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Mobile digital technologies as an integrator of the logistics of transport services in a Smart City

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ABSTRACT
The modern world is socio-technological with a city-centric exemplification. Literature studies and reports have identified an empirical research gap. It relates to the poor identification of the relevant construct components pertaining to digital mobile technology solutions that support urban transport services from the users' perspective. Filling this gap involved distinguishing a research problem related to insufficient identification of the desired application components as representations of mobile technology solutions in the context of the urban transport services' uptake. The article mainly aims to diagnose and evaluate the use of mobile digital technologies to support the logistics of transport services from the perspective of Smart City residents in accordance with the concept of sustainable development. The specific objectives were a theoretical objective, defined as the development of a theoretical model for the creation and management of public transport services resulting from the needs of Smart City residents, and an empirical objective, defined as the verification of the impact made by components of the digital mobility solutions construct on the choice of urban transport services. A nomothetic approach was used based on triangulation of results obtained from mixed studies. The source basis for qualitative research was bibliographic data obtained from the Scopus and Web of Science (WoS) databases, monographs, reports and other netographic sources. They were verified and analysed using the bibliometric technique of word occurrence and co-occurrence analysis (co-word analysis) based on critical content analysis. VOSviewer software was used to conduct the qualitative part of the study. In turn, the source base for quantitative research was city residents, who were surveyed using the CAPI (Computer Assisted Personal Interview) online survey technique. IBM SPSS Statistics software was used to analyse the data. The research indicates the necessity to use mobile digital technologies for managing urban transport services' logistics in the spirit of Society 5.0.

KEY WORDS
mobile technologies, digitalisation, Smart City, logistics of services, transport

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Introduction

Technological evolution is inherently related to the evolution of social and community relations. (Cantwell & Vertova, 2004). The history of the ancestors (homo habilis) of modern humans (homo sapiens) started about 3 billion years ago and was marked by the creation and use of the first tools and the formation of social hominid groups. The socio-cultural evolution oscillating around the tools, methods and techniques available to and used by people has led to the existential transformation of humanity from nomadic tribes living in the spirit of nature to techno-

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logical and digital nomads (Basalia, 1999). According to e-numerativity, the evolution started with a society based on hunting and gathering (1.0), to the agrarian (2.0), the industrial (3.0), the information (4.0), and the super-intelligent collaborative digital society (5.0) (Deguchi, 2020).

The cohesion of social groups, the development of language, and the improvement of communication methods, along with the organisational division and specialisation of work and the creative design of inventions, allowed people to improve and subordinate the world. Such inventions as the wheel, wagons, boats, the printing press, calculating machines, and steam engines led to an environmental revolution. The ecosystem in which people functioned transformed, resulting from the absorption of green areas for crops and the infrastructure of buildings and roads. A sedentary lifestyle and increasingly advanced technologies resulted in people creating settlement units, i.e., cities characterised by high development intensity, little agricultural land, and a population working outside agriculture (Papalia, 2007).

At the turn of the 19th and 20th centuries, the global population was 1.7 billion, and it took another half a century to increase it to 2.5 billion. In 1987, the world population reached 5 billion. It took 12 years for it to exceed another billion, reaching 6 billion in 1999. It took another 12 years to exceed 7 billion. The current population, according to the UN, is over 8 billion, and it will exceed 9.7 billion in 2050. Today, the number of Earth's inhabitants is twice as high as it was 50 years ago (Latos, 2019). Currently, over 500 million people live in cities with a population of 10 million or more. In 2030, it will be 730 million. Globally, it is now over half (55 %) of humanity. It is estimated that in 2050, 41 cities will have a population of over 10 million, 63 — a population of 5 to 10 million, while the number of cities with a population of 1–5 million will increase to 558, and those with 0.5 to 1 million will be 731 (Madej & Sumara, 2019). Therefore, it is expected and extremely valuable to think about the solutions that will help city inhabitants to live in such conditions, considering their living, working, and leisure. It means the need for new ideas for public services, such as transport, healthcare, and administration. This is one of the reasons why the authors chose the topic for this research.

Urbanisation, as a specific process indicating an increased number of people living in cities in relation to the total population, has contributed to migration transformations for centuries. Urbanisation has resulted in an increasing population density per square kilometre. Such a large number of people meant and still means great creative potential and great expectations, as well as great threats (Spencer et al., 2009).

Old technologies that have contributed to the current development of cities are necessary for their continued survival and development in the future, especially considering the specificity of the so-called urban lifestyle related to the interface of nature and technology, recognised as a sub-model of civilisation with laws, language, folklore, traditions and an existential model identified with the improvement of individual-collective coexistence. The Smart City concept (ChuanTao et al., 2015) is an exemplification of such an approach. In the spirit of digital technology, the concept fits into the idea of a super-intelligent collaborative digital Society 5.0, where combining physical space (the real world) and cyberspace creates conditions for a comfortable and satisfying life for the inhabitants of these super cities, thanks to new, mobile digital technologies operating on ICT layer combined with IoT, AI, big data, cloud computing, machine learning and deep learning. Here, old or classical technologies are supported by new digital solutions (Deakin, 2013; Kumar, 2017; Šulyová & Kubina, 2022; Kinelski, 2022).

In the course of evolution, technological solutions have contributed to the propagation of anthropocentrism, which considers a human to be the centre of all reality, or even technocentrism, a concept that accepts technology as the main value in the development of civilisation, moving away from the biocentric approach with a human as a part of nature without the central position in the world. The Smart City concept is an aberration of such thinking. "Smart" as a concept is broad and ambiguous in itself (Baraniewicz-Kotasińska, 2020). In relation to cities, the meaning is narrowly identified using terms such as intelligent, innovative, cognitive and creative. In a broader sense, a Smart City is a city that contributes to meeting the needs of its inhabitants, using the benefits of modern technologies while not limiting the development opportunities of future generations (Kanter & Litow, 2009). Considering this definitional aspect of Smart City, relating to care for future generations, it emphasises the element of sustainability of the so-called Smart Growth included in Agenda 21. Technology-based development should consider the environmental ecosystem and treat humans and technologies as its parts rather than something above them. This is the essence of the aberration. Humans need nature to survive and function because they are living individuals. Technology alone is insufficient for humans as their survival depends on the natural environment. Therefore, another component, "Sustainable", can be added to the "City" concept, emphasising the importance of the environmental aspect. Therefore, a "Sustainable City" (Khansari et al., 2013) bases its functioning not so much on technology but on respect for nature. To sum up, metropolises can be called "Smart Sustainable Cities" if they combine innovative technology applications with the natural habitat, integrating stakeholders and providing all interested parties an opportunity to develop without reducing such opportunities for future generations (Höjer & Wangel, 2014). As the Smart City concept includes the assumption of environmental sustainability, it will be used in the further part of the article to maintain the coherence of the argument.

Based on the descriptors defined by the SRF — the Center of Regional Science of the Department of Spatial Planning of Vienna University of Technology, a Smart City has a smart economy, smart environment, smart mobility, smart people, smart living and smart governance (European Smart Cities). This multidimensional characteristic provides several connections related to residents whose domain of activity is movement. Smart mobility is the component that integrates, unifies and bonds the entire Smart City concept. For the concept to become a reality, it is necessary to guarantee the efficient operation of the city's functional areas, including the mobility of residents in terms of migration and circulation, i.e., their physical transfer in space. In this respect, new technologies play an important role, especially in the area of communication and transport, which represent a holistic approach to urban logistics (Dembińska et al., 2018).

The importance of ensuring the effectiveness of activities while reducing the degree of environmental degradation in meeting the transport needs of city residents sets new trends in the creation and use of new technologies. Including digital technologies in the fabric of urban logistics means digitising information supporting the management of transport services. Travel planning and its implementation inherently involve the use of digital technologies (Taniguchi et al., 2016; Szpilko et al., 2023a). In this approach, it becomes important to create such technical and operational solutions for sustainable digital mobility that will be based on ecological methods and means of transport thanks to interdisciplinarity combining the concepts of transport management, spatial development, respect for the natural environment and safety of residents (Allen & Browne, 2010). The layer of digital space created by digital mobile applications plays an important role in this process.

The article's main objective is to diagnose and evaluate the use of mobile digital technologies to support transport services logistics from the perspective of Smart City residents according to the sustainable development concept. The specific objectives were theoretical, defined as the development of a theoretical model for the creation and management of public transport services resulting from the needs of Smart City residents, and empirical, defined as the verification of the impact made by the components of the digital mobility solutions construct on the choice of urban transport services. Achieving the main objective and specific objectives required the use of mixed research methods. Qualitative methods were used first, followed by quantitative methods.

To realise the aim of the study, the authors decided on a three-stage research programme to objectively assess the level of use of digital mobile technologies that support logistics transport services in a Smart City. The research programme includes complementary qualitative and quantitative methods. Fig. 1 presents the research programme by stages, stating their purpose, references to research questions, associated hypothesis, data collection methods, and used analysis methods.

To diagnose the current state of scientific achievement on the Smart City topic and the use of mobile digital technologies to support the transport services' logistics, qualitative research methodologies were used, including a search and query of Scopus and Web of Science (WoS) databases for the occurrence and co-occurrence of terms within the subject scope under study and a critical content analysis covering the body of literature. The following research questions formed the basis for starting the research procedure for the qualitative part:

- RQ1. What is the essence of modern city logistics, and what system and process technology challenges must the transport services' logistics meet in serving Smart City residents in the 21st century?
- RQ2. What is the manifestation of logistics technologisation in managing the representation of the communication and transport construct of the Smart City community?

The literature review helped define an empirical research gap, which indicated poor recognition of relevant construct components of digital mobile technology solutions supporting urban transport

STAGE 1

Method: qualitative
Purpose: diagnosis of the current state of scientific achievement
References to research questions: RQ1, RQ2
Associated hypothesis: N/A
Data collection methods: search of Scopus and Web of Science (WoS) databases
Type of analysis: occurrence and co-occurrence of terms, critical content analysis.

STAGE 2

Method: quantitative
Purpose: diagnosis and assessment of the availability of mobile digital technology solutions to support the transport services' logistics in selected cities in Poland from the perspective of Smart City residents.
References to research questions: RQ3, RQ4, RQ5
Associated hypothesis: H1, H2
Data collection methods: CAPI online survey
Type of analysis:
- the distributions of the variables in the contingency tables
- $\chi 2$ test of independence between selected variables (Cramer's v coefficient)
- Bartell's test of sphericity
- KMO coefficient
- correlation matrix based on $\chi 2$ coefficient

STAGE 3

Method: conclusions and summary
Purpose: development of a theoretical model for the creation and management of public transport services resulting from the needs of Smart City residents.
References to research questions: N/A
Associated hypothesis: N/A
Data collection methods: N/A
Type of analysis: N/A

Fig. 1. Research programme

services from the users' perspective. The definition of this gap was based on formulating specific questions for a research model based on quantitative research methodology:

- RQ3. What is the current availability of digital solutions informing people about transport services in cities in accordance with the idea of sustainable development?
- RQ4. How important are digital information sources in providing and updating information about changes in public transport services for residents?
- RQ5. What technological solutions in the area of communication and information should be disseminated in urban transport services for residents to be consistent with the idea of sustainable development of a smart city?

Filling this gap involved creating a quantitative research model for an identified research problem regarding insufficient identification of desirable application components as a representation of mobile technology solutions used for disseminating public transport services. Also, research hypotheses were formulated and the study population and the unit of study were identified. Then, the sampling method was defined, the survey implementation method was selected, the survey instrument was constructed, methodologies for the collected data analysis were selected, and hypothesis testing was formed. This approach combined the strengths of qualitative and quantitative methods and obtained research material to complement the existing theoretical output and to identify practical recommendations. The approach has the following strengths: maintaining due research care and obtaining the end result in compliance with the scientific discourse. Its shortcomings, especially in the quantitative part, are a limited surveyed population of a few Polish cities and the methodology of non-random selection of units to the sample, which only allows suppositions about possible regularities.

The article, in particular the conclusions and recommendations, provides a better understanding of the role and importance of the use of digital mobile technologies in the implementation of logistics processes of transport services in cities. Considering the ongoing processes of virtualisation and technologisation and the broadly understood digital transformation of many socio-economic areas of cities, the coming years will be marked by the necessity of digital technologies to be present everywhere, including and, perhaps, primarily, in logistics processes, and especially in communication and transport processes. This is important because, according to preliminary estimates, in 2050, 75 % of the world's population will live in cities. Therefore, the guarantee of efficient and sustainable urban travel, i.e., movement within urban agglomerations, is becoming a priority both in terms of creating new models and the practice of operational applications.

1. Literature review

The population migration to cities forced authorities to adapt to a new situation. So far, the natural growth of the urban fabric has not been sufficient, giving rise to new problems. It is especially visible in crowded city centres, where congestion problems hinder the movement of residents (Kauf et al., 2018). However, urbanisation problems, especially in developing cities, can be divided into categories (Winkowska et al., 2019) related to social and sociological problems, technical infrastructure, and the environment and logistics. Of course, in the context of new concepts, such as ESG (environment–social–governance) (Pollman, 2022), all these elements influence each other, making it difficult to isolate one area of interest. However, research prompted an attempt to indicate how logistics activities can support residents, also in the context of other problematic areas.

An important aspect of the logistics approach is to ensure the appropriate flow of people and goods, which is the essence of logistics. Hence, the concept of urban logistics focuses on providing a transport system that meets the expectations of all stakeholders, including residents, enterprises, service providers, city managers, etc. (Neghabadi et al., 2019; Bjørgen & Ryghaug, 2022; Przybylska et al., 2023). Such a transport system should consider the mobility of residents individually (Caban, 2021) and collectively (Ceder, 2019). Another important issue is securing the supply of goods and services, which involves developing a system that facilitates access of large vehicles to the city or ensuring deliveries from satellite warehouses around cities (Moore, 2019; Mepparambath et al., 2021).

Mobility in cities changed under the influence of the Industry 4.0 concept when people started to think about creating "thinking" digitalised cities. This is how the Smart City concept was born, including many components, such as smart economy, smart mobility, smart environment, smart people, smart living, and smart governance (Winkowska et al., 2019). However, researchers indicate that a uniform definition of a Smart City is not possible, and although the name itself potentially refers to the use of modern technologies, the focus should also be placed on elements related to the sustainable management of city resources with the participation of its inhabitants to achieve their well-being (Tomaszewska, 2021). Certainly, modern IT systems are supportive, facilitating the management of data generated in the city's ecosystem (Szum, 2021).

The COVID-19 pandemic added a new dimension to urban logistics, which made home deliveries, collection points (Sułkowski et al., 2022), and even safe public transport (Rasca et al., 2021) more important. More attention is paid to ensuring that transport services can be considered ecological, which requires appropriate technological solutions (Kiba-Janiak et al., 2021; Kunnapapdeelert et al., 2022). In addition, attention is paid to the sustainable development goals implemented by governments of various countries, including in the EU (Shrestha & Haarstad, 2023). From the perspective of residents, mobility is still treated as one of the most important elements of choosing a place of residence as it affects job possibilities, the availability of public services (schools, kindergartens, and shopping), and gives a sense of freedom from a sociological point of view (Wawer et al., 2022).

Digital mobile technologies play an important role in the Smart City concept, contributing to improved efficiency and sustainable development of urban areas. Mobile applications are a key element of digital mobile technologies in the Smart City context. These applications allow city residents to monitor traffic, purchase tickets, access information on public transport delays and failures, and plan routes, considering multiple transport modes. They help residents use various transport services more effectively, increasing public transport availability and reducing road congestion (Janoskova et al., 2021). Another important element is data transmission, monitoring and analysis systems, particularly BI and processing large data sets, such as Big Data (Hussain et al., 2019). Thanks to the GPS (Global Positioning System) technology, the possibilities offered by wireless data transmission in 5G mobile networks (Gohar & Nencioni, 2021) and sensors mounted on transport means, and, in particular, the IoT concept (Bauer et al., 2021) cities can track the movement of vehicles and passengers in real-time. This enables traffic management, quick response to failures and better planning of transport infrastructure. Moreover, the analysis of data from various sources allows for more accurate decisions to be made, increasing the efficiency of transport systems. Digital mobile technologies are an indispensable element of the Smart City concept, influencing the efficiency and availability of transport services. Mobile applications facilitate the use of various transport means, while monitoring and data analysis systems enable better traffic management and planning of transport infrastructure. In this context, it is also very important to maintain appropriate experiences for mobile application users (Diamantaki et al., 2015). Developing these technologies is key to creating more sustainable and smarter cities, improving the residents' quality of life and reducing the negative impact of transport on the environment (Barr et al., 2021).

2. Research methods

The considerations in the theoretical analysis (based on qualitative research methodologies), covering the scientific achievements so far, became the basis for the practical verification of the scope pertaining to the use of digital mobile technologies to support the transport services logistics provided in selected cities in Poland (based on the quantitative research methodology).

A study was made at the turn of April and May 2023, focusing on the research issue of diagnosing and assessing the availability of solutions in mobile digital technologies supporting the transport services logistics in selected Polish cities from the perspective of Smart City residents. The subject of the measurement was the residents' knowledge, attitudes, and opinions in selected Polish cities regarding the use of applications representing digital mobile technologies that support the logistics of public transport services. Such subject definition led to a descriptive and explanatory study, which required to prepare the characteristics of the information construct pillars defining the availability of public transport services and demonstrating the validity of introducing possible improvements in the implementation and applicability of mobile digital technologies for representing applications as support for the logistics of transport services dedicated to Smart City residents.

The study's assumptions were implemented based on the inductive proof methodology using two research hypotheses:

H1: Residents who have knowledge about mobile digital solutions are more willing to and more often use various forms of digital information sharing regarding the transport services logistics, i.e., mobile digital applications .

H2: Residents who appreciate digitalisation for providing information about the transport services logistics use various public transport forms much more often.

Information from city residents was required to verify the hypotheses. It was assumed that the study population would consist of Polish residents over the age of 15 who lived in the city during the six months before the study. The decision to test a part of the population was made due to limitations in the availability of potential subjects, time and the research budget. Consequently, the minimum sample size was determined.

In the calculation processes, the sample was comprised of Polish residents who were 15–64 years old as of 31 December 2022. According to the Central Statistical Office, the number of such residents amounted to 14,472,409 (Statistics Poland, 2023). It was assumed that the fraction of the proportion value including people using public transport was 0.4 compared to 0.6 of people not using it (Gadziński & Goras, 2019), and the assumed level of random error will be of the order of 5 % with a confidence level of 0.95.

A formula was used to calculate the minimum sample size:

$$n_{min}=NP(\alpha^2\cdot f(1-f))/NP\cdot e^2+\alpha^2\cdot f(1-f) \qquad (1)$$

where:
n_{min} means the minimum sample size,
NP — size of the study population,
α — confidence level for the results,
f — fraction size,
e — assumed maximum error.

After calculations, the minimum sample size was n_{min} = 369 units. To examine the determined number, the diagnostic survey method was used with the CAPI (Computer Assisted Personal Interview) Internet survey technique. The research tool was a questionnaire consisting of 17 closed questions, including nine based on the Rensis Likert scale of attitudes, which was prepared in a digital version and placed on the https://www.ebadania.pl/ platform. A link to the questionnaire was placed on social networking sites in local groups devoted to urban issues. For the technical selection of sample units, the method of non-random sampling of typical units with snowball elements was used, which means that the study could include people registered on social media in urban groups who meet the conditions for participation in the study. They could send a request to other people who could take part in the study, provided they also met the participation conditions. The advantage of this approach was the increase in the number of study participants, yet the disadvantage was the inability to supervise who completed the questionnaires. This measurement method means the study is fragmentary, deterministic, and representative of the selected study population.

Respondents could complete a questionnaire shared on social media for two weeks. Ultimately, 1,278 completed questionnaires were obtained, which is three times more than initially expected. The obtained data were anonymised and coded in IBM SPSS Statistics. Then, they were verified and validated to check and assess the suitability of the material for statistical processing. After passing this stage, the material could be subjected to a proper three-stage analysis.

In the first analysis stage, data is aggregated into tables, distributing the values of answer variants obtained from basic and specific questions. Then, in the second stage, the representativeness of the sample was verified using a consistency test based on the χ^2 statistic written:

$$\chi^2 = \sum_{i=1}^{r} \frac{(n_i - np_i)^2}{np_i} \qquad (2)$$

where:
p_i — the probability that feature X will take a value belonging to the range of class "i",
np_i — the number of units that should be in the i-th interval.

Assuming that the statistics have a χ^2 α distribution with k = (r - 1), where: k is the number of degrees of freedom and r is the number of class intervals. In turn, the empirical value of the χ^2 statistic is calculated from the data obtained from the study. The form of a critical set: $P(\chi^2 < \chi^2_\alpha) = \alpha$ where χ^2_α is the critical value determined from the χ^2 distribution tables for k = r - 1 degree of freedom and p = α. The values obtained from the study sample for the variables gender, age, and place of residence were compared with the distributions characterising the population. Thus, the representativeness of the sample for the surveyed population of Polish city residents was confirmed (Table 1).

Tab. 1. Verification of the tested sample against the population based on the χ^2 significance test.

Variable	Value x^2 Real	Value x^2_α Theoretical	Test realization $x^2<x^2_\alpha$
Sex	0.385	3.841	concordance
Age	10.299	12.592	concordance
Place of accommodation	3.028	11.070	concordance

1 a α — confidence level

In the third analysis stage, a reference was made to answers to the basic questions and metrics, compiling the results in the form of contingency tables and verifying the possibility of a relationship between the selected variables using the χ^2 independence test in the form:

$$\chi^2 = \sum_i^r \sum_j^s \frac{\left(n_{ij}-\tilde{n}_{ij}\right)^2}{\tilde{n}_{ij}} : \chi^2_{(r-1)\cdot(s-1)} \quad (3)$$

where:
nij — empirical conditional numbers resulting from the contingency table,
$\tilde{n}_{ij}$ — theoretical conditional numbers that would appear in the array if the features were independent.

The V-Cramér coefficient calculated from the formula was adopted as a verifier confirming the existence of the relationship:

$$\mathcal{V} = \sqrt{\frac{\chi^2}{n \cdot min(r-1,k-1)}} \quad (4)$$

where:
$\mathcal{V}$ — is the V-Cramér coefficient between two variables,
χ^2— χ^2 test result for a pair of variables,
n — number of observations,
r — number of levels of one variable,
k — number of the second variable,
min (r-1, k-1) — the smaller value of the two (r-1) or (k-1) is selected.

This three-stage procedure allowed for obtaining material to verify the hypotheses, the results of which are presented in the research results section. However, for the purposes of this article, the authors developed only those questions that were consistent with the main thread of the article.

3. Research results

To confirm the level of interest in the topic of mobile technologies in the context of transport in a Smart City, a qualitative study was conducted within existing databases of scientific publications. The source basis for qualitative research was bibliographic data obtained from two interdisciplinary databases, Scopus and Web of Science (WoS), regarding scientific publications in the area of mobile digital technologies used in the Smart City concept. For the query to the Scopus and Web of Science databases, a common search phrase was established, "Mobile technologies in Smart City transport", which was literally used for the query in the Web of Science database, and for the query to the Scopus database, the phrase was appropriately fragmented. Due to the very specific research area, no publication time limits were set in the search results regarding the field or scientific discipline. The analysis focused on scientific articles, monographs and book chapters. Queries from the above databases made it possible to analyse the occurrence and co-occurrence of words (co-word analysis) using the VOSviewer software. The analysis was carried out considering all connections between co-authors and citations between publications, and the minimum level of keyword occurrences was set to three, which resulted in the extraction of 28 keywords characteristic of the search phrase. The figure below (Fig. 2) shows the visualisation of the network of occurrence and strength of connections of keywords appearing in articles related to digital mobile technologies in Smart City transport.

As a result of the query with the given search and analysis parameters, 208 publications were identified in the Web of Science database and 476 in the Scopus database, which were subjected to analysis of the occurrence and co-occurrence of words (co-word analysis) using the VOSviewer software. The time horizon for the co-occurrence of keywords for a given search phrase covered the years 2003–2023. The analysis indicates that the most frequently occurring words and key phrases in the analysed scientific publications are: "smart city" ("smart cities"), "information and communication", "mobile phone", and "internet of things". Additionally, a strong correlation (distances on the link map) was observed between the phrases "smart city" and "information and communication" and "internet of things", and a smaller correlation with the phrase "mobile phone". In the

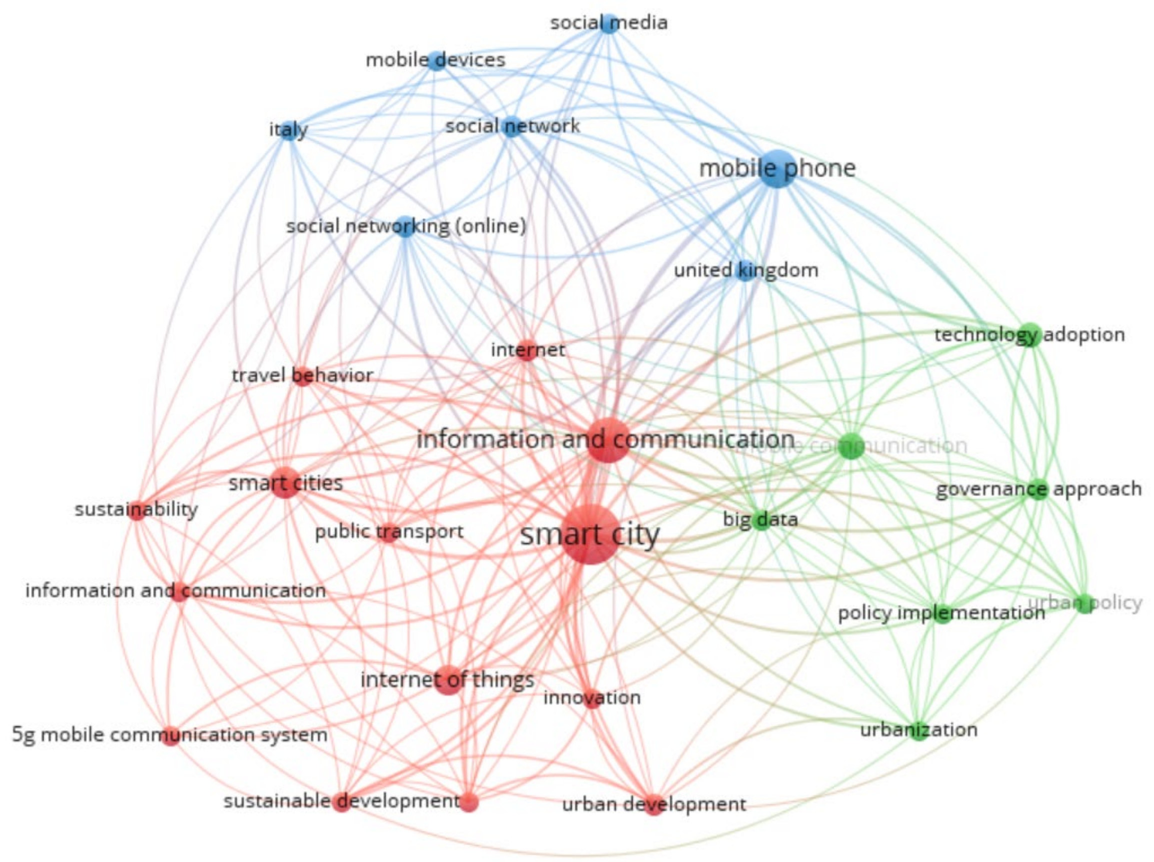

Fig. 2. Results of keyword co-occurrence analysis for the phrase "Mobile technologies in Smart City transport"

Tab. 2. Solutions for the digital availability of transport services in selected Polish metropolises in 2023

	Gender			Age			Place of accommodation		
Variable	χ^{2}[a]	p[b]	V[c]	χ^2	p	V	χ^2	p	V
Public Wi-Fi access	2.367	0.305	0.046	96.033	0.001	0.207	50.220	0.001	0.150
Smart City platforms that provide information about activities in the city	32.752	0.001	0.201	77.958	0.001	0.219	64.662	0.001	0.200
Personalised messages	16.361	0.001	0.121	72.298	0.001	0.180	77.141	0.001	0.186
Mobile applications for finding available parking spaces	26.600	0.001	0.181	148.020	0.001	0.302	146.403	0.001	0.301
Mobile sharing applications (carsharing/ bikesharing)	43.220	0.001	0.195	163.851	0.001	0.269	149.174	0.001	0.256
Mobile applications for planning public transport trips and purchasing tickets	28.187	0.001	0.154	101.570	0.001	0.207	215.906	0.001	0.301
E-commerce mobile applications enabling ticket purchase transactions	16.298	0.001	0.116	160.362	0.001	0.258	96.998	0.001	0.201
Mobile application for communication tracking and delay visibility	17.260	0.001	0.127	112.791	0.001	0.230	80.468	0.001	0.195

[a] χ^2 — test value at α=0,05 [b] p — asymptotic significance [c] The strength of the relationship calculated using V-Cramer

context of the conducted query, what is quite characteristic is the weak representation and strength of connections of keywords related to the social area, including platform and application. Such results became the basis for conducting research on the use of mobile digital technologies to fill the research information gap, which, based on the literature review, was formulated as poor recognition of the relevant components of the digital construct of mobile technology solutions to support urban transport services from a user perspective.

Quantitative research conducted at the turn of April and May 2023 allowed the authors to diagnose the current state of knowledge and identify the potential for the availability of mobile digital technologies to support the logistics of public transport services in selected Polish cities from the perspective of Smart City residents. The research describes the profile of the surveyed population, the distances and ways of moving respondents in urban space, and information solutions in the area of mobile digital technologies that support residents in decision-making processes in the field of urban travel logistics. This approach ultimately allowed the authors to build a model proposal in the form of a model application construct as a representation of solutions in the area of mobile digital technologies supporting the logistics of transport services in cities from the customer's perspective.

The study conducted in May and April 2023 involved 1,278 people from five metropolitan areas such as Cracow (20.3 %), Lodz (10.0 %), Poznan (13.1 %), Warsaw (43.2 %), and Wroclaw (16.4 %). The vast majority of respondents indicate that having knowledge of the essence of the Smart City concept, the cities in which they live can be called Smart City (70.0 %). The majority of respondents were working people (72.4 %), compared to those studying and not working (11.0 %), teaching and working (15.1 %), and retirees (1.5 %). Most respondents indicated that they were fans of new technologies (84.5 %) compared to people who were sceptical about new technologies (15.5 %). Regardless of their attitude towards new technologies, respondents indicated that they were familiar with the phrase new technologies and understood its meaning (36.6 %), they knew the phrase and understood the need to use new technologies (31.0 %), and they knew the phrase and actively participated in the processes of implementing new technologies (21.1 %). Only several respondents indicated that they had never heard the phrase "new technologies" (2.8 %).

Residents of urban agglomerations participating in the study indicated that when moving around the city, they move within a radius of up to 1 km (24.0 %) or travel within the city covering distances from 1 to 5 km (12.1 %), from 5 to 10 km (35.8 %), from 10 to 15 km (8.5 %), from 15 to 20 km (9.3 %) or above 20 km (10.4%). Respondents declared that they most often cover the distance to their destination on foot (19.7 %) or using transport infrastructure such as their own car (22.5 %), tram (23.9 %), bus (19.7 %), bicycle/scooter (5.6 %), train (4.2%) or shared car (4.2 %).

When moving around the city, residents have the opportunity to use digital solutions supporting the logistics of individual and collective transport services. Among the available solutions, respondents indicate that three groups of solutions are available to them. The first group consists of general digital solutions such as Wi-Fi, Smart City platforms and applications with personalised messages. The second group are applications dedicated to users of individual and public transport. The third group of solutions are digital solutions integrally related to mass public transport.

When analysing the availability of applications as digital solutions supporting transport services, the first look should be at the solutions available to everyone, including those who live in the city. Such solutions include public Wi-Fi access, Smart City platforms and applications with personalised messages. Thus, most respondents (87.3 %) are aware of the possibility of access to public Wi-Fi as a digital communication solution in a given city, and just over half (58.0 %) use it. There is no relationship between Wi-Fi use and gender. Considering age, this digital solution is more often used by people aged 35–44 (19.3 %) and 25–34 (9.8 %) and residents of Warsaw (18.2 %), Krakow (13.0 %), and Lodz (10.5 %). Another solution is Smart City platforms, which enable the provision of information about activities in the city and ensure communication with residents. Such solutions are relatively little known to respondents. Only slightly more than half of the respondents (63.4 %) are aware that such a solution exists in their city, and even fewer respondents use it (40.0 %). This solution is used more often by women (22.4 %) than men (17.5 %), people aged 35–44 (18.4 %) and residents of Cracow (12.3 %) and Warsaw (10.0 %). Applications that send personalised messages are important for city residents. Such solutions are known to the majority of respondents (87.3 %), and just over half of the respondents use them (59.7 %).

Such solutions are used more often by men (33.6 %) than women (26.1 %), people aged 35–44 (18.4 %) and residents of Warsaw (20.3 %) and Cracow (14.5 %). The use of general digital solutions available to everyone and which can potentially be used by everyone is weakly dependent on gender, age and city, which is consistent with the basis of their availability and universality and which is confirmed by the χ2 independence test with the strength of the relationship determined by V-Cramer (Table 2).

Another group of digital solutions are applications supporting urban transport logistics from the point of view of individual and public transport users. Such applications that enable the search for free parking spaces in a given city are known to more than half of the respondents (63.4 %). However, they are used by only one in four respondents (24.4 %). This solution is used more often by men (15.8 %) than women (8.6 %), people aged 35–44 (12.5 %), and residents of Cracow (5.4 %) and Wroclaw (7.1 %). Another digital solution available to residents is applications involving "sharing means of transport", such as "carsharing" and "bikesharing". These solutions are known to the majority of respondents (88.7 %). And here, as in the case of parking space applications, there are few users (23.1 %). This solution is used more often by men (16.9 %) than women (16.4 %), people aged 35–44 (15.0 %) and residents of Cracow (10.5 %) and Warsaw (6.5 %). The use of such digital solutions, considering the user of individual personal and public transport, is weakly dependent on gender and moderately dependent on age and city, which is confirmed by the χ2 independence test with the strength of the relationship determined by V-Cramer (Table 2). In turn, the last group of digital solutions are those that are integrally related to mass public transport. First of all, these are mobile applications that are used to plan public transport trips and purchase tickets. According to respondents' declarations, such solutions are available to them (93.0 %), and they are willing to use them (80.3 %). This solution is used more often by women (42.7 %) than men (37.5 %), people aged 25–34 (18.9 %) and 35–44 (21.6 %), and residents of Warsaw (31.0 %) and Cracow (21.1 %). Another digital solution available to residents in the field of public transport is applications enabling online ticket purchase transactions. These solutions are known to the majority of respondents (94.4 %), and they use them equally often (73.1 %). This solution is used more often by men (38.3 %) than women (34.9 %), people aged 35–44 (22.3 %) and 55–64 years (14.8 %) and residents of each agglomeration, mostly in Warsaw (26.8 %), Cracow (16.1 %), and Lodz (13.1 %). The last solution integrally related to public transport is mobile applications that enable tracking of communication means and their delays. The majority of respondents (83.1 %) are aware of the existence of such solutions in the city. And over half of the respondents (61.0 %) use them. Such solutions are used more often by women (32.8 %) than men (28.2 %), people aged 35–44 (15.1 %) and 25–34 (14.5 %) and residents of every agglomeration, mostly in Warsaw (23.6 %), Cracow (15.7 %), and Wroclaw (9.2 %). To sum up, the use of digital solutions supporting mass public transport is weakly dependent on gender and moderately dependent on age and city, which is confirmed by the χ2 independence test with the strength of the relationship determined by V-Cramer (Table 2).

Among the available solutions, respondents admit that they use applications supporting urban travel from smaller towns to a city operating within an agglomeration based on suburban railway infrastructure and solutions, applications supporting the selection of public transport means and purchasing tickets. It should be added that not all applications are available in all cities. Most often, respondents indicated the use of applications, such as jakdojade.pl (73.2 %), koleo.pl (59.2 %), and portalpasazera.pl (43.7 %). Somewhat often, respondents indicated that they used such solutions as mmpk.info (36.6 %), mobilet.pl (25.4 %), and bilkom.pl/ (23.9 %). The respondents were least likely to mention such applications as skycash.com (19.7 %), buslive.pl (18.3 %), and kiedyprzyjedzie.pl (15.5 %). When assessing the indicated applications on a scale from -3 (lowest rating) to +3 (highest rating), the respondents rated the following as the highest: koleo.pl ($\bar{x}$ - 20.85 points), mobilet.pl ($\bar{x}$ - 20.54 points), kiedyprzyjedzie.pl ($\bar{x}$ - 16.83 points), and portalpasazera.pl ($\bar{x}$ - 16.83 points), and the lowest ratings were given to jakdojade.pl ($\bar{x}$ - 1.41 points), mmpk.info ($\bar{x}$ - 1.39 points), and buslive.pl ($\bar{x}$ - 0.59 points).

Due to the above evaluations of the application, the authors believe that it was worth examining the components of the application's utility construct that should be included in the construction of a model digital solution supporting the logistics of transport services for the population in the city, so that it meets the expectations of potential individual users.

For this purpose, a question with 15 answer options was constructed based on a multi-part nominal scale, where each variant was assigned an ordinal scale based on Rensis Likert scaling. Analysing the obtained results, it was found that the most important functional components for application users due to their answer "definitely yes" were the intuitive ticket purchasing module (77.5 %), the ability to quickly search for connections (66.2 %), remembering fixed routes (64.8 %), updating information in real-time and indicating delays (64.8 %), and optimising routes using various transport means (63.4 %). According to the respondents, the functional components that are slightly less important in the construct are information about the location of stops (59.2 %), combining various forms of communication (59.2 %), and indicating transfer hubs such as "park & ride". The least important are intuitive graphic visualisation (45.1 %), the ability to read information on various media (43.7 %), and image scalability (36.6 %). However, the utility components of marginal importance for respondents who are users of the application are indications of sustainable means of transport (electric/hybrid transport) (18.3 %), indications of the score for choosing low-emission transport — promotional discounts/bonuses in fees for using public transport (18.3 %), showing the carbon footprint created when choosing a given means of transport (9.9 %) and the possibility of voice support in the native language and foreign languages (the most common) (9.9 %).

By analysing the potential relationships between the components of the application's utility construct and factors describing the population, the following information was obtained. Namely, the intuitive ticket purchasing model as a component of the application's utility construct is slightly more important for women (48.5 %) than men (45.9 %), people aged 35–44 (24.4 %) and residents of the agglomeration of the cities of Warsaw (33.8 %) and Cracow (20.2 %). In turn, the ability to quickly search for connections is slightly more important for women (48.5 %) than men (45.9 %), people aged 35–44 (23.2 %) and residents of the agglomeration of Warsaw (33.9 %) and Cracow (20.3 %). Similarly, remembering fixed routes is slightly more important for women (45.9 %) than men (38.6 %), people aged 25–34 (20.1 %) and residents of the agglomerations of Warsaw (29.6 %) and

Tab. 3. Expectations that should be met by the components of the utility construct of digital mobile applications in urban transport services

	Gender			Age			Place of accommodation		
Variable	χ^{2A}	p[B]	V[C]	χ^2	p	V	χ^2	p	V
Ability to quickly search for connections	21.032	0.001	0.128	173.976	0.001	0.213	303.325	0.001	0.281
Intuitive ticket purchasing module	5.946	0.051	0.068	106.257	0.001	0.204	83.362	0.001	0.181
Image scalability	46.847	0.001	0.191	231.953	0.001	0.213	179.002	0.001	0.187
Ability to read information on various media (desktop/smartphone)	57.529	0.001	0.212	248.364	0.001	0.220	220.525	0.001	0.208
Possibility of voice control in the native language and foreign languages (the most common)	106.875	0.001	0.289	327.839	0.001	0.253	179.958	0.001	0.188
Intuitive graphic visualisation	24.593	0.001	0.139	84.617	0.001	0.149	188.694	0.001	0.222
Real-time information updates and delay indication	43.569	0.001	0.185	76.823	0.001	0.173	93.024	0.001	0.191
Memorising fixed routes	37.291	0.001	0.171	199.159	0.001	0.197	235.880	0.001	0.215
Indication of transfer hubs, e.g. "park & ride" / bus – train	4.705	0.195	0.061	319.888	0.001	0.289	412.569	0.001	0.328
Optimisation of travel routes using various means of transport (travel time/cost)	105.124	0.001	0.287	123.755	0.001	0.156	252.264	0.001	0.222
Combining various forms of communication	56.256	0.001	0.210	130.077	0.001	0.160	362.398	0.001	0.266
Location of stops	40.094	0.001	0.177	78.628	0.001	0.143	205.795	0.001	0.232
Scoring for choosing low-emission transport — promotional discounts/bonuses in fees for using public transport	78.869	0.001	0.248	140.505	0.001	0.166	106.712	0.001	0.144
Showing the carbon footprint created when choosing a given means of transport	64.681	0.001	0.225	283.188	0.001	0.272	189.368	0.001	0.222
Indications of sustainable means of transport (electric/hybrid transport)	55.979	0.001	0.209	99.654	0.001	0.161	156.472	0.001	0.202

[a] χ^2 — test value at $\alpha=0.05$ [b] p — asymptotic significance [c] The strength of the relationship calculated using V-Cramer

Cracow (19.7 %). Similarly, updating information in real-time and indicating delays is slightly more important for women (48.8 %) than men (47.0 %), people aged 35–44 (24.5 %) and residents of the agglomeration of the cities of Warsaw (32.7 %) and Cracow (20.3 %). Also, the optimisation of travel routes using various means of transport (travel time/cost) is slightly more important for men (47.1 %) than women (43.0 %), people aged 35–44 (22.7 %) and residents of the Warsaw agglomeration (30.2 %) and Cracow (18.7 %).

In turn, the component of stop location is slightly more important for women (45.4 %) than men (43.3 %), people aged 35–44 (22.2 %) and residents of the agglomeration of Warsaw (31.3 %) and Cracow (18.4 %). Similarly, combining various forms of communication is slightly more important for women (41.9 %) than men (32.5 %), people aged 35–44 (20.6 %) and residents of the agglomerations of Warsaw (30.0 %) and Cracow (18.0 %). However, indicating transfer hubs, e.g. "park & ride"/ bus–train, is slightly more important for women (43.4 %) than men (38.4 %), people aged 35–44 (21.8 %) and residents of the Warsaw agglomeration (28.5 %) and Cracow (19.9 %).

The next group of components indicates that intuitive graphic visualisation is slightly more important for women (41.1%) than men (35.0%), people aged 35–44 (19.3%) and residents of the agglomeration of Warsaw (27.3%) and Cracow (19.2%). Similarly, the ability to read information on various media (desktop/smartphone) is slightly more important for women (41.2 %) than men (24.9 %), people aged 35–44 (19.8 %) and residents of the Warsaw agglomeration (26.8 %) and Cracow (16.9 %). As well as image scalability is slightly more important for women (35.25 %) than men (32.4 %), people aged 35–44 (17.4 %) and residents of the agglomeration of Warsaw (22.6 %) and Cracow (13.8 %).

As for the last group of components, the indication of sustainable means of transport (electric/hybrid transport) is slightly more important for women (24.9 %) than men (14.5 %), people aged 35–44 (10.7 %) and residents of the agglomeration of the cities of Łódź (11.4 %) and Warsaw (10.9 %). Similarly, the score for choosing low-emission transport — promotional discounts/bonuses in urban transport fees is slightly more important for men (28.5 %) than women (23.6 %), people aged 35–44 (12.1 %) and residents of the Warsaw agglomeration (16.7 %) and Cracow (12.0 %). In turn, showing the carbon footprint created when choosing a given means of transport is slightly more important for women (18.7 %) than men (9.7 %), people aged 35–44 (20.6 %) and residents of the agglomeration of Cracow (9.5 %) and Lodz (7.8 %). Similarly, the possibility of voice service in the native language and foreign languages (the most common) is slightly more important for women (13.9 %) than men (10.0 %), people aged 35–44 (6.9 %) and residents of the Warsaw agglomeration (10.1 %) and Cracow (6.2 %).

To sum up, the analysis of the application's operational components from the point of view of the statistical verification procedure indicates that they are weakly dependent on gender, apart from the lack of dependence in the case of the components: the intuitive ticket purchase model and the indication of transfer hubs, e.g., "park & ride"/bus, and moderately dependent on age and city, which confirms $\chi 2$ independence test with the strength of the relationship determined by V-Cramer (Table 3). By specifying the dependencies between the components of the utility construct of applications supporting the logistics of transport services in cities and defining the aggregation pillars for the utility components, it was decided to process the data using factor analysis allowing for the identification of potential connections between the components, which will allow for the identification of dependency regularities. The boundary conditions for the analysis were:

- K–M–O marginal statistics,
- Bartlett's test of sphericity,
- correlation matrix based on the $\chi 2$ coefficient,
- Oblimin simple rotation with the elimination of coefficients below 0.4.

After processing the data in SPSS, the value of the K-M-O marginal statistics was obtained at the level of 0.708, which proves the adequacy of the sample selection and is the basis for aggregating components into pillars and creating a model. This approach is confirmed by Bartlett's test of sphericity, where the approximate value of the $\chi 2$ statistic was 9491.341 with a significance level of <0.001. On this basis, a matrix was proposed that includes four pillars of the application's utility construct that should be included in a model digital solution supporting transport services in the city so that it meets the expectations of potential individual users (Table 4).

The identified four pillars of the utility construct in building a model digital solution supporting transport services in the city can be appropriately described:

- pillar 1 — interactive communication,
- pillar 2 — proactive transaction,
- pillar 3 — modular logistics,
- pillar 4 — sustainable progression.

Tab. 4. Results of factor analysis of the construct components of digital mobile applications in urban transport services

Variable	Pillar 1	Pillar 2	Pillar 3	Pillar 4
Ability to quickly search for connections	0.841			
Intuitive ticket purchasing module	0.670			
Image scalability	0.666			
Ability to read information on various media (desktop/smartphone)	0.569			
Possibility of voice control in native language and foreign languages (the most common)		0.890		
Intuitive graphic visualisation		0.794		
Real-time information updates and delay indication		0.741		
Memorising fixed routes			0.803	
Indication of transfer hubs, e.g. “park & ride” / bus–train			0.801	
Optimisation of travel routes using various means of transport (travel time/cost)			0.787	
Combining various forms of communication			0.714	
Location of stops			0.633	
Scoring for choosing low-emission transport - promotional discounts/bonuses in fees for using public transport				0.920
Showing the carbon footprint created when choosing a given means of transport				0.902
Indications of sustainable means of transport (electric/hybrid transport)				0.598

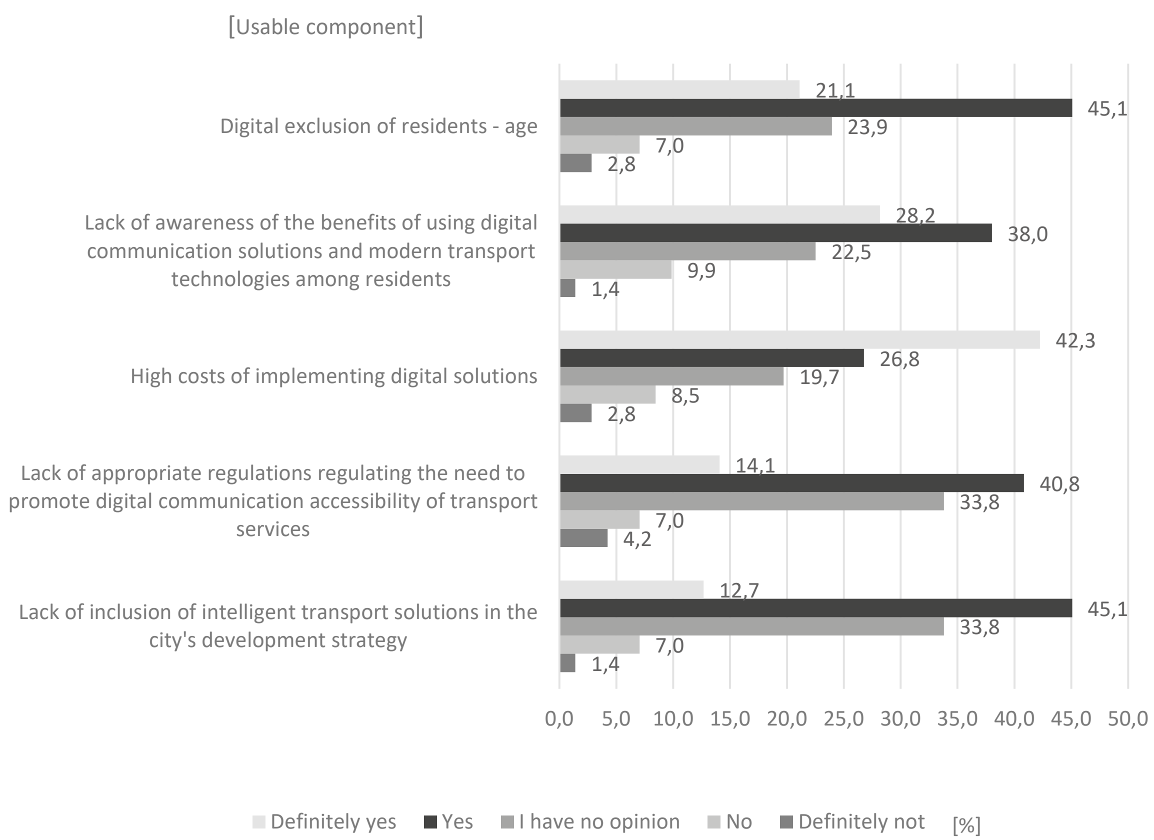

Fig. 3. Barriers to the implementation of solutions in the field of digital accessibility of public transport services [%]

Such a design of individual application components in line with users' expectations is important because, for many respondents (87.3 %), mobile digital solutions are currently the basic information and functional tools enabling transport services in the city. Although not everyone always uses available application solutions as tools for accessing public transport services, it is worth ensuring that such solutions appear and become popular. However, you should be aware that implementing modern technological solutions in cities is not easy. Very often, there are barriers to implementing intelligent digital solutions supporting the availability of public transport services.

Among the potential barriers, respondents indicate the high costs of implementing digital solutions (69.0 %), which often constitute a significant block in the digitisation of cities. According to respondents, another matter is the lack of awareness of the benefits of using digital communication solutions and modern transport technologies among residents (66.2 %), which translates into a low level of support for the implementation of such solutions and their adoption. Another factor that rather often inhibits the digitalisation of cities is the digital exclusion of residents due to age (66.2 %). Older people are less susceptible to using innovative solutions. Important factors hindering the digitalisation of cities may also be the failure to include intelligent transport solutions in the city's development strategy (57.7 %) and the lack of appropriate regulations regulating the need to promote digital communication accessibility of transport services (54.9 %). These barriers may potentially contribute to the slowdown in the process of digitising cities. It is worth being aware of this and introducing actions to prevent or eliminate such barriers.

To sum up, despite the potential barriers that may arise when implementing innovative technological solutions designed to support the logistics of transport services, it is worth looking for the best possible solutions in the field of mobile digital solutions because they are an important tool supporting the functioning of city residents in their everyday functioning.

4. Discussion of the results

As a result of the analysis, the research hypotheses were confirmed. Therefore, the answer to hypothesis H1 is "Yes, residents who have knowledge about existing mobile digital solutions are more willing to use various forms of digital sharing of information about the logistics of transport services, i.e., mobile digital applications, more often than others". People who are aware of various possible applications and the facilities associated with them are much more willing to use them when planning their trips around the city. It can be seen in other research, like in Seul, where the combined efforts of different stakeholders helped to improve an integrated platform for transit services (Lee et al., 2022). The same research pointed to the need for greater trust in the technology and support from governance. But the biggest challenge is the cooperation and trust between local communities and local governance (Spicer et al., 2023). The trust issue is also an element of another study conducted to determine the factors that influence residents and public servants following the Smart City concept (Habib et al., 2023). However, the idea of using new technologies to move around the city does not have to apply only to its residents but also to tourists (Chuang, 2023) using smart tourism service (STS). The use of artificial intelligence can be used to improve this type of solution (Elharoun et al., 2023; Szpilko et al., 2023b), and data can be collected, for example, using signals from mobile networks (Yang et al., 2023), and then, based on the analyses, it will be possible to share as appropriate information as possible for specific people. The research says that the possibilities of different technologies are wide, and it is up to the residents and local governance to implement the solution, which would be responsive but also give a chance for development and optimisation (Kolhe et al., 2023).

Similarly, a positive answer can be indicated in the form of "Yes, residents who appreciate digitalisation in terms of providing information on the logistics of transport services use various forms of public transport much more often than others", which means a positive verification of the H2 hypothesis. It can be seen that city residents are increasingly using public transport for various reasons, e.g., lower ticket prices (Wallimann et al., 2023) or the possibility of combining public transport with individual transport (Kosmidis & Müller-Eie, 2023). The research shows a possible correlation between the technology used and the residents' attitude towards travelling around the city (van Lierop & Bahamonde-Birke, 2023). With the increasing interest in new technologies and the availability of applications, including in the field of planning trips around the city, travelling by public transport is becoming much easier than travelling individually. Also, there is a possibility of much greater interest in on-demand mobility services, which can be an alternative to public transport services, a bit faster, cheaper, and more eco-friendly (Geržinič et al., 2023; Gkavra et al., 2023). Different forms of city transport suggest that it would be attractive for the technological solutions to combine all these options (Gokasar & Karaman, 2023).

This makes the city potentially more attractive as a modern and friendly place. High efficiency and effectiveness of the people's flow in transport processes is currently one of the basic areas of city management. The use of applications as information, communication, and operational tools can be an important stimulus for implementing the strategies of modern and innovative cities aimed at implementing the Smart City idea. This can also be the next step in developing cities as innovative and attractive places for living and working (Marchesani et al., 2023). Technology development in the context of city management depends on access to new innovative solutions. If city managers want to attract new investors and implement new solutions, they need to stay open-minded. This demonstrates the importance of the presented study and the possibilities for future research.

Conclusions

Considering the research results, it should be assumed that the future of cities will depend on the creation of opportunities that will be available to residents and visitors. Although the analysis of the occurrence and strength of connections in scientific publications indicates a relatively small share of keywords and phrases related to social media, it should be assumed that due to the mobile and context-dependent location-dependent nature of the operation of transport applications in the Smart City concept, the share of solutions based on social media will be growing. The rising interest in mobile solutions supporting travel management prompts a closer look at the functionality of such applications.

To meet the needs of city users, which were pointed out in the quantitative research, a model for creating and managing transport services in terms of the components of a digital mobile application was proposed (Fig. 4). The model consists of four pillars, also resulting from the described research: I — interactive communication, II — proactive transaction, III — modular logistics, IV — sustainable progression.

The information and communication pillar assumes the appearance of the application, which should primarily meet the criterion of accessibility, i.e., scalability and the ability to adapt to various operating systems. It is also a requirement regarding accessibility for various social groups, including those with disabilities.

The transactional pillar would concern the possibility and choice of transport services by providing data on transport connections or purchasing tickets.

The logistics pillar would concern journey planning and combining various forms of public transport in the city. It would also be possible to include functionality related to combining public transport with individual transport means, e.g., scooters and bikes for rent. It is important to build a personal profile to enable search optimisation.

A sustainable approach requires users to know their impact on the environment, hinting at possible actions to reduce their negative impact on the environment.

The uniqueness of this model results from its structure. It considers the communication form, transaction methods, possibilities of combining transport means, and the possibility of choosing branches and means of transport with a lower impact on the environment. In the eyes of respondents, these elements are increasingly important for their decisions. Therefore, the authors believe that managers of public transport services or IT companies providing mobile services in the context of urban transport should consider the issues of using and ensuring the availability of information on low-emission means of transport.

Research shows that city residents pay increasingly more attention to living conditions and require them to be more health-friendly. The concept of healthy cities (Thompson et al., 2023) is becoming more popular. Therefore, local authorities and public transport managers should consider the issue of appropriate selection of transport means and take care of the infrastructure for other, more ecological choices, e.g. bicycles. Another important aspect is ensuring the quality of available digital services related to the provision of information on the current state of urban transport. The availability of such applications should certainly be greater, especially since more and more people use public transport and mobile devices to plan routes.

The limitation of the research was obtaining answers from residents of only five Polish metropolises (Cracow, Lodz, Poznan, Warsaw, and Wroclaw).

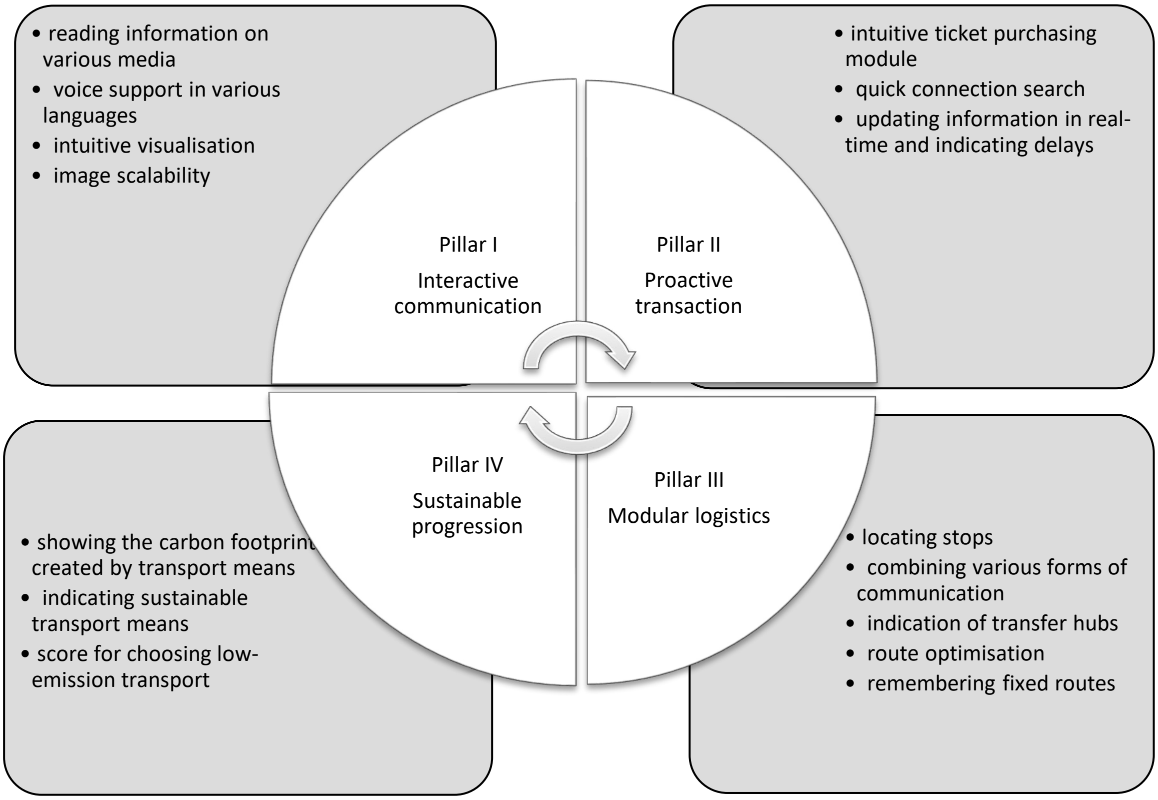

Fig. 4. Model for creating and managing transport services as a component of a digital mobile application

The research could be extended to include agglomerations such as Tricity or the Silesian agglomeration, where transport services are much more extended, and it would be expected to examine the state of public transport services in these cities and check the applicability of the results, but also to examine the state of public transport services in these cities.

The proposed model can also be extended and changed with additional functionalities in individual pillars so that it is as flexible as possible and adapts to the capabilities of specific cities. Certainly, in the future, a good solution would be to create one application model for different cities, but due to the large differences in topography and communication systems, this will be extremely difficult.

Literature

Allen, J., & Browne, M. (2010). Sustainability strategies for city logistics. In A. McKinoon, S. Cullinane, M. Browne, & A. Whiteing (Eds.), *Green Logistics: Improving the Environmental Sustainability of Logistics* (pp. 282–303). London: Kogan Page Limited.

Baraniewicz-Kotasińska, S. (2020). Smart City. Four approaches to the concept of understanding. *Urban Research & Practice, 15*(1), 1-24.

Barr, S., Lampkin, S., Dawkins, L., & Williamson, D. (2021). Smart cities and behavioural change: (Un)sustainable mobilities in the neo-liberal city. *Geoforum, 125,* 102457. doi: 10.1016/j.geoforum.2021.06.010

Basalia, G. (1999). *The Evolution of Technology.* Cambridge: Cambridge University Press.

Bauer, M., Sanchez, L., & Song, J. (2021). IoT-enabled smart cities: Evolution and outlook. *Sensors, 21*(13), 4511. doi: 10.3390/s21134511

Bjørgen, A., & Ryghaug, M. (2022). Integration of urban freight transport in city planning: Lessons learned. *Transportation Research Part D: Transport and Environment, 107,* 103310. doi: 10.1016/j.trd.2022.103310

Caban, J. (2021). Traffic congestion level in 10 selected cities of Poland. *Scientific Journal of Silesian University of Technology. Series Transport, 112,* 17-31. doi: 10.20858/sjsutst.2021.112.2

Cantwell, J., & Vertova, G. (2004). Historical evolution of technological diversification. *Research Policy, 33*(3), 511-529. doi: 10.1016/j.respol.2003.10.003

Ceder, A. (2019). Urban mobility and public transport: Future perspectives and review. *International Journal of Urban Sciences, 25*(4), 455-479. doi: 10.1080/12265934.2020.1799846

Chuang, M.-Ch. (2023). The conceptualization of smart tourism service platforms on tourist value co-creation behaviours: An integrative perspective of smart tourism services. *Humanities and Social Sciences Communications, 10*(1), 367. doi: 10.1057/s41599-023-01867-9

ChuanTao, Y., Zhang, X., Hui, C., JingYuan, W., Daven, C., & Bertrand, D. (2015). A literature survey on smart cities. *Science China, 58,* 2415–2429. doi: 10.1007/s11432-015-5397-4

Deakin, M. (2013). From intelligent to smart cities. In *Smart Cities* (pp. 15–32). 1st Edition. London: Routledge.

Deguchi, A. H. (2020). What is society 5.0? In H.-U. Laboratory (Ed.), *Society 5.0* (pp. 1–24). Tokyo: Axel Springer.

Dembińska, I., Frankowska, M., Malinowska, M., & Tundys, B. (2018). *Smart Logistics.* Kraków: edu-Libri.

Diamantaki, K., Rizopoulos, C., Charitos, D., Tsetsos, V., Kovatsis, P., & Theona, I. (2015). Evaluating the user experience of a mobile user in a smart city context. *International Journal of Intelligent Engineering Informatics, 3,* 120. doi: 10.1504/IJIEI.2015.069902

Elharoun, M., El-Badaway, S. M., & Shahdah, U. E. (2023). Artificial intelligence techniques for predicting individuals' mode choice behavior in Mansoura City, Egypt. *Transportation Research Record, 2677*(10), 605–623. doi: 10.1177/03611981231162598

European Smart Cities. Retrieved from www.smart-cities.eu

Gadziński, J., & Goras, E. (2019). *Raport o stanie polskich miast. Transport i mobilność miejska [Report on the condition of Polish cities. Transport and urban mobility].* Warszawa: Instytut Rozwoju Miast i Regionów.

Geržinič, N., van Oort, N., Hoogendoorn-Lanser, S., Cats, O., & Hoogendoorn, S. (2023). Potential of on-demand services for urban travel. *Transportation, 50,* 1289–1321. doi: 10.1007/s11116-022-10278-9

Gkavra, R., Susilo, Y. O., & Klementschitz, R. (2024). Determinants of usage and satisfaction with demand responsive transport systems in rural areas. *Transportation Research Record, 2678*(6), 667-680. doi: 10.1177/03611981231198834

Gohar, A., & Nencioni, G. (2021). The role of 5G technologies in a smart city: The case for intelligent transportation system. *Sustainability, 13*(9), 5188. doi: 10.3390/su13095188

Gokasar, I., & Karaman, O. (2023). Integration of personnel services with public transportation modes: A case study of Bogazici University. *Journal of Soft Computing and Decision Analytics, 1*(1), 1-17. doi: 10.31181/jscda1120231

Habib, A., Alsmadi, D., & Prybutok, V. R. (2023). Factors that determine residents' acceptance of smart city technologies. In K. Papangelis, M. Saker, & C. Jones (Eds.), *Smart Cities at Play: Technology and Emerging Forms of Playfulness.* CRC Press. doi: 10.1201/9781003461043

Höjer, M., & Wangel, J. (2014). Smart sustainable cities: Definition and challenges. In L. L. M. Hilty & B. Aebischer (Eds.), *ICT Innovations for Sustainability, Advances in Intelligent Systems and Computing* (pp. 333–350). Zurich: Springer International Publishing.

Hussain, M., Beg, M., Alam, M., & Laskar, S. (2019). Big data analytics platforms for electric vehicle integration in transport-oriented smart cities. *International Journal of Digital Crime and Forensics, 11,* 23-42. doi: 10.4018/IJDCF.2019070102

Janoskova, P., Stofkova, K. R., Kovacikova, M., Stofkova, J., & Kovacikova, K. (2021). The concept of a smart city communication in the form of an urban mobile application. *Sustainability, 13*(17), 9703. doi: 10.3390/su13179703

Kanter, R., & Litow, S. (2009). Informed and interconnected: A manifesto for smarter cities. *HBS.*

Kauf, S., Szołtysek, A., & Wieczorek, I. (2018). *Transport zbiorowy w zaspokajaniu mobilności mieszkańców miast. Doświadczenia JST [Public transport in satisfying the mobility of city dwellers. LGU experiences].* Łódź: Narodowy Instytut Samorządu Terytorialnego.

Khansari, N., Mostashari, A., & Mansouri, M. (2013). Impacting sustainable behaviour and planning in smart cities. *International Journal of Sustainable Land Use and Urban Planning, 1*(2), 46-61. doi: 10.24102/ijslup.v1i2.365

Kiba-Janiak, M., Marcinkowski, J., Jagoda, A., & Skowrońska, A. (2021). Sustainable last mile delivery on e-commerce market in cities from the perspective of various stakeholders: Literature review. *Sustainable Cities and Society, 71,* 102984. doi: 10.1016/j.scs.2021.102984

Kinelski, G. (2022). Smart city 4.0 as a set of social synergies. *Polish Journal of Management Studies, 26*(1), 92-106. doi: 10.17512/pjms.2022.26.1.06.

Kolhe, R. V., William, P., Yawalkar, P. M., Paithankar, D. N., & Pabale, A. R. (2023). Smart city implementation based on Internet of Things integrated with optimization technology. *Measurement: Sensors, 27,* 100789. doi: 10.1016/j.measen.2023.100789

Kosmidis, I., & Müller-Eie, D. (2023). The synergy of bicycles and public transport: A systematic literature review. *Transport Reviews.* doi: 10.1080/01441647.2023.2222911

Kumar, T. V. (2017). *Smart Economy in Smart Cities.* Berlin: Axel Springer.

Kunnapapdeelert, S., Johnson, J. V., & Phalitnonkiat, P. (2021). Green last-mile route planning for efficient e-commerce distribution. *Engineering Management in Production and Services, 14*(1), 1-12. doi: 10.2478/emj-2022-0001

Latos, M. (2019). *Miliard w 12 lat. Tak szybko przybywa ludności na świecie [A billion in 12 years. The world's population is growing so quickly].* Retrieved from https://businessinsider.com.pl/wiadomosci/liczba-ludnosci-na-swiecie-statystyki-i-prognozy/ceep8qj

Lee, J., Babcock, J., Pham, T. S., Bui, T. H., & Kang, M. (2022). Smart city as a social transition towards inclusive development through technology: A tale of four smart cities. *International Journal of Urban Sciences, 27*(sup1), 75–100. doi: 10.1080/12265934.2022.2074076

Madej, Ł., & Sumara, A. (2019). *Największe miasta świata – Ranking 2021. W których miastach mieszka więcej niż 10 mln osób? [The largest cities in the world - Ranking 2021. Which cities have more than 10 million people?]*. Retrieved from https://inzynieria.com/budownictwo/rankingi/48810,najwieksze-miasta-swiata-ranking-2021

Marchesani, F., Masciarelli, F., & Bikfalvi, A. (2023). Smart city as a hub for talent and innovative companies: Exploring the (dis)advantages of digital technology implementation in cities. *Technological Forecasting and Social Change, 193,* 122636. doi: 10.1016/j.techfore.2023.122636

Mepparambath, R. M., Cheah, L., & Courcoubetis, C. (2021). A theoretical framework to evaluate the traffic impact of urban freight consolidation centres. *Transportation Research Part E: Logistics and Transportation Review, 145,* 102134. doi: 10.1016/j.tre.2020.102134

Moore, A. M. (2019). Innovative scenarios for modeling intra-city freight delivery. *Transportation Research Interdisciplinary Perspectives, 3,* 100024. doi: 10.1016/j.trip.2019.100024

Neghabadi, P. D., Samuel, K. E., & Espinouse, M.-L. (2019). Systematic literature review on city logistics: Overview, classification and analysis. *International Journal of Production Research, 57*(3), 865-887. doi: 10.1080/00207543.2018.1489153

Papalia, D. E. (2007). *Human Development.* New York: McGraw-Hill.

Pollman, E. (2022). The making and meaning of ESG. *University of Pennsylvania, Institute for Law & Economics Research Paper No. 22-23,* European Corporate Governance Institute - Law Working Paper No. 659/2022. Retrieved from https://ssrn.com/abstract=4219857

Przybylska, E., Kramarz, M., & Dohn, K. (2023). Analysis of stakeholder roles in balancing freight transport in the city logistics ecosystem. *Research in Transportation Business & Management, 49,* 101009. doi: 10.1016/j.rtbm.2023.101009

Rasca, S., Markvica, K., & Ivanschitz, B. P. (2021). Impacts of COVID-19 and pandemic control measures on public transport ridership in European urban areas – The cases of Vienna, Innsbruck, Oslo, and Agder. *Transportation Research Interdisciplinary Perspectives, 10,* 100376. doi: 10.1016/j.trip.2021.100376

Shrestha, S., & Haarstad, H. (2023). Do EU goals matter? Assessing the localization of sustainable urban logistics governance goals in Norwegian cities. *Cities, 137,* 104317. doi: 10.1016/j.cities.2023.104317

Spence, M., Clarke Annez, P., & Buckley, R. M. (2009). *Urbanization and Growth.* Washington: The World Bank.

Spicer, Z., Goodman, N., & Wolfe, D. A. (2023). How 'smart' are smart cities? Resident attitudes towards smart city design. *Cities, 141,* 104442. doi: 10.1016/j.cities.2023.104442

Statistics Poland. (2021). *Społeczeństwo informacyjne w Polsce w 2020 r. [Information society in Poland in 2020].* Warszawa-Szczecin.

Statistics Poland. (2023). *Ludność. Stan i struktura oraz ruch naturalny w przekroju terytorialnym w 2022. Stan w dniu 31 grudnia [Population. State and structure and natural movement in territorial section in 2022. state on 31 December].* Retrieved from https://stat.gov.pl/obszary-tematyczne/ludnosc/ludnosc/ludnosc-stan-i-struktura-ludnosci-oraz-ruch-naturalny-w-przekroju-terytorialnym-stan-w-dniu-31-grudnia,6,34.html

Šulyová, D., & Kubina, M. (2022). Quality of life in the concept of strategic management for Smart Cities. *Forum Scientiae Oeconomia*, *10*(3), 9-24. doi: 10.23762/FSO_VOL10_NO3_1

Sułkowski, Ł., Kolasińska-Morawska, K., Brzozowska, M., Morawski, P., & Schroeder, T. (2022). Last mile logistics innovations in the courier-express-parcel sector due to the COVID-19 pandemic. *Sustainability, 14*(13), 8207. doi: 10.3390/su14138207

Szpilko, D., Budna, K., Drmeyan, H., & Remiszewska, A. (2023a). Sustainable and smart mobility – research directions. A systematic literature review. *Economics and Environment*, *86*(3), 31-61. doi: 10.34659/eis.2023.86.3.584

Szpilko, D., Jiménez-Naharro, F., Lăzăroiu, G., Nica, E., & Torre Gallegos, A. d. l. (2023b). Artificial intelligence in the smart city — a literature review. *Engineering Management in Production and Services*, *15*(4), 53-75. doi: 10.2478/emj-2023-0028

Szum, K. (2021). IoT-based smart cities: A bibliometric analysis and literature review. *Engineering Management in Production and Services, 13*(2), 115-136. doi: 10.2478/emj-2021-0017

Taniguchi, E., Thompson, R. G., & Yamada, T. (2016). New opportunities and challenges for city logistics. *Transportation Research Procedia, 12,* 5-13. doi: 10.1016/j.trpro.2016.02.004

Thompson, S., Rahmat, H., Marshall, N., Steinmetz-Weiss, C., Bishop, K., Corkery, L., Park, M., & Tietz, C. (2023). Merging smart and healthy cities to support community wellbeing and social connection. *Encyclopedia, 3,* 1067-1084. doi: 10.3390/encyclopedia3030078

Tomaszewska, E. J. (2021). Barriers related to the implementation of Intelligent Transport Systems in cities – The Polish local government's perspective. *Engineering Management in Production and Services, 13*(4), 131-147. doi: 10.2478/emj-2021-0036

van Lierop, D., & Bahamonde-Birke, F. J. (2023). Commuting to the future: Assessing the relationship between individuals' usage of information and communications technology, personal attitudes, characteristics, and mode choice. *Networks and Spatial Economics, 23,* 353–371. doi: 10.1007/s11067-021-09534-9

Wallimann, H., Blättler, K., & von Arx, W. (2023). Do price reductions attract customers in urban public transport? A synthetic control approach. *Transportation Research Part A: Policy and Practice, 173,* 103700. doi: 10.1016/j.tra.2023.103700

Wawer, M., Grzesiuk, K., & Jegorow, D. (2022). Smart mobility in a smart city in the context of Generation

Z sustainability, use of ICT, and participation. *Energies, 15*(13), 4651. doi: 10.3390/en15134651

Winkowska, J., Szpilko, D., & Pejić, S. (2019). Smart city concept in the light of the literature review. *Engineering Management in Production and Services, 11*(2), 70-86. doi: 10.2478/emj-2019-0012

Yang, Z., Xie, Z., Hou, Z., Ji, C., Deng, Z., Li, R., Wu, X., Zhao, L., & Ni, S. (2023). A method of user travel mode recognition based on convolutional neural network and cell phone signaling data. *Electronics, 12*(17), 3698. doi: 10.3390/electronics12173698