Ten individual in-depth interviews were conducted with representatives of local governments (vice-mayors and members of urban transport organisers) in voivodship cities, which represented six Polish macro-regions. Research results and findings indicate the main categories and subcategories of barriers related to the ITS implementation. The identified barriers are grouped into the following categories: economic, social, organisational, technological and legal. The contribution is twofold: first, in the presentation of the theoretical and practical barriers to ITS in juxtaposition; and second, in identifying the intelligent transportation impact, which affects the provision of being a smarter city. The findings can positively influence as important factors for local governments to focus on intelligent transport.

KEY WORDS

intelligent transport systems (ITS), smart city, smart mobility

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Introduction

Currently, urbanisation is one of the most important social processes from the perspective of urban development. According to UN statistics, by 2050, about 70 % of the global population (i.e., 7 billion people) will live in cities, which means that by 2050, urban areas will accommodate another 2.5 billion people (United Nations, 2018). This implies an inevitable expansion and densification of urban space. However, it can already be seen that the way cities and

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their spaces are designed should be thoroughly considered (SWECO, 2021). Otherwise, in the near future, few of us will want to live in a city where the problems associated with its excessive growth will make everyday life much more difficult, e.g., by reducing the capacity of urban roads, transport congestion, etc. Cities face environmental, economic, social and spatial problems. With increasing globalisation, urbanisation processes and growing economic development, there is a growing demand for high-quality urban transport services (Rodrigue et al., 2016). The popular concept of a smart city as a progressive city of the future assumes sustainable urban development based on innovative technologies, the application of which is to support the residents and provide them with comfortable, economical and safe lives (Kos, 2019; Komninos et al., 2011). Therefore, in recent years there have been records of increased interest on the part of local authorities in the search for sustainable, innovative and intelligent technological solutions to optimise the urban transport system.

Improving mobility and transportation, ensuring accessibility and decreasing traffic congestion are significant elements of smart cities and some of the greatest challenges facing them today (Iqbal et al., 2018; Pawłowska, 2018; Kachniewska, 2020). The organisation of transport as a basis for the daily functioning of society and the economy in cities is an issue widely reported in the literature. However, reliance on motorised transport as an everyday function contributes significantly to global climate change (Chapman, 2007). Some of the most common local government proposals for reducing carbon emissions include encouraging innovation and deployment of low-carbon technologies; encouraging modal shift from the private car to less polluting options, i.e., walking, cycling, and public transportation; promoting more efficient forms of traffic management and driving styles; and executing strategies that aim to reduce the need to travel totally (e.g., land use planning) (Grant-Muller & Usher, 2014). Therefore, a special role is assigned today to modern, intelligent technological solutions to facilitate urban transport management, including intelligent transport systems (ITS). ITS demonstrate a new approach and application of advanced management and technical-technological solutions, and ICT has renovated the urban transportation perceptions (Mandžuka, 2020; Mathew, 2020). The availability of services offered by intelligent transport systems is the key to developing the smart city concept (Lewicki et al., 2019). Technological advances and the global connectivity provided by the Internet today are causing transportation systems to undergo a profound transformation that is significantly changing the way people and products move through cities. Existing and emerging transportation challenges are prompting a search for ways to adapt modern technologies to the needs of users. This is facilitated by a range of computational tools for compiling and analysing real-time data that help to predict and optimise the performance of urban transport services in the next step. As a result, it is possible to improve mobility for all users of urban services, increase the economic efficiency of the city and reduce pollution levels. It is therefore expected that in the future, smarter, more autonomous and safer vehicles that communicate with other vehicles and urban buildings, road signs and other infrastructure will become the standard (Jimenez, 2018).

In recent years, increased interest in ITS and the benefits associated with their implementation have been apparent in local governments and academic circles. An increasing number of researchers are addressing the existing and anticipated implications of the ICT revolution for transport (Banister & Stead, 2004; Giannopoulos, 2004; Cohen et al., 2002). Increasing globalisation and technological development also increase the number of scientific studies on intelligent transport systems, their applications, benefits, as well as the factors determining their development. The number of scientific publications published between 2001 and 2020, containing the phrase "intelligent transport systems" or "intelligent transport" in their topic (title, abstract and keywords) amounted to 6 065 papers available in the Web of Science database and 1 3671 in the Scopus database. Over the last 20 years, the interest in this topic has multiplied and almost annually shows an upward trend (Fig. 1). This is undoubtedly related to the observed dynamic development of technology and telematics in transport and the desire of local governments to "be a smart city". On the other hand, it is influenced by the enormous increase in the number of people living in cities and the progressive urbanisation.

The paper aims to identify barriers related to the implementation of intelligent transport systems in cities from the point of view of people responsible for the organisation of urban transport representing the local government of selected voivodship cities in Poland. To reach the goal, the article uses qualitative research, namely, individual in-depth interviews (IDI) with representatives of local authorities.

The theoretical part of the paper presents the smart city concept with a particular focus on intelli-

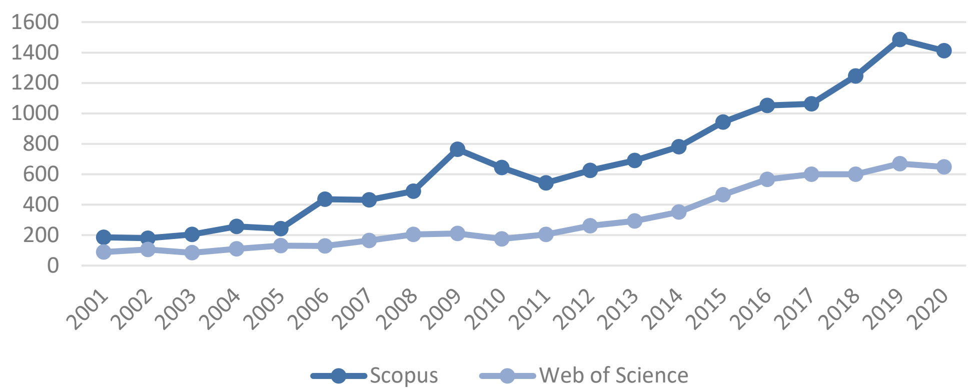

Fig. 1. Number of publications in the field of "Intelligent transport systems" published in 2001–2020, available in the Web of Science and Scopus databases.

gent mobility and intelligent transport systems (ITS). Based on the literature review, the author enumerates the barriers associated with ITS deployment in the city, as earlier identified in the works of previous researchers. The next part of the paper presents the results of the qualitative research and proposes main categories of barriers related to ITS, and then indicates new contributions to the existing literature on the subject.

1. Literature review

1.1. Smart city concept

In search of the ideal city, the answer could be a metropolis that retains the benefits of urbanisation at the same time eliminating its negative effects, which is the complex and multidimensional concept of a smart city (Kos, 2018). It is one of the most promising ideas for the future development of cities, and at the same time, a response to the increasing urbanisation processes. The intelligence of such a city manifests itself in the sum of various improvements in urban infrastructure, resources and public services (Allwinkle & Cruickshank, 2011).

Smart city issues are widely described in the literature (Bashynska & Dyskina, 2018; Bibri & Krogstie, 2017; Albino et al., 2015; Wang & Wu, 2015; Allwinkle & Cruickshank, 2011; Komninos, 2009; Szpilko, 2020; Hajduk, 2021). Researchers have shown that many cities are being developed under the smart city banner (Cugurullo, 2020). The academic definitions of a smart city are varied because the label "smart city" is a fuzzy concept and is used in ways that are not always consistent (Nam & Pardo, 2011). Gil-Garcia et al. (2015) indicate the need to develop an integrated and holistic approach to a smart city. The majority of publications related to the concept of a "smart city" is focused on the technological aspect, but in fact, cities can hardly become smart because of technology alone (Nam & Pardo, 2014). As Neirotti et al. (2014) emphasised, a smart city represents a kind of "ecosystem that is largely developed through the effective use of technology to improve the quality of life of citizens through efficient integrated systems and services". In turn, Guo et al. (2017) defined a smart city as an urban development based on the integration of many information and communication technology (ICT) solutions to manage the city's resources. Similarly, Peng et al. (2017) stressed that a smart city uses a set of advanced technologies, such as wireless sensors, smart meters, intelligent vehicles, smartphones, mobile networks or data storage technologies. According to the literature review, smart city phenomenal is related to the use of ICT, sustainable urban environment, advanced infrastructure, encouraged community participation, well-being and satisfaction of citizens, optimum utilisation of resources, well-performing governance, innovations, information management, and sustainable economic growth (Samarakkody et al., 2019). In this context, a smart city should be seen as a city that is better, more sustainable, improves the quality of life for its citizens to better meet their housing, transport, energy and other infrastructure needs, creates a more welcoming environment, and has stronger economic development prospects as a key strategy to combat poverty and inequality, unemployment and energy management (Barrionuevo et al., 2012; Lazaroiu

& Roscia, 2012; Lee et al., 2014; Yigitcanlar, 2018; Winkowska et al., 2019; Mundada & Mukkamala, 2020; Szpilko et al., 2020a; 2020b). The smart city is most often defined by models with specific dimensions of smart cities (so-called "smart factors"). The most widespread is the one established by Griffinger et al. (2007), characterising a smart city with six dimensions: smart economy, smart governance, smart environment, smart mobility, smart living, and smart people with their activity of self-decisive, independent and aware residents. Still, Lim et al. (2018) provided twelve application areas related to smart cities, i.e., smart home, smart health, smart transportation, smart energy, smart building, smart logistics, smart farming, smart security, smart hospitality, smart education, smart device, and smart environment. According to various research approaches, among the basic dimensions of the smart cities' model, there is always "transportation" (or "mobility" and "transport infrastructure"). It is recognised that economic growth is increasingly linked to transport development. Mobility can be viewed as a reliable indicator of urban development since limited mobility hinders development, while increased mobility is its catalyst (Rodrigue, 2016).

The growing population in cities and the increasing complexity of their mobility (Kiryluk et al., 2021) needs have necessitated the evolution of transportation systems. The efficiency of the urban transport sector can be improved by the development of information and communication technologies (ICT) observed in recent years (Machin et al., 2018). One dimension of a smart city is smart mobility, which usually refers to ICT-based sustainable mobility (Mangiaracina et al., 2017; Papa et al., 2017; Caragliu et al., 2011; Kitchin, 2014; Szymańska et al., 2021). According to literature, a basic principle for achieving sustainable mobility is reducing the inconvenience inherent in urban transportation and transferring using various means of transport (Hernandez & Monzon, 2016). Urban mobility is one of the global smart city projects. Wang & Wu (2015) highlighted that it offers real-time traffic management, passenger transportation asset management, tracking applications and logistics, car-sharing services, parking management, and smarter mobility services (Yue et al., 2017). The task of smart (intelligent) mobility is, therefore, to use advanced technologies to make rational use of the transport infrastructure while optimising traffic flow. ICT can support greater automation in the transport system, and using intelligent speed adaptation, they can also represent a further step towards environmental protection by reducing carbon dioxide emissions (Grant-Muller & Usher, 2014). According to Albino et al. (2015), efficient public transport is considered key for city growth. Thus, many of the new approaches related to urban services (for instance, urban transport) have been based on harnessing technologies, helping to create intelligence of a city. In this context, smart mobility is perceived by the accessibility of information and communication infrastructure through the development of sustainable, innovative and safe transport (Winkowska et al., 2019).

1.2. Intelligent transport system in a smart city

In the above context, intelligent transportation greatly impacts the possibility of a city being smarter. According to Reyes-Rubiano et al. (2021), interrelationships between a smart city and transportation are noticeable because some authors consider that the smart city favours smart transport, while others consider that without intelligent transportation, there would not be any smart city. Currently, stable urban mobility and efficient passenger transport cannot be guaranteed without integrating modern technological and organisational solutions in transportation with the management of the urban transport network (Tzvetkova, 2018). ITS is a solution that may address these challenges, offering advanced applications that aim to provide innovative services related to different modes of transport and traffic management. These systems aim to provide better information and a safer, more coordinated and "smarter" use of network transport to different users (Directive 2010/40/EU). These are currently the most effective instruments for improving the efficiency and quality of the city's transportation system, increasing travel safety (Zhang et al., 2011). They allow, among other things, to control traffic, create special zones of limited traffic, which, in connection with the reduction of the number of private cars in city centres, contributes to environmental protection and low carbon dioxide emissions (Strategy…, 2013). In accordance with Directive 2010/40/EU, ITS "integrate telecommunications, electronics and information technologies with transport engineering in order to plan, design, operate, maintain and manage transport systems" (p. 14).

The main components of ITS include transport infrastructure, service and software infrastructure, vehicles, telematics equipment for transport infrastructure elements and vehicles, intelligent sign systems, variable message signs and traffic signals with remote control capability, and centres for collecting and processing information, decision-making and traffic management (Rudskoy et al., 2021).

ITS applications for road safety can be divided into three basic operational areas: data collection, information sharing, and emergency response and enforcement (Shinde & Waghmare, 2019). According to Rudskoy et al. (2021), ITS of the modern city include:

- continuous and fast collection of information about the traffic situation on the roads (via detectors, cameras, etc.);
- a powerful but easy to use tool for storage, processing, validation and analysis of measurement data;
- a state-of-the-art tool for predicting the traffic situation for the nearest 15 minutes and the next day (using real-time, continuously updated detector data);
- use of modern equipment for traffic signal control and creation of a single real-time traffic control centre, as well as providing a quick response to vehicle accidents and other unpredictable traffic situations.

Hence, Chandra et al. (2017) stated that the main objectives of ITS are to evaluate, develop, analyse and integrate new technologies and concepts to achieve traffic efficiency, improve environmental quality, save energy and time and, at the same time, improve the safety and comfort of drivers, pedestrians and other traffic users. According to Rudskoy et al. (2021), the three basic functions of ITS include transport modelling, regulation and monitoring of traffic lights, planning and management of the transport network. They claim that using these means significantly helps ITS in solving the following tasks (Rudskoy et al., 2021):

- optimising the distribution of traffic flows on the network in time and space;
- increasing the capacity of the existing transport network;
- ensuring travel priorities for a particular transport mode;
- managing transport in case of accidents, disasters, or measures affecting transport traffic;
- improving road traffic safety (in effect, increasing traffic capacity);
- reducing the negative impact of urban transport on the environment;
- providing information on the state of the road to all interested users.

In light of the literature, many publications consider benefits related to ITS implementation. Thus, they ensure reduced congestion and a more efficient transport network (Rodrigue, 2016; Molnar & Alexopoulos 2008; Alrawi, 2017; Małecki et al., 2014; Smith et al., 2005), encourage and mobilise passengers to choose an environmentally friendly mode of travel, and use public transport or another green mode of transport, and ensure information exchange and cooperation between people, vehicles and technical infrastructure (Huang et al., 2017). ITS collect, process, and deliver data in a high-quality and efficient way, reduce congestion, thereby reducing wasted time, fuel and energy consumption, and traffic pollution emissions, and ultimately, reducing traffic accidents and increasing safety (Grant-Muller & Usher, 2014; Tomaszewska & Florea, 2018; Neverauskiene et al., 2021; Huang et al., 2017; Barth & Boriboonsomsin, 2009). With technologies such as electric cars and autonomous vehicles, ITS minimise toxic emissions into the environment while improving the car's interaction with the surrounding infrastructure to avoid accidents (Zhao & Jia, 2021). Researchers emphasise the numbers in favour of ITS, which make transport more sustainable (for instance, reduced energy consumption by 45–70 % or of pollutant emissions by 30–50 %) (Barth & Boriboonsomsin, 2009; Njord et al., 2006; Oskarbski et al., 2006; Alrawi, 2017; Crişan et al., 2021). As Barth & Boriboonsomsin (2009) highlight, that most of these improvements are additive (greater benefits can be achieved when multiple environmentally friendly ITS subsystems are implemented).

Definitely, fewer publications focus on barriers and problems with the implementation of ITS. The transformation of cities into smart cities includes, but is not limited to, the development of ITS as the core urban service on which all other services are based (Schlingensiepen et al., 2016). The reliability of the entire system is therefore crucial. The ideal situation is when the entire ITS system works autonomously without human intervention, while employees should only be involved in implementing and monitoring such a system (Levina et al., 2017; Singh et al., 2019). However, there are many factors and barriers that hinder the construction and management of ITS. The most important inconvenience related to ITS deployment is its cost intensity (Shinde & Waghmare, 2019). Typically, local governments struggle with the lack of sufficient funds for this purpose and the problem of ensuring efficient and cost-effective selection and prioritisation of urban projects. A number of co-financing initiatives with regard to such projects fostered by the European Union come in handy (Intelligent Transport Systems, 2019). Problems may also relate to the legal aspects of ITS construction and the lack of a common urban policy as well as inadequate legislation (Kozerska & Konopka, 2018). According to the European Commission, deployed ITS systems in the Member States are not interoperable for a variety of reasons, including inconsistencies in the interpretation of legislation, technological standards (specifications) and their inability to work together (Nowacki et al., 2012). Another problem identified in the literature related to ITS deployment is that they are vulnerable to security threats. The main security problems in operational transportation are related to the fact that ITS operate large data sets with heterogeneous concepts, request platforms and resources (Crişan et al., 2021). In ITS, the most significant issues are security and privacy, and the open nature of ITS as a wireless communication technology leads to many related challenges. These mainly concern confidentiality, authentication, integrity, non-repudiation, location privacy, identity privacy, anonymity, certificate revocation and certificate recognition (Ali et al., 2018). On the other hand, the lack of appropriate road infrastructure or the lack of telecommunications infrastructure necessary for the implementation of ITS (as is the case in developed countries) is a particularly important problem in developing countries (Mfenjou et al., 2018).

While looking at ITS deployment problems, it should be noted that they may occur at different stages of implementation, i.e., the process of system design, implementation, monitoring and supervision. The aspect of the system design itself is extremely important, giving rise to the need to find specialists competent in integrating knowledge from many different fields, e.g., transport modelling and information systems development, GIS, etc. This is a major issue as the integration of knowledge and systems will be a key factor in ITS development (Taie & Elazb, 2016). Due to its direct impact on the safety of road users, ITS can only be considered effective if it has been designed following certain standards and requirements (Nowacki & Kamiński, 2011).

Neverauskiene et al. (2021) identified problems appearing in the ITS area in the current conditions of globalisation. According to the authors, difficulties are faced mainly by ITS providers and countries planning to install ITS. As the researchers emphasised, it is connected with high competitiveness, migrations, insufficient funds for ITS implementation and insufficient cooperation with other countries. On the other hand, Kozerska & Konopka (2018) emphasised that in the case of Polish ITS, the implemented projects are mainly insular, i.e., independent and unconnected. In their analysis, the authors also noted that Polish ITS were not interoperable in the technical (connections between computer systems and services), semantic (guaranteeing the intelligibility of the exchanged information for another application – not originally developed for this purpose), and organisational context (defining business processes and initiating cooperation between administrative units, which may be characterised by different internal structures and procedures).

2. Research methods

The paper aims to identify the main barriers associated with the implementation of ITS in cities from the point of view of people responsible for the organisation of urban transport, representing local governments of selected voivodship cities in Poland. The aim formulated in this way allowed to investigate the following research question: what are the barriers to implementing ITS in the city from the local government's perspective?

The authors selected an individual in-depth interview (IDI) as a research method since the analysed problem requires more profound knowledge of research participants who are difficult to access. IDI assesses a given phenomenon and understands the process of its generation using freely and openly expressed opinions. The IDI scenario as a tool for qualitative research has an unstructured form, which means questions can be adjusted for each respondent according to the course of the interview and the given answers (Bryman & Bell, 2007; McDaniel & Gates, 2010).

IDIs were conducted in the first quarter of 2019 in selected Polish voivodship cities representing individual macro-regions of Poland, i.e., the city of Gdańsk (northern macro-region), the city of Poznań (north-western macro-region), the city of Wrocław (south-western macro-region), the city of Kraków (southern macro-region), the city of Łódź (central macro-region), and the city of Białystok (eastern macro-region) (Fig. 2). The capital city of the country representing the Mazowieckie voivodship macro-region was deliberately excluded from the study, as its size is incomparable to other voivodship cities (due to the incomparably larger urban area and the population). The authors assume that voivodship cities, due to their size and function, are a good analysis example and that each macro-region reflects and represents a situation characteristic for a given area. While intentionally selecting these cities for the study, the authors assumed that the sampling quality would comply with the "suitability" criterion (Flick, 2007). When selecting interviewees, the following criteria were considered: broad knowledge of the analysed subject and several years of experience related to active ITS deployment in a given city. The analysed voivodship cities are examples of good ITS implementations on a national scale (ITS Poland). It is worth emphasising that the Polish ITS projects usually constitute large and complex transportation solutions consisting of many subsystems (Qumak, 2015).

In the research process, two IDIs were planned in each of the six analysed cities. Finally, a total of ten interviews were conducted. The group of interviewees consisted of executives in charge of transport management and organisation and/or ITS management in the city (including two city vice-mayors responsible for sustainable development and urban transport) (Table 1). Each interview lasted between 60 and 90

Fig. 2. The division of Poland into NUTS 1 units

Source: Central Statistical Office.

Tab. 1. Structure of IDI participants

City (macro-region)	IDI number	Number and structure of IDI participants
Wrocław (south-western)	1	3 (1 — Head of the Department for Traffic and Public Transport Management, Roads and City Maintenance Authority; 1 — Intelligent Transport System Construction Specialist, Roads and City Maintenance Authority; 1 — an employee of the Department for Traffic and Public Transport Management, Roads and City Maintenance Authority)
Łódź (central)	2	2 (1 — Vice-Mayor of the City; 1 — Head of Traffic Control Team at the Traffic Engineering and Control Department, Road and Transport Authority in Łódź)
Kraków (southern)	2	2 (1 — Head of Transport Organization Department, Public Transport Authority in Kraków; 1 — senior specialist, Public Transport Authority in Kraków)
Białystok (eastern)	2	2 (1 — Head of Traffic Management Department, Municipal Roads Management; 1 — Director of Białystok Municipal Transport Authority)
Gdańsk (northern)	1	2 (1 — Vice-Mayor for Sustainability; 1 — Head of Traffic Engineering Department)
Poznań (north-western)	2	2 (1 — Deputy Director of Public Transport, Public Transport Authority; 1 — Head of Traffic Control Department, Municipal Roads Authority in Poznań)

minutes and was recorded. The author used a research tool in the form of a prepared interview scenario and analysed the research area related to ITS evaluation. The respondents were asked to answer to open-ended questions freely and express their opinions. Interview transcripts were analysed using content analysis and a set of categories developed by the author.

3. Research results

To answer the research question, the respondents were asked about the perceived problems and barriers related to ITS deployment. As indicated by the interviewees, several barriers related to ITS development can be distinguished. Besides the most important financial barrier, participants face a technological barrier and a social barrier, i.e., the reluctance of the inhabitants to innovate. The survey results and suggestions provided by the interviewees clearly indicate that the problems associated with ITS deployment and expansion can be grouped into the following five main categories: economic, organisational, legal, technological and social, as presented in Table 2.

Considering the category of economic problems, it should be noted at the outset that the costs of ITS implementation are very high. Thus, the basic barrier is, of course, financial. The process of financing ITS always encounters numerous obstacles, which is especially important in the context of limited budget funds for investments. All respondents are fully aware that insufficient funding — low budgets and enormous cost-intensiveness of such solutions — hinders the realisation of transport investments, including ITS. All interviewees indicated that this includes both ITS construction costs, including initial project expenses, construction and installation costs, operation and maintenance costs, and system upgrade costs, system and equipment maintenance, and other unexpected expenses. According to the participants, the investment costs are likely to be even higher than the expected monetary benefits in the future. However, based on their experience, the most expensive solutions are usually also the most effective. ITS acquisition costs are related to their complexity and the extent of the coverage in the city. The respondents emphasised looking for optimal solutions in terms of cost-effectiveness and, depending on the available financial resources, planning, improving, or increasing the scope of ITS. According to the analysed local government's perspective, public transport is well organised nowadays, although there are places where certain issues should be improved further. Considering the available financial resources, public transport and the network of transport connections mostly correspond to the real needs of residents. According to the interviewees, the availability of external co-financing is important, as it makes a wide range of investments possible. The respondents emphasised that without the support of EU funds, local governments would be forced to significantly reduce costs and thus reduce the scope of ITS (a small number of subsystems), or they would not be able to build them at all. One of the interviewees emphasised that there

Tab. 2. Problems and barriers of ITS in the opinion of IDI interview participants

No.	Problem category	Identified barriers according to responses by interviewees
1	Economic	• high costs of ITS implementation • low budget of local government units for ITS investments due to other, growing expenditures (the need to subsidise the project)
2	Organisational	• dependence on ITS provider • availability of a wide range of ITS makes it difficult to choose the most effective solution • difficulties in recruiting experts with broad multidisciplinary knowledge • difficulties in managing ITS
3	Legal	• security of collected data • limited activity of local authorities due to legal procedures
4	Technological	• ageing of technology • limited availability of highly modern and intelligent transport solutions
5	Social	• growing needs and too high expectations of all traffic users (difficult to reconcile) • aversion to change among citizens • lack of trust in local governments with regard to the undertaken investments • mistrust barrier especially visible in cooperation between public and private sector entities

is quite a high level of the cumbersomeness of the procedures related to obtaining the financing, both in terms of the number of required documents and formalities to be fulfilled. The respondents also perceived currently emerging categories of problems, such as the increase in prices of construction services, which has been particularly visible recently. Unfortunately, as a result, they will not be able to implement many good and "cool" investments or have to postpone them.

Organisational barriers constitute a broad category of problems. The interviewees emphasised that ITS require domain expertise. In the event of an ITS shutdown (or system failure), people will suffer significant losses in terms of time, health, mobility, etc. The interviewees also noted great difficulties in employing specialists with wide, multidisciplinary knowledge of this type of advanced system operation, which is necessary, especially at the ITS design stage. A highlighted and important problem is the issue of selecting a system contractor because to change anything in the system, it has to be done through the supplier as well as interdependence on system providers. Another problem involves the selection of the ITS manufacturer/supplier and the decision of whether it will be a leading foreign company. Local authorities are aware of the risk related to the dependence on one ITS provider, so they are afraid of such close cooperation, but on the other hand, they are forced to accept a certain level of risk.

As these are large systems and cannot always be split up or done independently, the key issue is this dependence on a system provider that could prove problematic in the future. Most analysed cities are "doomed" to one provider, which is undoubtedly a certain barrier. In the opinion of participants, knowing that they are somehow dependent on the contractor may in the future lead to contractor-imposed cooperation conditions. Some local government officials opposed this approach and brought it to their attention during the design and procurement of the system.

So, their system was based on complete openness and access to the "inner layer" of technology so that they were independent of any system provider. Thus, having access to all possible algorithm layers, ITS engineers have already reprogrammed all intersections with traffic lights. However, most cities in Poland have semi-centralised systems, while fully centralised ones exist as well. Several cities in the world manage the whole system on such a level, becoming practically self-sufficient.

National and international interest in ITS is growing, reflecting the willingness of authorities to implement them and gain tangible benefits. In terms of legal aspects and regulations on ITS, as identified by the interviewees, the difficulties relate to the processing of large data sets and the security of such a large amount of collected and processed data on the network. As the interviewees point out, they are using Big Data solutions but still struggling to take full advantage of the opportunities offered by analysing huge data sets. The respondents also commented on the future of Big Data. As they emphasised in the near term, the problem will be both the abundance of data and costs associated with their processing. Thus, the limitation in the future of ITS will be the abundance of collected data and its selection. Although, some procedural barriers may arise when planning ITS investments. The respondents also noted that the traffic structure would undoubtedly change, as will all ITS, or Big Data, which would be key to the communication system.

Technological problems are related, among other things, to the choice of appropriate information and communication technology as a facilitating factor in creating a new kind of smart city environment. It should be emphasised that many countries, including Poland, are lagging behind existing transport management systems in European cities in installing new transport infrastructure in cities to optimise networks for multimodality and cohesion (Strategy for Sustainable.., 2019). Considering novel technologies, it is worth noting that the availability of a wide range of ITS subsystems also makes it difficult to choose the most effective solution. Often, the above-mentioned choices are conditioned by the financial resources at one's disposal; however, for example, the purchase of low-quality equipment (and associated financial savings) ultimately results in the loss of these resources, and at the same time is connected with an inability to obtain the assumed or expected benefits. Innovative scientific and technological achievements are the basis for the functioning of ITS, e.g., the perception and interaction of traffic conditions, simulation and control of urban road networks and vehicle networks, coordination of vehicles with infrastructure and the management of road safety intelligence. In addition, ITS use a variety of technologies, the selection and adaptation of which to user needs is also a very important and time-consuming process. The organisation of transportation in the city, according to the interviewees, is problematic due to the uncertain future and preferred amenities or technological transportation solutions: "Even if we don't have some functionalities today, it doesn't mean that we won't use them soon. What is more, we do not use all the functionalities available to us today". Another category of ITS-related problems is inadequate infrastructure and technology ageing. Due to a relatively long implementation time, modern solutions at the moment of their "purchase" by the local government administration become "old" before they are implemented (there is a risk that new, better adjusted technological solutions may enter the market in the meantime). As the respondents stressed, technology ageing is a factor that undoubtedly has a negative impact on the decisions made. They emphasised that this is exactly the kind of field that requires the use of modern technology, and the current technology offers enormous possibilities. For instance, in analysed cities, the traffic light control system is optimised and very well adapted to traffic conditions while ensuring user safety. IDIs participants were aware of the ageing technology and the need to upgrade the system in the future and develop the architecture of the intelligent transportation system by implementing new solutions. The main problem they need to overcome is exact predicting what will happen in several decades, given the rapid development of technology. The aim is to improve ITS, to create an integrated, highly technologically advanced and user-friendly system.

Some issues facing intelligent transportation are social, such as active collaboration and highly reliable communication. It is crucial to recognise transportation needs so that planned investments (including both their scope and location) meet the expectations of different groups as much as possible. The interviewees pointed out that today, ITS meet the transport needs of inhabitants and are constantly improved to fit their needs even better. It should be stressed that according to the participants of interviews, the local urban community was increasingly aware of the benefits resulting from the application of ITS solutions and expected new investments from the local government in this field. Many ITS systems focus on enabling the users to change their behaviour (e.g., shifts in driver behaviour), which is also problematic, as it is connected with their resistance and unwillingness to change. The problematic issue is then the attempt to reconcile different users of traffic, including, e.g., drivers, pedestrians, public transport passengers, and cyclists. Each of these groups expects the system to, for example, improve its performance, safety, and environmental protection. According to the respondents, the specific goals and interests of individual traffic users and their preferred way of moving around the city also translate into different expectations as to the direction and scope of transport investments, which may cause various conflicting situations. For example, the conflict of interests may concern the prioritisation of public transport and the preference for launching the so-called "green wave" for individual drivers. The interviewees were highly aware of the existing resistance to change among traffic users, or the choice of the right mode of transport, which makes them reflect on the whole transport system only from the point of view of their individual needs, sometimes even conflicting with the needs of other travellers. The participants stressed that the system was never built just for the sake of having it, but it was designed and then improved for the sake of residents as the ultimate end-users. However, the main problem is that not everyone perceives it this way. Residents see their own difficulties, their individual needs, their so-called self-interest without looking at the bigger picture of the entire system. Undoubtedly, the social problem involves educating residents about what the transportation system is and for what it is used. The interviewees noticed that they missed one thing in the construction of the system to avoid social problems — a good explanation of why and how the system works. Thus, giving a priority for transit to certain groups of vehicles and traffic users means that others have to wait longer for their turn. However, changing the perception of public transport and matching the urban transport system to the needs of the population is currently a particularly important and developing issue in the context of developing lanes for urban cycling, cars or buses.

The problem identified during the research also relates to the mistrust barrier evident in the cooperation between public and private sector entities. To implement ITS efficiently, the public sector should expand opportunities for close cooperation with private sector entities providing transport services. This will contribute to mutual benefits, e.g., through the openness of the local government to novelties, new forms of cooperation, or agreements with suppliers.

Fig. 3 illustrates the main established categories of barriers and proposes its key subcategories identified by the author. In light of the conducted research, the most important are economic and social barriers related to improving transport towards intelligent solutions (forming the base of the pyramid). The economic category is based on high costs of ITS and the source of its funding, the social category is related

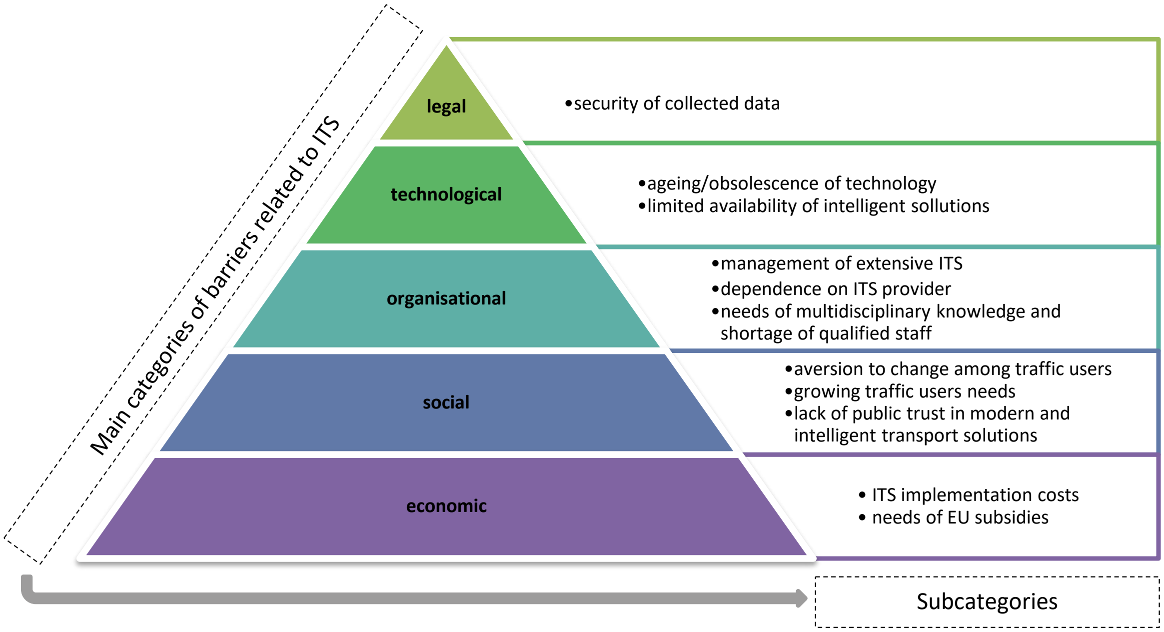

Fig. 3. Main categories and subcategories of barriers related to ITS

to attitudes, evaluation, perception of the local community, the organisational category — to the organisation and management of the ITS, the technology category is related to intelligent technology solutions and the problem of its ageing, and the legal category — with the care for the security of big data.

4. Discussion of the results

The literature indicates that ITS cannot fully solve various urban transportation problems. However, they constitute a valuable set of instruments allowing to significantly reduce them (Jarašūniene, 2006). By perceiving, processing and publishing traffic information, ITS ensure information exchange and cooperation between people, vehicles and technical infrastructure (Huang et al., 2017). Moreover, they enable the collection and sharing of essential real-time traffic information to help traffic users make more informed and sustainable choices about their travel. Thus, they encourage and mobilise passengers to choose an environmentally friendly mode of travel and use public transport or another green mode of transport. They are intended to make these journeys more efficient and thus help reduce the negative impact of transport on the environment, which may be one of the primary objectives of ITS deployment worldwide (Neverauskiene et al., 2021; Pel & Boons, 2010).

For ITS, the benefit-to-cost ratio is typically 10:1, making the political case for investing in or supporting this type of technology (Shinde & Waghmare, 2019). The key in analysed problems is to communicate with system users and to provide access to information about possibilities, benefits connected with the choice of a particular transport mode to all traffic users in a given city to raise their awareness. The creation of some kind of vision of ITS development accepted by the society could be helpful in overcoming the resistance to changes and facilitating communication with users (Jarašūniene, 2006). When considering the social aspect, it should be noted that by introducing a number of improvements or by upgrading the urban infrastructure, sometimes the opposite effect can be achieved, as car transport becoming more efficient may eventually encourage people to travel more often. The literature provides that while considering the potential impact of ITS systems, it is important to recognise the possibility of negative secondary effects (Tuominen & Ahlqvist, 2010; Jänicke & Lindemann, 2010). As Pel & Boons (2010) argued, some ITS may reinforce dependence on cars instead of "greener" modes of transportation. As Grant-Muller & Usher (2014) aptly described, the primary goal should therefore be to consider the full range of possible impacts of ITS on the development of a transportation strategy. When talking about costs, ITS can also be considered in terms of social costs related to, e.g., saving travellers' time. Also, Zhang et al. (2018) analysed the cost-effective evaluation of Intelligent Public Transport Systems, examining it from three perspectives: public transport companies, passengers, government and society.

Focusing on the problems and barriers of mobility and intelligent transport systems, it should be noted that these are insufficiently analysed scientific areas. According to Kachniewska (2020), as a component of a smart city, transport or mobility relates to the hard and technic domain of a smart city. Therefore, the most important barriers and threats to smart mobility are related to the highest importance to technological factors. Jarašūniene (2006) made conclusions similar to the findings identified during the present research by claiming that the introduction of ITS in the transportation sector encounters various problems and barriers, such as:

- considerably low level of technical and organisational knowledge in this field;
- low-level political and public awareness and support;
- uncertain financing from public and private sources;
- difficulties of interinstitutional cooperation.

As the author pointed out, ITS architecture needs to be developed to coordinate all system components into a single framework so that interoperability can be achieved in providing necessary services to customers. In addition, the low commitment to intercity cooperation results in a continued lack of consistent improvements on a national scale. As Jarašūniene (2006) claimed, the ITS environment is complex and multifaceted, and the problem of their creation should be considered at all levels of the country, i.e., by the central government, municipalities, stakeholders and all traffic participants. This will ensure close cooperation of the above institutions.

The research author confirmed some problems identified in the literature and related to ITS. The main categories and subcategories of barriers were indicated. Based on the opinions of people responsible for the organisation of transport and ITS cities, the conducted survey allows identifying key problems and barriers in the analysed area, which are grouped into broader five categories. Individual interviewees had in-depth knowledge of the problems and barriers related to various stages of ITS deployment and city transport organisation in general. The main barrier limiting the wide range of ITS implementation and innovative technological solutions in transport is costs (economic barrier). First of all, the low budget of local government units is a key factor, limiting the possibilities of activities in this area considerably. Since local governments have to implement various investments in parallel, they need EU subsidies for projects and other forms of planned activities in the city. The interviewees emphasised that the implemented ITS usually do not have a holistic approach, and initially, they most often amount to traffic regulation. The interview participants also had high awareness of organisational and cooperation barriers with suppliers, especially with respect to interdependence on ITS provider and difficulties in employing specialists (both at the stage of system design and management). Among legal barriers, the key issue is to ensure the security of large sets of collected data. The main technological problem results from the observed technological progress and rapid ageing of available technologies. Finally, the category of social barriers refers primarily to the growing needs and high expectations of all traffic users (the difficulty of reconciling individual interests). Another crucial factor, according to the respondents, is the observed reluctance to change among citizens, such as changing the mode of transport, existing habits of traffic users, etc.

Conclusions

The smart city concept, implemented in many cities worldwide, has captured the attention of theoreticians and practitioners from local governments. As Papa & Lauwers (2015) stressed, the transport and mobility domain has the highest number of initiatives worldwide within the approach to a smart city. Transport systems play a key role in supporting socio-economic activities around the world. In particular, they provide users with better transport services characterised by high reliability and frequency while implementing low-carbon solutions (Molnar & Alexopoulos, 2008). Transport, understood as an element of the economy, has a significant impact on the environment and requires special attention to its protection. Thus, the emission of pollutants associated with urban transport has a wide range of environmental consequences that ultimately have to be borne by society (Rodrigue, 2016).

According to the literature, most scientific research confirms the idea that ITS support smart mobility in a city (Mangiaracina et al., 2017; Papa et al., 2017; Papa & Lauwers, 2015). Undoubtedly, ITS bring a city closer to being intelligent. Particularly in large cities, ITS applications play a significant role in combating climate change and reducing environmental pollution by providing greater flexibility in urban traffic (Molnar & Alexopoulos, 2008). Consequently, ITS lead to, among other things, reductions in the number of accidents, congestion and greenhouse gas emissions while at the same time improving the quality of urban transport services (Neverauskiene et al., 2021). Beyond any doubt, ITS bring several benefits to all users of the transport system, e.g., drivers, road users, passengers, public transport, people with reduced mobility, and institutions involved in transport activities (Grant-Muller & Usher, 2014; Shaheen & Finson, 2013).

The presented research results confirm some of the problems and barriers identified in the literature review. For instance, interviewees emphasised the lack of financial support from external funds, which makes it impossible to take specific action to improve urban transport and ITS. However, in light of the research, there is a certain discrepancy between the theoretical assumptions presented at the beginning of the article and the perspectives of local authorities of a voivodship city. The structure of urban traffic has changed significantly in recent years, and mobility management has become one of the most challenging areas of urban management. Nowadays, cities especially struggle with a shortage of finance and technological competence related to ITS. Additional problems and barriers can be identified considering the experience of local governments.

The author of the study indicates that local government representatives are highly aware of the barriers of ITS related to their implementation. The identified barriers are grouped into the following categories: economic, social, organisational, technological, and legal. However, without EU funds, cities would not necessarily be able to afford the highly expensive construction of a system. The universal value of the research is deepening the knowledge of ITS and their potential while highlighting the barriers related to their implementation. The interviewees emphasised that currently, cities do not fully use the available technological solutions to facilitate urban transport management. Therefore, the dissemination of knowledge on the subject and experiences of various cities will influence the improvement of implemented transport systems. Following the experience of local governments, this will make it possible to verify the validity of selected subsystems in terms of achievable benefits, their multiplication and planning the most sustainable solutions in this area. The findings can have a positive influence as important factors for local governments to focus on intelligent transport. Additionally, the dissemination of knowledge will allow other local governments to eliminate many problems related to ITS.

Undoubtedly, the research challenge involves the identification of barriers concerning ITS deployment. The theoretical contribution is twofold: first, the juxtaposition of theoretical and practical benefits of ITS; and second, the identification of the impact made by intelligent transportation, affecting the becoming of a smarter city.

The author is aware of certain limitations of this study based only on the implementation of exploratory qualitative research. Another limitation is the scope of the research and the fact that the analysis covered only a small number of voivodship cities, representing particular macro-regions of Poland. This poses a significant limitation to the interpretation of the obtained results and the conclusions drawn on their basis. The conducted in-depth interviews are a turning point and inspiration for further research in a wider scope and descriptive analysis. The multifaceted nature of issues concerning the identified benefits of urban transport and ITS, in connection with their observed dynamic development, provides a substantive direction for further scientific analysis. In the next stage of the research work, the author plan to widen the research focusing on the analysis of barriers and benefits of ITS and conduct quantitative studies concentrating on smart mobility and ITS that include cities from other European countries.

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