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SUSTAINABLE TRANSPORT WITHIN THE CONTEXT OF SMART CITIES IN THE SLOVAK REPUBLIC*

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Abstract. The presented article focuses on the area of sustainable transport within the Smart City concept. Mobility, created in connection with the Smart City concept, is a service integrating several other types of transport services into one complex platform. The article examined the current situation in this area and its future development in the Slovak Republic. The main motivation of the authors for focusing on the Smart City concept was the topicality of this issue and its usability for process optimization, cost savings, and the achievement of sustainability. Methods such as orientation analysis, content analysis of documents, or sociological questioning using the questionnaire survey technique were used in the analysis. Several research questions and a research hypothesis were defined. It focused on the operation of local governments in the implementation of the Smart City concept and their orientation on the aspect of transport. The main findings include the fact that 22 Slovak cities out of the total number of 39 analysed cities are interested in the application of modern technologies. Another finding concerns the availability of a strategy focused directly on the Smart City concept on the city's website. It can be argued that only five websites had such a strategy available. The output of the research presented in this article was the creation of recommendations aimed at the implementation of the Smart City concept regarding the support of sustainable transport in the Slovak Republic. Using these recommendations, local governments will be able to formulate their digital strategies more effectively, leading to the practical implementation of the Smart City concept.

Keywords: Smart City; sustainable transport; sustainable mobility; digital strategy

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1. Introduction

The rapid development of information and communication technologies (ICT) has a positive effect on the processes of everyday life of people. ICT support processes that improve the standards of how cities operate. The main problem areas of a city, which can be solved via ICT, include: *improving the environment, improving the quality of public and individual transport, supporting and developing tourist activities, improving the quality and sustainability of electronic services for residents*, and others.

The term Smart City originated during the 1990s in the USA. In Europe, the Smart City concept has become important since 2008 in connection with the economic crisis. The main reasons for the development of this concept in Europe include the following: *the need to optimize processes, save costs, support processes and their sustainability, share information with citizens using electronic forms of communication*, etc.

The Smart City topic is currently also described by the ISO (International Organization for Standardization) standard no. 37120/2014 entitled Sustainable Development of Communities. The standard defines key indicators for evaluating the performance of cities with a focus on the services provided by the city and the quality of life of its residents. These indicators include: *economy, education, energy, environment, finance, rescue services, local government, health, recreation, security, waste management, telecommunications and innovation, transport, local planning, and water management* (ISO 37122, 2019).

The key indicators in the standard create a reference model to enable the city's stakeholders (management, politicians, researchers, businesses, experts, etc.) to influence and ensure the sustainable development of the city regarding the people's quality of life, environmental issues, and economic situation (Eremia et al., 2017; ISO 37122, 2019; Dameri et al., 2019; Fakunle, & Ajani, 2021; Fidlerová et al., 2022; Chehabeddine, Grabowska, & Adekola, 2022).

The transition of the city and the very mindset of its officials and residents is a complex process. It must be sufficiently organized to ensure acceptance by all the stakeholders. It starts with the initial phase. At this phase, the idea comes from the city officials. Such an idea and the effort to change the city comes mostly after the elections when the citizens elect their representative directly. The elected representative (mayor), in cooperation with the city council, can start building an intelligent city – a smart city. Since mayors are elected for four years, it is necessary that the whole society is set to understand the benefits of building a smart city. This is mainly because the strategy and vision are not planned for a four-year horizon, but for longer (ten years and more). In the initial phase, it is necessary to resolve the staffing that will be responsible for performing analyses and preparing the vision and strategy to be implemented (Mičiak, 2019; Siokas et al., 2021).

The increase in traffic at present also represents an increase in the number of means of transport on the roads. However, the infrastructure built is no longer sufficient for this trend. Therefore, traffic jams are being created, slowing down the transport of people and goods. In 2015, there were 1.1 billion cars and almost 400 million trucks in the world. In 2040, it is estimated that 2 billion cars and 800 million trucks will drive on the roads around the world. Transport is an organized activity the purpose of which is to move tangible objects or persons from the initial point to their destination using means of transport, considering the spatial and temporal aspects. In general, it can be argued that it is a service meeting the transport needs both in terms of freight and passenger transport. (Enviroportál.sk, 2021b; Zraková et al., 2019)

In mobility, Smart City brings a completely new business model. Mobility as a service integrates several other types of transport services into one complex platform. The operator mediates the offer of transport options to satisfy the transport requirements. These are primarily public transport, services of shared bicycles, scooters, the

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availability of taxis, motor vehicle sharing, etc. A major added value is the availability of the city mobility application for customers. Via one platform, the customer can satisfy the need for transport in several ways by paying in one application. The advantage for the customer is the simplification of city travel planning and the payment itself. On the other hand, for a mobility operator, it brings the availability of information useful for improving the service. The basic goal is to provide passengers arriving in the cities with a suitable alternative to the individual transport. An important part of this functionality is a sufficient infrastructure – 3G/4G/5G networks and their security, daily updated information on the availability of individual services, timely information on updating timetables, and the availability of payment systems. To meet the demanding requirements for the infrastructure, the cooperation of individual representatives of the service is necessary (including city management, telephone operators, payment service providers, public transport providers, and shared services). The city's data service providers are also important here. They are responsible for the website and the mobile application of the service. This component is generating a large amount of data, which is used for further analysis and management. Carriers and shared service providers are major players in the service. Third parties such as Uber get still more and more attention (Slavík, 2017; Zrakova et al., 2019; Siokas et al., 2021).

The main concepts examined in this article were captured in the following scheme (Figure 1). These elements relate to sustainable transport in the Smart City concept *promote sustainable mobility* via joint interconnection. The main building block is the city's strategy the content of which is influenced by the degree of digitization. This strategy determines the extent to which the city focuses on the implementation of the Smart City concept. The specific element examined within this concept was transport, which also influences the overall focus of the city's strategy.

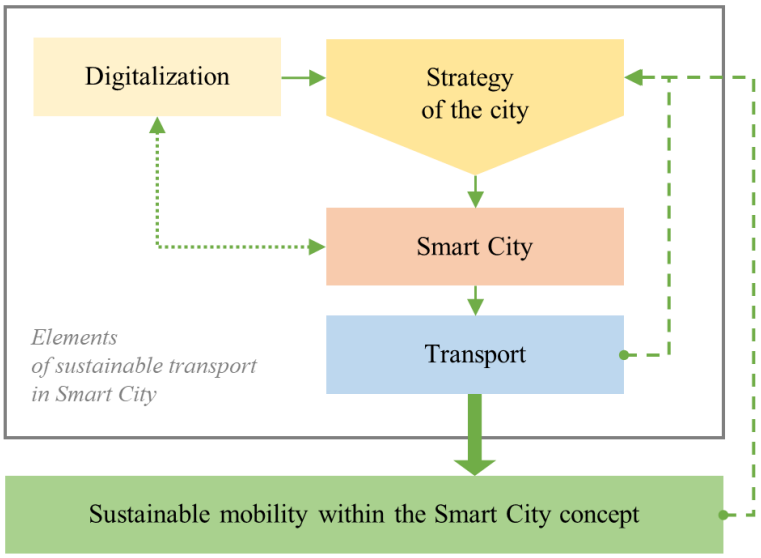

Figure 1. The main elements studied and their interconnections

Source: own elaboration

An appropriate setting *of sustainable mobility within the Smart City concept* has a retroactive effect on the updating of the city's strategy. It can be assumed that the strategy can be more ambitious every year and the city can thus become "Smart" in all areas of the presented Smart City concept.

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2. Theoretical background

The analysis of the theoretical basis focused on two main areas, specifically on the Smart City concept and the digital strategies of local governments. The latter specifically focused on transport as part of sustainable mobility in a smart city.

2.1. Smart City

Currently, the term Smart City is described by several definitions the authors of which try to identify its essence from different perspectives (Table 1).

Table 1. Smart City features

Author	Smart City feature
Ministry of Economy of the Slovak Republic, 2017	- a modern approach to the processes associated with the management and planning of entire regions - the use of technological innovations including ICT to ensure information processes at the city level and their sustainability - improving the quality of life and the access to services (safety, cleanliness, energy efficiency, ecology, flexibility to the needs of society, etc.) - ensuring sustainability in the business environment in the city and the whole region
Khudyakova et al., 2020	- a new approach to the city administration - the use of digital technologies in the management processes of urban areas - a rational approach to the efficient use of resources to improve the quality of life and the environmental situation in the region
European Commission, 2020	- a city with modern ICT infrastructure - more efficient services via process digitization - a positive impact on the quality of life of the population and the entrepreneurial activity of businesses
Slavík, 2017	- use of modern technologies for the needs of strategic management of the city - achieving economic, social, and quality goals in the city with the support of modern ICT
Kalašová et al., 2018	- accelerating progress with ICT support in transport, energy, and other sectors - improving the use of energy resources, interconnection of transport systems, improving mobility
Pauhofová et al., 2019	- raising the standard of living of the population with the use of digital ICT

Source: own elaboration

Based on the definitions listed above, the concept of Smart City can be summarized as a *concept of city management solution, which uses numerous modern pieces of ICT to improve the lives of the city residents*.

The development of the Smart City concept was positively influenced by Industry 4.0 in combination with the Internet of Things (IoT). These modern approaches focused on the use of modern ICT for efficient data transmission and communication can be identified as key elements for the development of the Smart City. These are mainly sensor networks aimed at supporting various areas such as production, mobility, healthcare, building solutions, energy, waste management, intelligent city management, etc. (ISO 37122, 2019). The definition of smart cities includes both their *characteristics* and *the tools* that can be used to implement the concept in practice. Their categorization is graphically captured in Figure 2.

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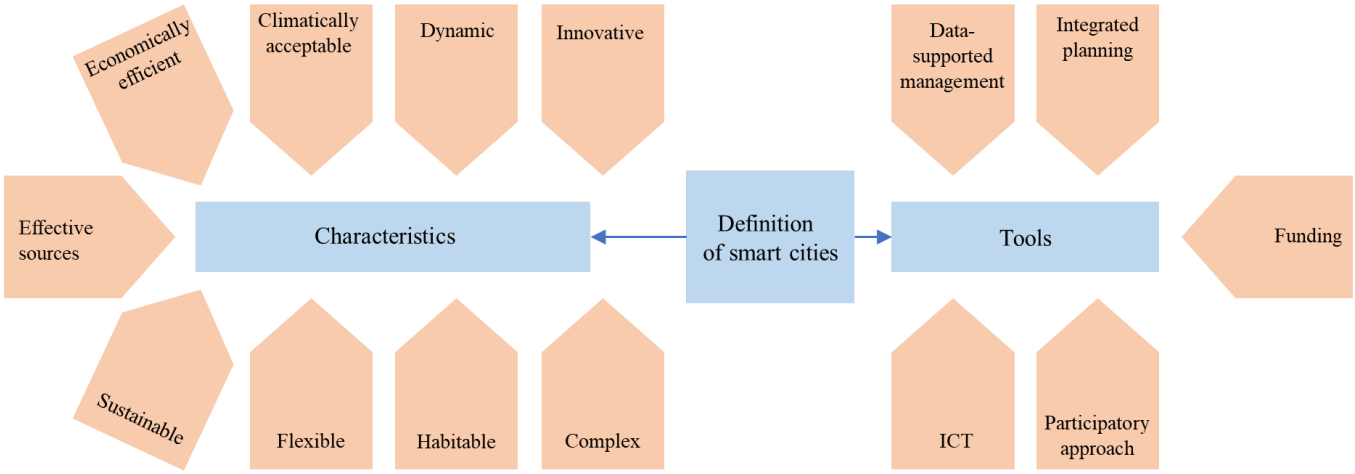

Figure 2. Characterization of the Smart City concept

Source: ISO 37122, 2019

The rapid development of ICT also influenced the development of the Smart City concept. The individual phases of Smart City development are listed in the following table.

Table 2. Phases of the Smart City development

Phase	Characteristics
Smart City 1.0	- providers offering IT services to municipalities - lack of understanding of the benefits for the self-governing regions - misunderstanding of the benefits of ICT by the city management - the absence of a clear strategy to support the lives of citizens within the Smart City concept
Smart City 2.0	- proactive and progressive leadership, which defines the importance of ICT and innovation in the city - focus on ICT to support the city residents' quality of life - implementation of projects focusing on public Wi-Fi networks, intelligent lighting, electromobility, etc.
Smart City 3.0	- currently the latest concept - primary orientation on the city's residents and their needs - direct involvement of the city residents in the projects - self-government body as a mediator between the people's needs and ICT implementation projects - a significant focus on the sustainability of the management for the Smart City concept, the citizens' quality of life, the protection of the environment, etc.

Source: Mayor of London, 2016

The city management based on the Smart City approach is very closely connected with the onset of the fourth industrial revolution, which is referred to as Industry 4.0. The main characteristic of Industry 4.0 is the implementation of ICT directly into the production and provision of related services.

Internet of Things (IoT) is a basic technology without which the concept of a smart city would not be possible. The essence of this technology consists of the IoT devices, sensors, and applications. These devices can be interconnected, and thus can communicate with each other (Kubina, Lendel, 2015; Gill et al., 2019).

The basic capabilities of these devices include monitoring, control, optimization, autonomy, and an effective decision-making process. Within the Smart City concept, this technology represents, e.g., intelligent lighting

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based on sensors, automatic switching of signals at the intersections for the public transport vehicles, information on the fullness of containers, etc. IoT devices can generate large volumes of data, which then serve as a basis for managerial decisions. The main advantage of introducing such devices is the fact that the data are available in real-time. One of the disadvantages is the need for their correct evaluation and analysis (Gill et al., 2019).

In the paragraphs below, basic elements of the Smart City concept are briefly described. These include: *Big Data artificial intelligence; cloud services; the city and its management; government and local governments; smart buildings; mobility; energy and the environment; education; health.*

Big Data – generation of large volumes of data is the result of the Internet of Things technology, which is essential for building the Smart City concept. Especially regarding the sensors deployed. Nowadays, the processing and interpretation of data is a necessary step in the expansion of urban structures. Data can be obtained from different urban areas, which ultimately leads to a holistic understanding of urban structures. It is the generation of large volumes of data that brings additional opportunities for managers in terms of monitoring the development of cities and their adaptation to real conditions. However, large volumes of data are also characterized by their complexity (Gill et al., 2019).

Artificial Intelligence (AI) – is closely linked to the generation of large amounts of data as well. AI can be applied to the analysis of data collected by sensors located on various physical devices within the city. AI can be characterized as machine learning seeking to mimic thought patterns. With the help of AI, human behaviour can be simulated. The accuracy of the results is increased by increasing the input data and subsequent processing by machine learning. Due to this, the data needs to be sufficient and available in real-time. Within individual cities and their management, AI and the results of analyses performed by it create a solid basis for their management and further strategic planning (Malichová, Mičiak, 2018; Gill et al., 2019).

Cloud services – are services using cloud computing technology. This is a type of service where servers, storage, and applications are available remotely via networks. The main advantage of such services is that they do not burden the software or hardware of the user devices with which they enter the cloud services. Thus, it can be argued that cloud computing reduces the overall costs that would be required to procure additional software and hardware. On the other hand, the availability of services is increasing. Reliability, security, and energy efficiency can be identified among the basic parameters of a high-quality cloud service (Gill et al., 2019).

The city and its management – a self-government body have responsibility for several different areas and institutions that are directly on their territory in the daily agenda. Institutions provide services to other stakeholders. All these areas can be included in the Smart City concept (Bělohlávek, et al., 2001; Ansoff, 2007; Hitka, Balážová, 2014; Cities in Motion Blog Network, 2020).

Government and local governments – currently the most often used English term for the digitization of public administration is the eGovernment. The digitization of public administration is linked to the Smart City concept. The electronic message itself was introduced to improve the quality of services provided with a focus on the use of information and communication means. The Smart City concept is based on collecting, processing, integrating, and using data to a greater extent than ever before. All of this directly leads to better decision-making and higher-quality services. Finally, it supports the creation of more comprehensive partnerships among individual stakeholders (Ferenc et al., 2017; Mechant, Walravens, 2018).

Smart buildings – this type of building, or rather the term smart buildings, has begun to be used to describe the various technologies that are integrated into buildings. There is currently no clear definition of what makes a building smart. It is possible to talk about buildings that are automated and have systems based on sensors. Such a building adapts to the needs of users in real-time. Smart buildings can collect data on how and when a building is

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used, providing a real-time picture. The basic generated data can include the most exposed times of use of the building, the number of people in the building, etc. Subsequently, the data can be further analysed so that the forecasts are made (Hoy, 2016).

Mobility – urban mobility is currently playing an increasingly important role in the development of the city. It is necessary to consider the fact that in the last century, the cities were designed for much lower traffic intensity. Today there is a situation where the construction of additional transport infrastructure is limited, and it is necessary to approach other alternatives that can improve the problem of city transport. The implementation of an efficient public transport system can solve some of the problems caused by high traffic intensity. However, smart mobility itself offers other solutions that are based on sustainable ways of providing mobility to the citizens. It is primarily the development of fuels for public transport with high respect for the environment (e.g., electricity, liquefied, compressed natural gas, etc.). Ultimately, smart mobility should be supported by smart technologies which also require progressive behaviour of the citizens (Klamár, 2010; Baucells, 2016).

Energy and the environment – waste production is becoming a rapidly growing problem in urban agglomerations. It is not only the fact that it is necessary to ensure the export of waste to dumps but also the dumps themselves represent an environmental issue. This is where the possibility of intelligent waste management emerges as an advantageous solution. Elements of the IoT, including sensors, will support solutions for waste handling, collection, and recovery. The application of the Smart City concept can also include energy management, which currently faces several challenges, such as efforts to reduce the negative impact on the environment and the use of fossil fuels. The energy efficiency of traditional systems is no longer sufficient for today's cities and their citizens (Esmaeilian et al., 2018; Golpîra, Bahramara, 2020).

Education – is a key component of smart cities' development. The areas of primary, secondary, higher education, lifelong learning, infrastructure, and e-learning should become a part of applying the Smart City concept. The aim of such education is primarily to educate graduates with modern knowledge, practical skills, and attitudes that are based on cooperation. Smart education itself can be defined as a learning model adapted to new generations of citizens and students. It is not just distance learning where digital technologies can play an important role. It is also about focusing on digital literacy, effective communication, teamwork, and the ability to create and participate in high-quality projects (Glasco, 2019).

Health – this component of a smart city is mainly focused on public health. Public health can be defined as the science of support, disease prevention, and prolongation of life via organized efforts in society. Telemedicine, care for disadvantaged groups with the help of innovative technologies, and integrated health systems interconnected at all levels can be included among the components of the smart city (Salvo et al., 2017).

The creation and development of a Smart City application are directly influenced by stakeholders since the very first phase of applying this concept (Pouš, 2013). The individual stakeholders that influence the creation of a smart city in practice are listed in Table 3.

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Table 3. Stakeholders within the Smart City concept

Stakeholder	Characteristics	Importance within the creation of a Smart City application
City	- city mayor - members of the city council - employees of the municipal office	- correct understanding of the concept in terms of the possibilities and needs of the city and its citizens
Citizens	- residents of the city	- initialization and acceleration of changes in the city
Businesses	- supporters of the smart city conducting business in the area - a specific role for IT and energy companies	- support for the development of the Smart City concept with its solutions, investments, and know-how
State	- individual ministries	- creating appropriate economic and legislative standards - allocating funds including the European funds to support the Smart City concept application
Universities	- education sector - research institutions	- research focused on ICT - knowledge sharing - developing strategic partnerships between cities and stakeholders
Non-governmental organizations	- various associations of towns and municipalities - clusters and other entities	- sharing good practice - establishing partnerships to increase the chances of obtaining funding for the application of the Smart City concept

Source: Pouš, 2013

It is necessary to emphasize that a city cannot become smart without the involvement of several stakeholders. Cooperation of entities should start with the creation of a strategy, which subsequently leads to the creation of individual-specific measures.

2.2. Local governments' digital strategies

The approach to the strategy itself in the implementation of the Smart City concept can be different. It depends on various factors such as the setting of political representatives, the characteristics of the city's population, or the centralization of projects. Table 4 shows a basic overview of the factors influencing the creation of the entire Smart City strategy (Holubcik, Soviar, 2021; Siokas et al., 2022).

Table 4. An overview of the factors influencing the strategy creation

Area	Citizen aspect	Description
Participation	emphasis on technology	efforts to use online tools to involve citizens in the process of creating a smart city, the application of analytical tools
	emphasis on participation	focus on participation and measurability of the impacts of citizens' participation in the decision-making
Involvement in the strategy	top-down	the draft is based on the collective knowledge of all stakeholders
	bottom-up	the city is in the role of coordinator; citizens participate in the public life
Degree of centralization	centralized	implementation of a pilot project to establish communication with stakeholders
	decentralized	coordination position via working groups
Creation of plans	high priority	the plans are accepted by the city officials while assessing the influence of citizens on decisions being made in the city
	low priority	plans are accepted by the city officials
Maturity of citizens	high maturity	the citizens participate online in project creation
	low maturity	online activities must be complemented by off-line activities; the need to encourage citizens to use online technology

Source: Siokas et al., 2021

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The next step after the initial phase is planning. As part of the planning, the current strategy of the city is evaluated, and a new strategic framework is created. This is focused on building the Smart City application. It is essential to select the areas that will be addressed in the concept. These areas can include everything covered by the city (transport, environment, public administration, health, etc.). It also needs to be emphasized that the city should implement activities in areas that it can finance, from public or private funds (Varmus et al., 2015). City officials should select areas that are perceived by several stakeholders as problematic (e.g., traffic jams, increased noise, etc.). During the planning phase, work teams responsible for individual areas are beginning to form. Teams can consist of newly hired employees who will be responsible for the implementation of the Smart City concept, as well as other experts, e.g., from businesses, citizens, Smart City experts, and others. The teams can also be built via the project organizational structure where the city employee is a member of several teams. Furthermore, the creation of the projects themselves in predefined areas is implemented and the methodology of monitoring and evaluating the solutions is set. This is followed by the stage of projects' implementation. In addition to creating the project, it is important to address the issue of funding the proposed solutions. Project funding can come from city resources, foreign funds, EU funds, and public-private partnerships. The last phase is the monitoring of projects. This takes place continuously after their implementation, including the evaluation of the results that the projects brought. It is mainly an impact assessment focused on measurable indicators such as reduction of air emissions, reduction of noise, reduction of traffic intensity, increase in public transport utilization, etc. During all the phases, communication between individual stakeholders and the presentation of solutions to the citizens in a suitable form is of vital importance (Holubcik et al., 2018; Mora et al., 2019; Simonofski et al., 2021).

Mora and Bolici (2017) defined strategic principles for building a smart city. In this research, four European cities were analysed – Amsterdam, Barcelona, Helsinki, and Vienna. The research was carried out qualitatively using content analysis of unstructured data with Atlas.ti software support. As a result, the authors defined new strategic principles for building a Smart City application:

- monitoring current technologies,
- creating a functional model involving all institutions,
- combining approaches (top-down, bottom-up),
- integrating new ICT services into cities,
- public-private cooperation.

The strategy can be implemented with several (or only one) selected areas of the city. Ideally, the implemented technologies can cover several areas at once with the right strategy. For example, transport, safety, administration, etc.

2.3. Transport as part of sustainable mobility within the Smart City concept

Standard STN 018500 defines transport as *"the intentional movement of means of transport on transport routes or the operation of transport equipment by which transport is being performed"*. At present, the concept of mobility is at the forefront. This is a broader concept than transport, including the movement of goods and services via transport. Mobility as such is an approach to getting people to selected places safely, at the right time, and at a reasonable price level (schools, work, hospitals, etc.), (Figure 3). It does not consider which means of transport are used (Sedlák, 1997; Smith, 2016; Mora, Bolici, 2017; Ližbetinová et al., 2017; Varmus et al., 2022).

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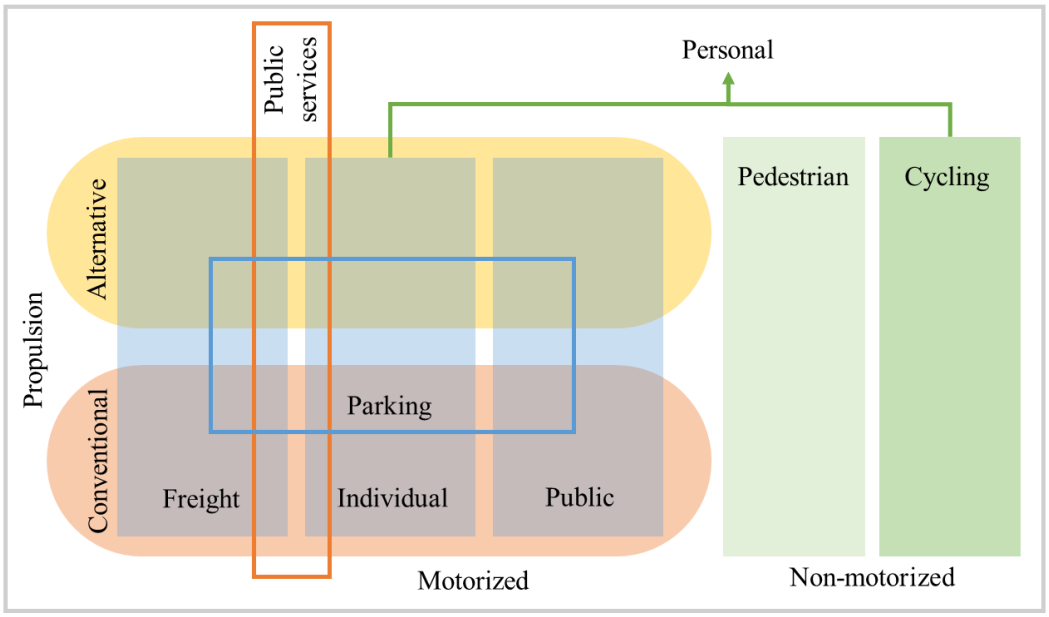

Figure 3. The structure of the city mobility

Source: own elaboration

Within smart cities, mobility is one of the basic components. Mobility in a smart city can be described as smart mobility. Šurdonja described this type of mobility as *"a set of coordinated measures aimed at improving the efficiency and environmental sustainability of cities. Smart mobility could consist of a hypothetically infinite number of initiatives that are characterized by information and communication means"* (Tej, 2021). The basis is to facilitate the mobility of individuals and goods within the city, which can bring the following benefits:

- reduction of the intensity of individual urban traffic,
- reduction of travel times,
- reduction of travel costs,
- reduction of environmental impacts (air pollution, noise).

The basic characteristic distinguishing smart mobility is connectivity. It is connectivity combined with a large amount of data that allows all users to obtain and transmit data in real-time. For mobility passengers, information on traffic conditions, available parking spaces, accidents, and delays in public transport are being provided. With mobile applications, such pieces of information can reach users instantly. Based on them, users can plan their routes to avoid problem areas and get to their destinations on time. For road managers and coordinating staff in cities, such pieces of information represent the possibility of dynamic, real-time traffic management. Numerous different solutions are implemented worldwide. The most often used include navigation, e-parking, e-travel and parking tickets, e-motorway signs, information panels, autonomous vehicles, shared mobility services (bicycles, scooters, cars, etc.), online vehicle tracking, and demand-responsive vehicles (Benevolo, 2016; Soviar et al., 2018).

From the perspective of the implementation of mobility solutions, individual types of services can be divided into two basic types: public transport services within the city, where it is possible to include the use of alternative fuels, autonomous transport, uniform prices for several types of transport, integrated equipment systems for the customers; services in the field of individual transport such as car sharing, using the system of shared rides,

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navigation systems, shared non-motorized transport (bicycles, scooters, etc.). Furthermore, the infrastructure for public or individual transport services must be sufficiently built. The infrastructure can include car parks, dedicated bike paths, charging stations for electric vehicles, information boards on traffic in important places, intelligent traffic lights, zones without vehicles, zones with restricted vehicle entry, reserved lanes for buses, speed control by radars, and the navigation to free parking spaces. From the city's perspective, it is necessary to support the building of infrastructure as such directly via other managerial activities and policies influencing the citizens' behaviour within the mobility framework. These are the following activities (Benevolo, 2016):

- distribution and identification of various types of mobility entering the city,
- introduction of a single information system regarding both public and individual transport,
- setting up emissions controls in cities,
- pricing of individual services within the city mobility,
- defining the "green zones" where motor vehicles are prohibited from entering,
- setting timetables in line with stakeholders,
- division of the city into zones – residential, industrial, satellite, etc.

All the solutions listed above need to be supported by ICT elements. The basic ICT components of a smart city include (Benevolo, 2016):

- programmable, variable traffic signs showing up-to-date information for road users,
- 24/7 urban mobility monitoring,
- a single system of integrated urban mobility,
- a system for driving public transport vehicles in cities, including information on the current location of vehicles in the city,
- real-time traffic management systems (creation of rescue lanes, variable speed limit depending on the current traffic situation).

The ICT components can be described as components of intelligent transport systems (ITS), (Table 5). These systems can be defined as: "*advanced applications for the collection, storage, and processing of data, information, and knowledge for the planning, implementation, evaluation of integrated initiatives, and smart mobility policies"* (Benevolo, 2016).

Table 5. Possibilities of applying ICT in transport

Activity	Technical equipment for communication	Devices in vehicles
data collection	traffic detectors	vehicle identification
	weather monitoring	dynamic weighing
data processing	data in controllers	position system
	emergency detection	GPS
data transmission	fixed communication	mobile communication
	optical transmission of information	single-purpose communication
redistribution of information	variable message signs	radio channel, navigation
	Internet	traffic information service
utilization of information	tariffing	vehicle guidance
	traffic management	accident prevention

Source: Benevolo, 2016

Some components are part of the fixed infrastructure (e.g., IoT sensors, traffic signs) and another part of the equipment is located directly in the vehicles. Working with information at the level of transport infrastructure and in-vehicle equipment can be useful as it can suggest a route for drivers to avoid congestion, or it can warn them about imminent dangers on the road.

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3. Research objective and methodology

The main research objective was *to propose recommendations for the implementation of the Smart City concept focused on sustainable transport in Slovakia* based on an orientation analysis and analysis of the state of sustainable transport (as one of the main areas of the Smart City concept) in Slovak cities.

The research was divided into several parts to obtain relevant pieces of information leading to the fulfilment of the defined objective. Three main components are presented in the article, namely: *(1) orientation analysis, (2) content analysis of documents related to the Smart City concept, and (3) application of a questionnaire survey focused on the city officials' perception of the Smart City concept.* The content analysis of the documents was focused on feasibility studies and an analysis of the municipalities' social and economic development programs.

The questionnaire survey focused on 39 largest Slovak cities. The invitation to fill in the questionnaires was distributed via e-mail to the offices of mayors or deputy mayors. The questionnaire survey aimed to obtain city officials' opinions on the Smart City concept, the problems of cities, and their other possible solutions within this concept from a long-term, sustainable perspective.

The respondents were competent persons with sufficient awareness of the management processes in the cities regarding their development and possible future involvement in the concept described. Cities were divided into three categories:

- 20,000 – 30,000 citizens – marked as small cities,
- 30,001 – 50,000 citizens – marked as medium cities,
- more than 50,001 citizens – marked as large cities.

Within the research, 37 questionnaires were collected, thus it can be stated that the condition of a 95% significance level was met. The collection of at least 36 responses was required to confirm the representativeness of the research sample. Therefore, the sample can be considered representative.

To specify the research focus, the following **research questions** were defined:

- Q_1: Are Slovak cities interested in implementing the Smart City concept?
- Q_2: What areas do cities focus on while implementing the Smart City concept?
- Q_3: Are cities in Slovakia willing to participate in calls financed by the EU funds?
- Q_4: Is the Smart City concept included in the strategic documents of Slovak cities?
- Q_5: Do the cities' strategies focus on sustainable aspects of the Smart City concept?

Based on the questions listed above, **a research hypothesis** was formulated. It was designed to be tested using the data obtained via the selected methods described in this chapter. The hypothesis was stated as follows:

- H_1: If local governments implement the Smart City concept, it is primarily within the area of sustainable transport.

4. Results and discussion

The results were obtained from the application of various analyses, methods, and techniques. The first area that this article focuses on is an orientation analysis in the Slovak environment, followed by a content analysis of selected documents and the conduction of a questionnaire survey.

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4.1. Orientation analysis

The purpose of the orientation analysis was to delve into the issues of the Smart City concept within the conditions of the Slovak Republic and its future development. The following paragraphs present selected findings from this analysis, which were also used in other parts of the article.

The development of the Smart City market is happening continuously. Recently, a significant increase in its total value can be observed. Various digital solutions are being offered on the market, in demand mainly by local governments. Sales on some continents are expected to double by 2025 (Angelidou, 2016). The reason for the growing revenues of companies is mainly the state of constant global urbanization. According to the United Nations, up to 67% of the population is expected to live in cities and conurbations by 2030. That is why the world's big cities are expected to become the most attractive markets for Smart City solution providers. Due to this, it is expected that the demand for the implementation of intelligent solutions will increase in the Slovak Republic as well.

To implement the Smart City concept, it is necessary to monitor the use of the Internet in Slovakia, which determines the ability of residents to use various pieces of information technology. Looking at the population and digital literacy, it is possible to assess the indicator of the Internet use in Slovakia for the population aged 16 to 74, regardless of gender. This piece of information is summarized by the Statistical Office of the Slovak Republic in the survey. Based on this, it can be argued that more than 80% of the population within this age group have used the Internet in the last three months (Statistical Office of the Slovak Republic, 2020a, b, c). This creates a precondition for the adoption of the Smart City concept in Slovakia to the required extent.

An important part remaining is the availability of strategic documents of individual municipalities on their websites. Published strategic documents of individual municipalities and whole regions create a basic prerequisite for the participation of the population in the development of the entire city. The program of social and economic development of the municipality is a strategic document presenting the vision and strategic goals. Via the Open Strategies portal, it was found that most Slovak municipalities have this document published on their webs. Out of 2,954 municipalities inspected, up to 2,061 had strategic documents published on their websites, including the document *Program and social development of the municipality.* Most municipalities that did not have such document published had a population below 20,000 people. In the category of municipalities with more than 20,000 inhabitants, only 35 municipalities did not have strategic documents published (Open Strategies, 2022). The reason why small municipalities do not publish documents may be the fact that they do not have a website at all.

From the perspective of building intelligent cities in the conditions of the Slovak Republic, based on the survey of the Ministry of Economy of the Slovak Republic (2017), it can be stated that the representatives of Slovak cities are interested in this concept. The survey also showed that transport is perceived by city officials as an area that can be solved precisely via the application of the Smart City concept.

4.2. Content analysis of the documents connected with the Smart City concept

To perform the content analysis, freely available documents directly connected with the Smart City concept were selected. The first group of documents followed the response of cities to the call of the Ministry of Investments, Regional Development, and Informatization of the Slovak Republic. The second group focused on the strategic document of the social and economic development program.

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4.2.1. Analysis of the cities' feasibility studies

The Ministry of Investments, Regional Development and Informatization of the Slovak Republic has published the call no. OPII-2021/7/17 – DOP for the submission of Applications for a non-repayable financial contribution to *"Modern Technologies II"*. This call is aimed at all cities in the Slovak Republic except for the capital city – Bratislava. The non-refundable contribution is directly focused on IT technologies in cities *to improve security in the city, the quality of public transport, building management, the environment, and communication with the citizens*. The call is also focused on Higher Territorial Units. The total support from this fund is 35 million euros.

In connection with the published application form, the cities can participate in this call. The first step in the implementation was the **elaboration of a feasibility study.** The participating cities have published their feasibility studies in the *Central Public Administration Metainformation System*. Due to this, it was possible to identify which cities plan to invest in Smart City solutions as well as the amount of the non-refundable financial contribution required.

Table 6 summarizes the results of the content analysis of the individual cities' documents with a focus on the projects studied. The analysis examined 39 largest Slovak cities. Of these, 22 cities submitted their projects, which are listed in the table. The following areas have been identified in each of the submitted projects (World Population Review, 2020):

- **transport** – the creation of systems to obtain information on the traffic situation in the city for further traffic management, creation of mobile applications for payment and guidance to the parking spots,
- **environment** – the creation of systems focused on the sensory acquisition of data on the meteorological situation in the city and the current quality of the environment,
- **waste management** – the creation of systems based on sensor networks to provide information on the fulness of garbage cans,
- **data** – the creation of a platform for data visualization on the city panel, streamlining of local governments based on open data,
- **security** – acquisition of security data (monitoring via camera systems),
- **lighting** – generation of luminance information, possibility to report a non-functional public light.

Table 6. Results of content analysis of planned city projects

City	Name	Orientation*	Start	End	Total amount [€]	Annual costs [€]
Snina	Modern technologies for the city of Snina	TRN, ENV	01.03.2021	28.02.2022	463 000	33 000
Senica	Smart plan of the city of Senica	TRN, SEC	04.05.2020	31.12.2021	999 882	40 000
Brezno	Electronic services of the city of Brezno	DATA, TRN, ENV	25.08.2021	31.12.2021	996 213	8 320
Šaľa	Modern technologies – Šaľa on the smart road	TRN, ENV	01.01.2021	30.06.2022	999 282	168 996
Vranov nad Topľou	Modern technologies for the city of Vranov nad Topľou	TRN, ENV	01.03.2021	28.02.2022	441 000	32 000
Dunajská Streda	Smart plan of the city Dunajská Streda	TRN, SEC, LIGHT, ENV	30.04.2021	31.12.2021	987 54	47 419
Dubnica nad Váhom	Modern technologies for the city of Dubnica nad Váhom	TRN, ENV	01.03.2021	31.12.2021	592 000	41 000
Rimavská Sobota	Intelligent Rimavská Sobota	ENV, SEC, LIGHT	01.02.2021	31.05.2023	617 600	38 320
Topoľčany	Smart solutions for the city of Topoľčany	TRN, SEC, WST	10.06.2021	31.12.2021	999 938	199 987
Ružomberok	Smart technologies of the city	EVN, TRN,	01.03.2021	28.02.2023	885 000	44 250

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	of Ružomberok	LIGHT				
Bardejov	SMART Bardejov – a city within reach	TRN, ENV	01.07.2020	31.12.2020	650 000	50 000
Levice	Establishment of SMART technologies in the city of Levice	LIGHT	01.03.2021	28.02.2023	500 000	25 000
Spišská Nová Ves	Smart City Solution – SCS Spišská Nová Ves	SEC, DATA	04.08.2020	31.03.2023	750 000	20 000
Michalovce	Modern technologies – Smart City – City of Michalovce	ENV, WST	01.07.2020	30.04.2022	469 172	49 920
Považská Bystrica	Modern technologies SC Považská Bystrica	TRN, ENV	15.06.2020	30.11.2021	718 402,83	38 119
Zvolen	Data management of the city of Zvolen	DATA	01.01.2022	30.09.2023	200 000	20 000
Trenčín	Smart City plan of Trenčín	TRN, SEC	18.05.2021	31.05.2021	991 498	198 299
Trnava	Modern technologies for the city of Trnava	TRN, ENV	01.09.2020	31.12.2023	999 000	50 000
Banská Bystrica (BB)	Implementation of Smart City solutions in BB	TRN, ENV	01.01.2021	31.08.2022	999 992,72	51 280
Žilina	Modern technologies in the city of Žilina	ENV, LIGHT	01.03.2021	28.02.2023	1 000 000	50 000
Prešov	Introduction of modern technologies into traffic regulation	TRN	01.10.2020	31.05.022	999 781	51 5000
Košice	SC Košice	DATA, ENV, SEC, LIGHT	01.10.2020	30.09.2021	997 007	49 900

*TRN – Transport, SEC – Security, DATA – Open data system, ENV – Environment and meteorological monitoring, WST – Waste management, LIGHT – modern lightning and infrastructure

Source: European Committee of the Regions, 2021

Some of the analysed cities did not join the call and were therefore not included in Table 6. These cities include: Nové mesto nad Váhom, Hlohovec, Partizánske, Pezinok, Čadca, Trebišov, Piešťany, Lučenec, Liptovský Mikuláš, Humenné, Komárno, Nové Zámky, Prievidza, Poprad, Martin, Nitra, Bratislava (the city of Bratislava could not apply for a non-refundable financial contribution).

It should be emphasized that all participating cities have the status of the project marked as approved and ready for implementation. Some cities are already in the implementation phase. Finally, it can be stated that 22 cities submitted 381 projects showing that the cities are interested in the application of modern technologies.

4.2.2. Analysis of the program of social and economic development of the municipality

The analysis further focused on the program of social and economic development of the municipality. This document should be established by local governments according to Act 539/2008 Coll. *Act on the Support of Regional Development*. The document was analysed to identify the occurrence of the word *"smart"* or *"intelligent"*, given its closer meaning in the Smart City concept. These were, for example, the terms smart mobility, smart services, etc. The individual word counts with a specific focus are displayed in Table 7.

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Table 7. Identified occurrence of words related to the Smart City concept in the strategic document

City	Category	Horizon	Word count	Sustainable aspect
Brezno	Small	2022	4	management, transport
Hlohovec	Small	2023	3	infrastructure, public administration
Šaľa	Small	2022	1	infrastructure
Dunajská Streda	Small	2020	1	energy
Lučenec	Small	2025	4	vision, concept
Liptovský Mikuláš	Medium	2030	3	transport
Bardejov	Medium	2024	5	energy
Humenné	Medium	2025	5	energy
Nové Zámky	Medium	2025	3	strategy
Michalovce	Medium	2022	6	strategy, transport
Považská Bystrica	Medium	2022	2	strategy, energy
Zvolen	Medium	2027	1	public administration
Poprad	Large	2040	24	all aspects of the city
Martin	Large	2023	18	all aspects of the city
Trenčín	Large	2040	21	all aspects of the city
Trnava	Large	2030	12	all aspects of the city
Nitra	Large	2023	8	transport, lighting
Banská Bystrica	Large	2023	4	transport, city zones
Žilina	Large	2023	7	transport, energy
Prešov	Large	2025	3	transport
Košice	Large	2025	1	energy
Bratislava	Large	2020	1	transport

Source: elaborated using: Ostertagová, 2022

Some of the cities studied did not focus on the Smart City concept in the selected document; the occurrence of the analysed words was equal to 0, so they were not included in Table 7. These were cities: *Nové Mesto nad Váhom, Snina, Senica, Vranov nad Topľou, Partizánske, Pezinok, Dubnica nad Váhom, Rimavská Sobota, Trebišov, Topoľčany, Ružomberok, Piešťany, Levice, Komárno, Spišská Nová Ves, Prievidza.*

During the research of individual city websites, it was also monitored whether the cities offer access to the whole Smart City strategy itself. It was revealed that only five cities had the entire Smart City strategy available. All of them also showed an occurrence of the words analysed in the document Program of Economic and Social Development. Based on the examination of the occurrence of smart technologies in individual program strategies, the occurrence of the phrases studied was recorded in 23 surveyed cities. It is necessary to emphasize that the validity of the examined strategic documents for all cities started in 2015. Thus, it is possible that the cities did not have enough information to implement modern technologies at the time of preparing these strategic documents.

4.3. Results from the questionnaire survey

To obtain information about the actual opinions of city officials on the Smart City concept, a questionnaire survey was performed. This was sent directly to the mayors or their deputies.

4.3.1. Data description

The responses were mainly provided by the *heads of individual city departments* within the municipal self-governments. These were employees focusing on strategic urban development and the transport department. The deputy mayors were also well represented as the questionnaire was addressed directly to them. The questionnaire

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was also filled in by *transport officers* or *heads*. Based on this categorization, the persons who participated in the survey can be considered responsible for the questions asked. Figure 4 shows the individual distribution of respondents by their **profession**.

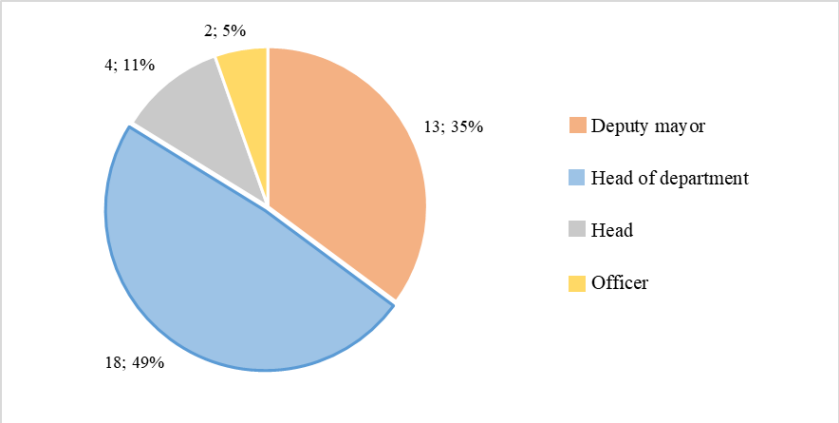

Figure 4. Distribution of respondents by profession

Source: own elaboration

From the perspective of the involvement of cities in the questionnaire survey, it can be confirmed that 37 cities from all size categories were involved – *small, medium, and large cities*. The representation of individual cities is divided proportionally; the overview is shown in Figure 5.

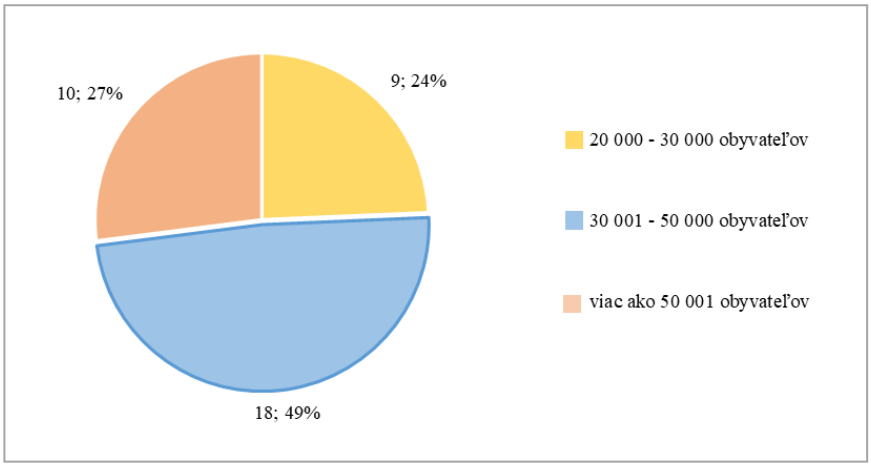

Figure 5. Distribution of the cities by their size

Source: own elaboration

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4.3.2. Evaluation of the questionnaire survey results in connection with H_1

How city officials perceive problems in the city they are managing is an important basis for motivation to use modern technologies to eliminate these problems. The results from the questionnaire survey were examined concerning the defined hypothesis *H_1: If local governments implement the Smart City concept, it is primarily within the area of sustainable transport.*

Attention can also be paid to the planned use of the funds within the projects regarding the implementation of Smart City solutions. A significant number of cities (15 of 22) plan to implement solutions in transport. Before performing the Chi-square test, the Shapiro-Wilk test was also performed to verify the normality of the data, i.e., to assess the suitability of the data for further statistical analysis (Table 8). The described relationship can then be examined by statistical evaluation using the Chi-square test (Table 9).

Table 8. Shapiro-Wilk test on the data for H_1

Area	W	p – value	Significance
Investments	0.631	<0.01	Yes
Environment	0.545	<0.01	Yes
Security	0.395	<0.01	Yes
Open data	0.233	<0.01	Yes
Intelligent lighting	0.350	<0.01	Yes
Waste management	0.233	<0.01	Yes
Transport	0.631	<0.01	Yes

Source: own elaboration

The results shown in Table 8 indicate the suitability of the selected data for further statistical analysis. To assess the relationship between the investments and the area that cities are focusing on when implementing the Smart City concept, the data were analysed using the Chi-square test. The results in Table 9 support the relationship between investing in smart technologies and specific three areas.

Table 9. Chi-square test on the data for H_1

Area	χ^2 values	p – value	Significance
Environment	10.392	0.001	Yes
Security	4.432	0.035	Yes
Open data	1.629	0.202	No
Intelligent lighting	3.444	0.063	No
Waste management	1.629	0.202	No
Transport	23.287	<0.01	Yes

Source: own elaboration

The statistical significance of the examined relationships in Table 9 points to the key importance of transport (χ^2 = 23.287; p-value <0.01) as the main area in which municipalities are trying to obtain funds or are directly investing in. Other justified areas (with statistically significant relationships) include *environmental and safety solutions*. Both categories can be linked to transport since transport is a major air pollutant, and safety is an important element in road transport.

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4.4. Evaluation of research questions and research hypothesis

Based on the analysed data and the presented results, the set research questions were answered. The orientation analysis, specifically the results presented in Table 6, led to the confirmation that *Slovak cities are interested in implementing the Smart City concept*. The same analysis also provides the answer to the second research question where it can be argued that cities focus mainly on the following areas: *transport, environment, waste management, data, security, and lighting* within the implementation of the Smart City concept.

Furthermore, it was confirmed that cities in Slovakia *are willing to participate in calls funded by the EU* (Table 6) and the Smart City concept is included in their strategic documents (Table 7). The last question concerned the sustainable aspects where it can be stated that the *cities' strategies focus on sustainable aspects of the Smart City concept* (Table 7).

Subsequently, the research hypothesis H_1 was tested: *If local governments implement the Smart City concept, it is primarily within the area of sustainable transport.* Based on the results displayed in Table 9, a statistically significant relationship between investment in smart technologies and the area of transport was confirmed ($\chi^2 = 23.287$; p-value = <0.01).

Conclusions

Based on the results of the performed analyses, recommendations for the implementation of the Smart City concept and sustainable transport in Slovakia were designed and described in this part of the article. They are divided into separate partial areas.

Unification of the city's strategic goals – the goals of individual self-government are defined in the document "Program of the municipality's economic and social development". This document contains goals from all areas of the city (environment, energy, education, healthcare, mobility, etc.). Given that mobility as an area of the city is a cross-cutting area, the individual goals from other areas should be logically connected. The primary strategic goal should be to manage the city via the implementation of the Smart City concept in all areas.

Involvement of the citizens in the strategy creation – the Smart City concept has a fundamental need to create a strategic combination of approaches (top-down, bottom-up). The citizens can identify common problems in the city. More proactive citizens can also come up with specific solutions that can be implemented after discussion with other stakeholders. The result of the citizens' involvement is focusing on the real problems of the city and positioning the citizens into the area of interest. Within the individual involvement of the population, four types of citizens can be defined according to the level of their participation and the time required for public affairs. Specifically:

- **passive citizen** – this is a group of citizens who are not interested in participating in the activities of the municipal self-government, do not want to spend any time supporting the development of the city, they are only willing to perceive the information communicated by the self-government,
- **comments giver** – this is a group of citizens who can spend some time to express their opinions, and thus help cities in their direction. However, they are not interested in solving factual arguments – they only present their opinions on the issue,
- **discussant** – this part of the population is interested in the development of the city, can present their opinions, perceive arguments. They devote their time to organized public debates,

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– **participant** – this is a group that is highly interested in the city's development, present their opinions, perceive arguments, and actively communicate with individual city representatives. They are involved in the city councils.

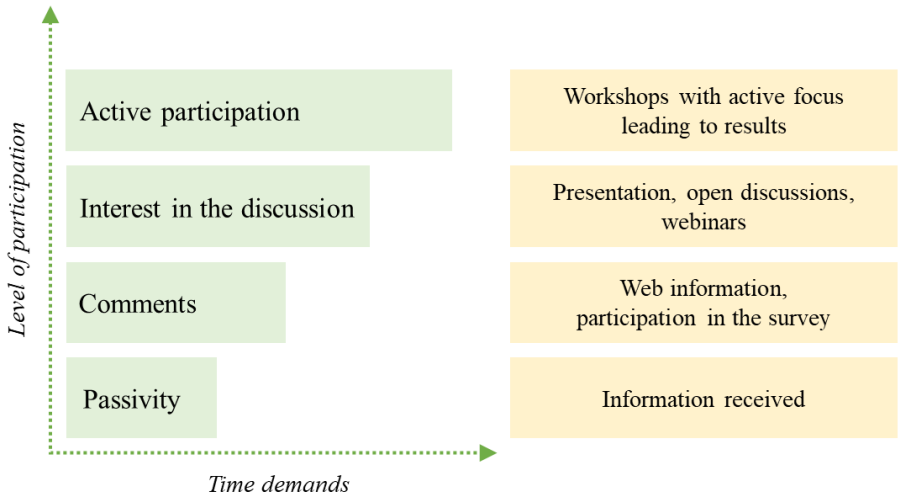

Figure 5. Levels of citizens' participation

Source: own elaboration

Implementation of mobility as a service – mobility as a service is one of the basic platforms for building Smart Cities. It is about connecting individual types of transport and their providers into one comprehensive platform managed by a central service provider. The advantage is the involvement of ICT in the whole process and the construction of a unified digital platform where the subsequent carrier can be a website or a mobile application. Users can use the following options via one platform:

– obtaining information on public transport options in the city, including micro-mobility services,
– the possibility of purchasing tickets for individual modes of transport,
– the possibility of guiding to a free parking area in the case of individual transport,
– the possibility of paying the parking fee,
– the possibility of obtaining information on shared journeys within (and outside) the city,
– obtaining information on weather and air quality within selected localities.

The introduction of mobility as a service brings many benefits to residents and tourists of the city. A significant disadvantage is the managerial complexity of the solution as it is a matter of the unification of several transport operators with the subsequent need for distribution of finance (e.g., profit).

Regulation of individual transport – car parks – following the mobility as a service comes the subsequent need to regulate individual transport. Municipalities approach regulation in Slovakia mostly by motivating motorists to change the means of transport (preference for public transport, lower rates for public transport, availability of connections, introduction of smart solutions). It is also possible to implement rigid measures based on the exclusion of motorists from the city centre and the introduction of car parks at the city borders, with the consequent rapid availability of public transport. This way, residents using individual transport are also forced to use public transport. However, such a decision of the self-government requires financial resources for the completion of the car park, or the possible reorganization of the public transport network. At the same time, it should be emphasized that the representative of the local government is elected for a certain period. For this

reason, political motives also enter decision-making. An unpopular decision may jeopardize the possible further candidacy of a local government representative.

Promotion of alternative (sustainable) sources of transport and the development of electromobility and hydrogen propulsion – transport is closely linked to the environment. The congestion of traffic in the city thus reduces the overall air quality and the quality of the citizens' lives. Cities should gradually use alternative sources of propulsion within the area of public transport. It is primarily about electromobility. The opportunity for hydrogen propulsion is also opening currently. By connecting alternative drives, the air quality can be increased.

By combining individual recommendations that have been defined, cities can create significantly better-living conditions for their citizens. Cities must have well-defined, interlinked strategic goals. It is also necessary that while creating a strategy, the citizens are involved because they can significantly influence the development of the city in the coming years. The essential fact remains that the defined objectives should be divided into concrete steps with subsequent implementation. A significant disadvantage remaining is that the cities often define goals, but the implementation does not occur for various reasons (lack of financial resources, weak motivation of the city representatives, political motives, etc.).

The **novelty** of this article consists mainly of *the analysis of the current state* of the Smart City concept application in Slovakia and *the indicators* that will influence future developments in this area. Another original aspect of the article is represented by the recommendations structured into several parts. The intention was to provide specific points that local governments could focus on when implementing the Smart City concept, particularly within the sustainable transport and mobility. These points include: *(1) Unification of the city's strategic goals; (2) Involvement of the citizens in the strategy creation; (3) Implementation of the mobility as a service; (4) Regulation of individual transport; (5) Promotion of alternative (sustainable) sources of transport and the development of electromobility and hydrogen propulsion.*

Geographical delimitation was identified as one of **the limitations** of the research. The research focused on the Smart City concept and its application only in Slovakia. Other limiting elements include, for example, the primary focus on transport issues within the broader Smart City concept. The last limitation is the utilization of the questionnaire survey distributed only to city mayors and their deputies.

In the **future,** the authors would like to focus their research on other aspects of the Smart City concept besides transport. When transforming a city into a smart city, it is important to proceed *gradually and systemically.* Gradual steps enable the creation of a digital city, where the first change within the implementation of this concept positively affects the introduction of another, creating suitable conditions for further development. In this article, the first change focused on the area of transport, which was identified as a key element within the current conditions of the Slovak Republic.

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