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The idea of smart city in the perspective of the development of the capitals of the Visegrad Group countries

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Abstract

The objective of this study is to analyze the implementation and utilization of information and communication technologies (ICT) in the development of Smart Cities by the authorities of the V4 capitals. This research examines the smart city concept in the context of the development strategies of the V4 capitals. The study utilizes quantitative and qualitative methods to assess the potential of each city and conducts a comparative analysis of strategic documents related to the smart city concept. The article initiates by examining the changing dynamics of public space management in light of the increasing significance of cybertechnology. The subsequent section highlights the key points outlined in the Agenda 2030 document. This is followed by an effort to conceptualize the smart city concept and an explanation for investigating the development of the V4 capitals. The subsequent portion of the article delves into the perception of economic and social development, drawing from the security and cybersecurity strategies of each V4 country. The cases of each country are then analyzed based on selected factors that define their technological potential. The analysis aims to identify the predominant aspects pertaining to the utilization of ICT within the Smart City concept in the V4 capitals. The comparative analysis will reveal commonalities, disparities, strengths, and areas that require further development in each capital. The insights derived from

this research prove vital for effective urban management. They facilitate an enhanced understanding of the interconnectedness between various economic and social resources and allow for the systematization of assumptions, visions, and underlying concepts related to urban space management. This, in turn, assists in identifying the factors that influence comprehensive engagement in smart city initiatives.

Keywords: smart city, Agenda 2030, Visegrad Group, cyber technology, innovation

Introduction

The rapid growth of information and communication technologies (ICTs) in the management of public spaces has created new opportunities for innovative applications in urban areas. This presents a need for policymakers, business representatives, managers, and residents to find effective solutions to address the challenges in urban space management.

This article examines the current trends in the development and regulation of smart cities, with a specific focus on the challenges faced by the Visegrad Group (V4) countries. The governments of the V4 countries are striving to keep up with technological advancements that set them apart from other economic sectors. One way they pursue this goal is by implementing the concept of the smart city, which utilizes advanced technologies to enhance urban management processes. The researchers highlight that the smart city concept is viewed as a means to implement modern production processes within the city, emphasizing the role of ICT in strengthening the competitive profile of urban areas (Caragliu et al., 2009, pp. 45–59). The Agenda 2030 document is relevant in this context as it provides a framework for the article. Based on the objectives outlined in Agenda 2030, the article discusses urban development strategies and analyzes the implementation of new solutions, which are significant for both local and national political spheres, as well as for the ICT sector. The study's findings can help describe potential outcomes for multi-sectoral governance in urban areas.

The objective of this article is to examine the development of the V4 capitals using quantitative and qualitative methods and a comparative analysis of strategic documents related to the smart city concept. This approach aims to provide valuable insights and conclusions regarding smart city development processes and identify the progress made by specific cities. These indicators

will facilitate a comparison of the achievements of V4 capitals and allow for the identification of trends. This case study can be particularly useful in assessing which city is more advanced in terms of development and which one effectively utilizes advanced technologies.

A city's governance model should be responsive to the needs of its citizens. Therefore, it is important to consider whether the strategies have content that addresses these needs and to determine if actions are abeing implemented accordingly. The article references documents that emphasize the necessity for innovative solutions. Analyzing official declarations at the local government level will enable the characterization and comparison of the actions taken by the different V4 capitals to achieve sustainable development.

The article proposes to examine the use of new technologies in the management of local development in the V4 capitals, which share regional ties and common historical experiences that potentially influence the technological potential of these countries and shape the socio-economic landscape of urban spaces.

The objective of this article is to investigate the extent to which urban development strategies prioritize activities that address the demands of digitization, particularly in the areas of environmental, economic, and social change. This challenge aligns with various studies conducted in the literature on this subject (Bibri, Krogstie, 2021, pp. 1–25; Caprotti, Cowley, 2017, pp. 1441–1450; Cugurullo, 2016, pp. 2417–2433; Khan et al., 2020; Verrest, Pfeffer, 2019, pp. 1328–1342).

With the assumption that the adoption of cybertechnology impacts the functioning and development of cities, it is worth examining whether there are similarities in urban space management among the V4 countries. This analysis could lead to the construction of a common model for perceiving development based on digitization in this region of Europe.

The research problem revolves around the factors that shape strategic plans and projects and influence the achievements of the authorities in the V4 capitals. This will be addressed through the analysis of empirical data to illustrate the level of socio-economic development related to cybertechnology. Additionally, the study will explore how the local governments of the selected cities perceive the possibilities of implementing urban plans and projects based on the application of cybertechnology. This qualitative

approach will involve examining the strategic documents created by each V4 capital.

The goal is to investigate how the globally adopted Agenda 2030 is translated from the national level to the realm of urban policy in the context of the V4 capitals. To shed light on the place and importance of cybertechnology in the governance process of local governments, it will be valuable to describe the factors involved. The article aims to contribute to a better understanding of urban policy-making, particularly in terms of developing urban spaces through the application of new technologies.

Determinants of change in the model of urban space management

In recent years, there has been growing attention towards the development of urban spaces, particularly in the context of integrating digitalization and ecology. This integration serves as an expansion tool for cybertechnology, which plays a significant role in implementing sustainable development. Authorities in numerous European capitals are actively working towards achieving sustainable development goals, often aligning with the targets set in Agenda 2030. These goals pose challenges not only in the present but also for the future, with ICT playing a key role in their attainment. As a result, advanced technologies are considered crucial in nearly every aspect of contemporary environmental management, both locally and internationally. Consequently, the use of cybertechnology is often presented as a solution to many of the challenges faced by modern cities (Bibri, Krogstie, 2021, pp. 1–25). Nowadays, the economy, local administrations, and central government entities are increasingly relying on technological innovation to achieve their goals and operate efficiently. Without technological innovation, urban management is likely to fall short of meeting the expectations and requirements of the socio-economic environment. Researchers from various disciplines have acknowledged the significant impact of technology, particularly digital technology, on the management of public spaces. They recognize that advancements in technology play a crucial role in shaping and improving the management practices of public spaces (Caruson et al., 2012, pp. 451–470; King, Kraemer, 2019, pp. 842–847; Reddick, Norris, 2013, pp. 453–476).

The literature on the subject points to the growing importance of the role of information systems in policy making to ensure the desired outcomes of urban management (Duncan, Zhang, 2019; Wood, 2016, pp. 65–121; Zhuravleva et al., 2019, pp. 41–47; Trencher, 2019, pp. 117–128). Local authorities and managers need to understand and participate in the decisions of IT-related environments because: these systems affect the whole city and related socio-economic actors, and ensure that these decisions have the necessary support, funding and other resources critical to success (Laudon, Laudon, 2014; Martin et al., 2018, pp. 269–278).

Innovations that span across multiple sectors play a crucial role in establishing connections and addressing challenges that may exist in separate domains. One example of this is the intersection between cybertechnology and urban development, creating opportunities for collaborative projects in various areas.

It is not surprising that planning for the advancement of cybertechnology is increasingly becoming a part of urban development policies. This recognition is supported by recent studies, which highlight the importance of integrating cybertechnology into urban development strategies (Duminy, Parnell, 2020; Jedwab, Vollrath, 2019, pp. 223–275).

Multisectoral action refers to the deliberate collaboration between practitioners or actors from different sectors of the economy or social life to achieve better outcomes. The value of such collaboration has long been recognized, particularly in relation to the functioning of urban spaces. However, the primary focus of this article is to highlight the dynamics of cities and their functioning in the context of technology driven by knowledge development.

Cities have gained significant political significance, and there is a growing need to generate knowledge about the planning and development of urban agglomerations. This knowledge serves as a guide to understanding how various aspects of urban governance influence the development of a digital society.

The development of a knowledge-based socio-economic environment relies on the collection of information to make informed decisions. Through the analysis of large volumes of data, patterns and trends can be identified, leading to insights and improvements in the optimization of efforts. Development is thus seen as the process of gathering information by managers

and city authorities to enhance existing service delivery activities and plan for the future (Granados, Noferini, 2019; UCLG, 2019).

In order for development in both the knowledge economy and the smart city domain to occur, it is important for both spheres to demonstrate a shared commitment and desire to enhance public space. Improving service delivery requires an understanding of the constraints that influence local government decisions, including political, moral, and financial considerations. However, these constraints can be effectively mitigated through the development of knowledge, which involves expanding research and development activities, fostering public-private partnerships, and establishing academic centers. It is therefore worthwhile to explore the relationship between knowledge development, scientific advancements, and the quality of life in specific geographic areas.

The demand for innovation in the utilization of cybertechnology has grown as more people have gained access to the Internet. Governments have recognized the value of information and communication technology (ICT) and have responded by sharing information and delivering services online. Policymakers at all levels have experienced pressure from the public to improve transparency while simultaneously safeguarding citizens' privacy rights.

The development of cybertechnology presents a significant challenge for local governments, as it disrupts traditional power dynamics and necessitates changes in decision-making processes. Technological advancements are reshaping perceptions of governance and the nature of power, bridging both horizontal and vertical distances. The digitization of public spaces contributes to increased transparency, fostering a more balanced relationship between governments and citizens. This transparency empowers citizens to exercise effective control and influence over decisions regarding the management of public space.

Both state institutions and the private sector must develop new skills to address the challenges associated with creating modern urban spaces, commonly referred to as smart cities. Optimal resource utilization, including the effective deployment of new technologies, is a key priority. The unique nature of these technologies requires innovative approaches to resource redistribution and management (Badran, 2011). Given the growing number of digital services, as well as the enormous popularity gained by artificial

intelligence, the new governance model can be a challenge for authorities not only locally but also trans-regionally or internationally.

Agenda 2030

The increasing technological pressure on local governments has emphasized the importance of building sustainability in urban areas. The design and development of urban spaces should consider various dimensions, including energy efficiency, ecological practices, infrastructure development, waste management, quality of life, mobility, accessibility, economics, and cultural aspects. These key elements must align with major social and intellectual trends, as well as advancements in science and technology.

This relationship is reinforced by the provisions outlined in the United Nations Agenda, which recognizes cybertechnologies as a means to promote socioeconomic development, environmental restoration and protection, resource productivity, infrastructure modernization, and industrial advancement. The need for stable urban development is reflected in the content of "Transforming our world: the 2030 Agenda for Sustainable Development", which emphasizes the importance of sustainable, resilient, and safe management of urban areas (United Nations, 2015).

Similar assumptions are echoed in the literature, where researchers emphasize that the primary objective of a smart city is to achieve enhanced economic development and quality of life through the utilization of data and technology. These arguments align with the emerging insights and evidence within the scientific discourse (Ahvenniemi et al., 2017, pp. 234–245; Batty et al., 2012, pp. 481–518; Bibri, 2019, pp. 2–64; Bibri, Krogstie, 2020, pp. 1–42). However, an integral component of sustainable development in public spaces is the incorporation of cybertechnology. Achieving sustainable development necessitates an integrated, multi-level approach to implementing the goals outlined in Agenda 2030. This strategic framework, established by the United Nations, encompasses 17 Sustainable Development Goals (SDGs) and 169 specific targets. Science and technology development are among the tasks associated with these goals.

The focus of the article is primarily on innovative urban development, and in this context, it is important to recognize the significant similarities

between the objectives outlined in Agenda 2030 and urban development strategies, particularly in relation to science and technology advancement. Both the 2030 Agenda and the smart city model share the aim of promoting innovation, fostering technological development, enhancing access to advanced technologies, and building resilient and sustainable communities. Both spheres also strive to achieve the Sustainable Development Goals, recognizing the crucial role of science, technology, and innovation in their attainment. Furthermore, it is important to acknowledge that the development and implementation of new policies and procedures related to emerging technologies require continuous effort, often with limited resources, especially at the local level (Mulholland, 2012; Rich, 2011). Failure of national political institutions to engage in the tasks outlined in Agenda 2030 may lead to a disconnect between these actors and other stakeholders actively involved in the strategy.

The Visegrad Group

The widespread adoption of cybertechnology in public spaces has prompted governments, including those in the V4 countries, to embark on initiatives aimed at modernizing cities and enhancing the quality of life for their citizens. The integration of technology into the economic and social spheres can be seen as a stage in the ongoing transformation process that began in the early 1990s when Central and Eastern European countries adjusted their political and economic reality to align with Western European standards. In this context, technology represents the fourth realm of change, following politics, economy, and society, and is driving the transformation process forward. Viewing the V4 countries from this perspective offers an intriguing analytical lens that contributes to our understanding of the evolving technology-based economy and society.

The region exhibits significant disparities in socioeconomic development, with Western Europe classified as a high-income region, while Central and Eastern Europe falls within the lower range of middle-income levels. Based on the widely referenced SDG 2023 index, the V4 countries' overall performance in meeting the Sustainable Development Goals is compared to the rest of the European Union (Global Sustainable Development Report 2023).

In all four Visegrad countries, digitization has become an increasingly significant aspect of political and economic life, and it holds a central position in their strategic policy agendas. It is important to analyze the factors that contribute to the development of national economic capabilities based on information and communication technology (ICT) and how these factors shape the positioning of countries on the international stage. Key questions arise: Which countries are likely to succeed in this digital transformation, and what are the determinants of their success? Does success depend on increased collaboration between the digital sector, academia, and industry, or on sufficient state financial resources?

The governments of the Visegrad countries have expressed a strong commitment to Agenda 2030. This commitment can foster effective connections between research and policy, especially in Central and Eastern Europe, where historical experiences have resulted in a lag in the implementation of new technologies and the number of patents in the field of cybertechnology compared to Western European countries.

Definition areas of smart city

The idea of the smart city was first introduced in a 1992 paper titled "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks" (Gibson, Kozmetsky, Smilor, 1992). Since then, the concept of a smart city has been closely associated with ICT (Information and Communication Technology) innovations, capturing the attention of researchers and stakeholders from various sectors (Albino et al., 2015; Ahlgren et al., 2016).

From an interdisciplinary perspective, the term smart city can be defined as a thriving ecosystem that facilitates the implementation of extensive digital deployments and services throughout the city across multiple sectors (Hernández-Muñoz et al., 2011). Researchers have described smart cities as urban innovation ecosystems that foster technological advancements and improve various aspects of city life (Hernández-Muñoz et al., 2011).

The discussed concept encompasses a combination of urban planning, ecology, and information technology, which is becoming increasingly reliant on smart technologies, knowledge, and artificial intelligence. The operation of a smart city necessitates a framework of legal, regulatory, and technical

foundations that directly pertain to the utilization of various applications. These applications play an increasingly significant role in managing urban infrastructure and contributing to urban planning priorities. The term smart city can be used in a broad or narrow sense, depending on the scope of the project. It can encompass a specific aspect of urban functioning or have an impact on the entire urban agglomeration. For instance, the installation of traffic sensors to enhance the safety and efficiency of urban transportation.

In this context, the concept of the smart city can be understood as the integration of cybertechnologies into the functioning of the city and their alignment with the implementation of agglomeration tasks. This perspective aligns with the definition proposed by new research (Ahvenniemi et al., 2017, pp. 234–245). Additionally, information and communication technology (ICT) can be seen as an innovative tool that supports urban public policy (Elmaghraby, Losavio, 2014, pp. 491–497).

In a similar vein, other researchers define the concept of the smart city by emphasizing the use of smart technologies to design and deliver comprehensive solutions for residents of metropolitan areas (Webb Henderson, 2015). In this context, digitization plays a key role in the development of the smart city, which can be defined as the integration of urban infrastructure with the digitization process (Ibrahim et al., 2018, pp. 5171–5186). The importance of new technologies for development has long been recognized and is not a novel idea. However, their implementation within the framework of the smart city provides easy access to improved services in an efficient and cost-effective manner (Lazaroiu, Roscia, 2012, pp. 326–332).

Therefore, in the literature, the modern city has been described as a complex and dynamic socio-technical system designed and developed with the needs of people in mind, aiming to enhance the living and working comfort of city residents (Finger, Razaghi, 2017, pp. 6–13). Many researchers emphasize the second aspect of using cybertechnology, which is to ensure that urban infrastructure services become more interactive and efficient (Bibri, 2021). Similarly, the International Telecommunication Union (ITU) describes the concept of a smart city as an innovative space that utilizes ICT to improve the quality of life, enhance operational efficiency, provide better services, and increase competitiveness (ITU Academy, 2016). In this sense, „smart" refers to the use of information technology and data to achieve sustainability,

openness, innovation, and resilience. A smart city can be seen as a creative system that connects knowledge-based operations and institutions.

Data and information serve as the foundation for smart city operations. For instance, smart waste management systems enable the optimization of garbage collection and recycling, while smart water networks monitor and control water consumption. These advancements can improve efficiency, reduce costs, and minimize environmental impact. The abundance of data generated by various cyber devices in the urban environment is utilized to enhance infrastructure performance and make informed decisions, including investment choices (Ranchordas, Klop, 2018). From this perspective, the urban space can be viewed as a convergence of various technological innovations, such as the Internet of Things (IoT), edge computing, big data, and cloud computing (Edwards, 2016). The concept of the smart city is driven by decision-makers who seek innovative solutions through cybertechnologies across all domains. However, to effectively achieve its goals, investment in human capital is equally crucial, as it, along with infrastructure, plays a significant role in economic development.

All of these efforts should be pursued through collective action and active involvement of residents, aligning with the concept of participation in the governance process (Schaffers et al., 2012). The progress of a city towards becoming "smart" is determined by the extent to which its residents participate in shaping public space. In other words, what matters is the integration and communication among citizens, enabling them to influence and shape local policy decisions. Therefore, investment in human capital is just as crucial as the adoption of modern information and communication technologies. A significant question in this context is whether local policymakers are dedicated to investing in the development of residents, institutions, and technology to foster interaction between these domains, such as through the provision of e-services.

Policymakers should allocate investments not only to smart infrastructure but also to human capital development (Beseiso et al., 2017, pp. 68–72). The aim is to empower citizens with knowledge and skills, fostering creativity, inclusion, and active participation in public life. This is crucial to ensure residents can adapt effectively to the standards of living in a smart city (Kitchin, 2015). The diverse areas where the concept of the smart city is

being implemented demonstrate its multidimensional nature (Schaffers et al., 2012). The multifaceted nature of the smart city concept and the integration of technical, social, and environmental components necessitate a transformation in the management of public space. This evolution also reshapes the nature of governance, impacting security management, local politics, and the conceptualization of development. Therefore, it is essential to examine these changes, as reflected in urban development strategies.

Development strategies of V4 capitals

Research on IT applications among local governments clearly indicates that governance is of paramount importance for achieving positive administrative performance (Merko, Breithaupt, 2014; Gibson, 2015). This necessitates local governments to effectively manage both cyberpower and urban space, which is the focus of this article's analysis. To conduct this study, a review of development strategies pertaining to the capitals of the Visegrad Group (V4) countries and national documents related to cyber security was undertaken to identify and examine the relevant areas of the knowledge economy and society.

Each of the V4 capitals strives to develop as a smart city through strategies that emphasize the use of modern technologies and innovative solutions to enhance residents' quality of life, improve city management efficiency, and promote sustainable development. Therefore, it is worthwhile to identify key elements of the strategy from a smart city perspective. The basis for the analysis will be the documents developed and published by the individual local governments representing each of the V4 capitals, and as far as Warsaw is concerned, this is: "Strategy #Warsaw2030". [Warsaw]; Prague: "Strategie rozvoje městské části Praha 5 2030+" [Prague]; Bratislava: "Bratislava rozumné mesto 2030: Koncepcia Smart City" [Bratislava]; and Budapest: "Budapest 2030 hosszú távú városfejlesztési koncepció"[Budapest].

Warsaw places a strong emphasis on the development of technological infrastructure, including broadband Internet access, 5G networks, smart transportation systems, and city monitoring. The city is also investing in its telecommunications infrastructure by creating wireless internet zones and offering free Wi-Fi access in public spaces. However, what sets Warsaw apart

from other cities is its significant focus on the social aspect, aiming to bridge the digital divide and ensure equal access to technology.

The city's strategy includes providing access to venues that facilitate incubation, testing, development, and presentation of ideas. Efforts will be made to accelerate the growth of companies and foster interdisciplinary networks involving scientific, research, business, cultural, public, and local community entities. Collaboration with Warsaw's scientific and research centers is also planned, along with the application of innovative solutions by the local government. An open information policy will promote the acquisition of knowledge about available resources and provide access to open data that can support the creation of innovative solutions [Warsaw, p. 46].

What sets Warsaw's strategy apart from other capitals is its strong emphasis on continuous monitoring and evaluation of the effects of smart city initiatives. Decision-makers analyze data and feedback from residents to make necessary adjustments and improvements to further enhance the quality of life, improve public services, and protect the environment. A common aspect among all the V4 capitals is the implementation of advanced traffic management systems that utilize technologies like cameras, sensors, and communication systems to monitor and optimize traffic flow.

Residents in these capitals have access to various digital public services, including the ability to handle official matters online, submit applications, make electronic payments, and communicate with authorities through online platforms. Additionally, there are city portals providing information on services, events, and initiatives. The primary aim of digital public services is to enhance the interaction and communication between citizens and the administration.

In Prague's smart city strategy, the focus lies on improving the public transportation system and reducing traffic congestion through the implementation of smart technologies. The city is investing in traffic monitoring systems, smart traffic lights, smart parking lots, and the development of data- and analytics-driven solutions for public transportation.

The information management model in Prague's smart city strategy is built on the concept of open data, where datasets related to various aspects of the city are made publicly available. Residents can access information on public transportation schedules, parking availability, cultural events,

local services, and other relevant city data. This accessibility of information aims to simplify residents' daily lives and encourage the use of eco-friendly transportation options.

Prague focuses on creating a seamless, safe, and comfortable transportation system within the city and its districts. It offers a variety of transportation modes, allowing travelers to choose or share environmentally friendly options that suit their needs. The city is establishing a network of bicycle paths and pedestrian connections, developing key transportation hubs for urban and regional public transportation, and ensuring a well-connected road network [Prague, p. 165].

In terms of energy efficiency, Prague is implementing intelligent building management systems to optimize energy resource utilization, monitor water and energy consumption, and enhance residents' comfort. The city is also investing in the expansion of electric vehicle charging infrastructure and integrating the energy grid with buildings and transportation systems. These efforts aim to promote sustainability and reduce environmental impact.

Prague is actively developing its IoT infrastructure to facilitate communication and interaction among various devices and systems.

As part of the city's e-government strategy, there is a need to establish an ICT concept to support the smooth operation of new services. This includes measures to ensure the availability of ICT systems for digitizing official activities, document digitization and circulation (such as digital archives, electronic circulation based on process models, electronic signatures, etc.), and the implementation and operation of ICT infrastructure for autonomous processes. Additionally, the utilization of ICT Operator, a.s. for state eGovernment services and the specification of services and ICT infrastructure for Prague's District 5 and related organizations will be integral components of the strategy [Prague, p. 259].

By implementing these initiatives, Prague aims to collect and analyze real-time data, enabling better resource management, process optimization, and faster response to changing conditions. The city is also implementing systems to monitor and optimize waste collection and disposal. Smart garbage containers equipped with sensors provide information on fill levels, enabling city services to schedule waste collection more efficiently.

The city of Bratislava, similar to Prague, Warsaw, and Budapest, is implementing digital platforms and applications to enhance residents' access to information, facilitate online requests, payments, and issue reporting. International cooperation is a significant component of Bratislava's smart city strategy. The city actively participates in international projects and programs, benefiting from access to best practices, solutions, and technologies that can be adapted and implemented in the local context.

Bratislava's involvement in the international organization EUROCITIES and active participation in the Committee of the Regions hold promise, especially considering the diverse range of topics covered, extensive membership base, and the organization's strong connection to European structures. Additionally, Bratislava is a member of the cross-border regional initiative CENTROPE, which aims to foster collaboration among Austria, Hungary, Slovakia, and the Czech Republic. This region is characterized as the cultural and innovative center of Central Europe, with a dynamic economy and a population of nearly 7 million [Bratislava, p.12]

Similar to other local governments, decision-makers in Bratislava are implementing various technologies to improve transportation systems. These include smart traffic signals, traffic monitoring systems, and parking management systems. The city is also promoting the use of public transportation, bicycles, and electric vehicles to enhance traffic flow, reduce emissions, and provide sustainable transportation options.

There is a growing demand for efficient, comfortable, and environmentally friendly transportation services that cover a wide area. It is important to minimize the negative impact of transportation on the environment, particularly in terms of air and noise pollution. One of the key challenges is to reduce individual car usage and encourage sustainable transportation modes such as public transit, rail, walking, and cycling. It is crucial to collect, analyze, and manage transportation data and infrastructure effectively while planning and implementing solutions. Sustainable and efficient transportation management involves the integration of urban transportation data, with a focus on creating a dynamic and healthy city on the move [Bratislava, p. 24]

Bratislava's strategy, unlike the strategies of other V4 capitals, places a strong emphasis on the monitoring and management of urban resources

such as water, energy, and waste to reduce waste and increase efficiency. This approach enables the city to have better control over resource consumption and minimize waste and pollution, ultimately contributing to sustainable development.

The city actively engages with commercial, research, and other entities to find solutions and promote cooperation in implementing these solutions. The EMOCITY cluster, which focuses on electromobility and smart city initiatives, plays a significant role in this regard, and the city is a member of this cluster. It is recommended to form partnerships with commercial entities, such as mobile operators or geolocation data companies, which can provide valuable data to the city [Bratislava, p. 49].

Furthermore, Bratislava's strategy places a stronger emphasis on creating favorable conditions for independent knowledge-based economic development. The local government supports the establishment of incubators, accelerators, and R&D centers that provide entrepreneurs with access to knowledge, mentors, capital, and collaboration opportunities. By doing so, the city aims to foster technological development, introduce innovative solutions, and attract investments.

Budapest, similar to other capital cities, is prioritizing key elements in its smart city strategy. The city is making investments in expanding its broadband network, establishing wireless city zones with Wi-Fi access, and developing smart telecommunications systems. The local government recognizes digital services as a means to streamline and simplify administrative processes, improving efficiency.

To enhance the overall efficiency of the city, it is crucial to improve both the urban infrastructure and the human resources within it. Budapest emphasizes the importance of a well-designed climate strategy for the city's sustainable development, economic competitiveness, and environmental sustainability [Budapest, p. 37].

Cross-sector collaboration and leveraging technological potential are common approaches taken by Budapest, as well as other capitals, to develop innovative solutions in transportation, energy, public administration, and environmental protection. In line with this, Budapest is introducing smart traffic management systems to enhance traffic flow and reduce congestion, addressing the transportation challenges faced by the city.

Intelligent transportation systems play a crucial role in the present and future of Budapest. The implementation of advanced technologies in transportation infrastructure contributes to increased efficiency and improved mobility processes. This includes various services such as providing passenger information, selecting optimal routes, traffic control, parking management, and the use of traffic data banks created by operators [Budapest, p. 157].

Moreover, Budapest is placing a strong emphasis on leveraging modern technology in the realm of public transportation. The city is introducing smart ticketing and electronic payment systems, enabling residents and tourists to conveniently access and utilize public transportation services. These advancements aim to enhance the overall user experience and promote the efficient use of public transportation in the city.

The V4 capitals are dedicated to the development of Smart Cities, harnessing technology, innovation, and citizen participation. Their strategies encompass a wide range of areas, including smart mobility, energy, natural resource management, and public services. The aim is to create cities that are more sustainable, efficient, and citizen-centric, prepared for future challenges and responsive to evolving community needs.

As anticipated, these strategies align with the goals of Agenda 2030, showcasing a common commitment to sustainable development. While there may be variations in emphasis, such as the Prague document highlighting ICT applications in ecology or Slovakia's emphasis on international cooperation due to its geographical location, overall, the cities share a common vision and objective in their pursuit of smart and sustainable urban development.

Factors identifying the development of smart city potential in V4 capitals

Focusing on the allocation of technological resources and its management is considered a crucial issue for stakeholders involved in smart cities. In this regard, the authorities of the respective capitals are expected to develop policies that facilitate the redistribution of resources, ensuring that the entire process contributes to the establishment of an innovative urban space.

By combining the components outlined in the table, it becomes possible to examine both the process and the outcomes achieved in the creation

of smart cities, drawing evidence-based insights from case studies of V4 countries. This approach allows for an exploration of the smart city construction process itself, along with the associated challenges. Describing the achievements of the V4 capitals also facilitates an analysis of this European region in the context of knowledge-based development.

When knowledge sectors, such as research and development, patents, and scientific endeavors, are prioritized by city authorities, they can drive the development process and influence the strategic planning and goal prioritization of local governments.

Education plays a pivotal role in the development of smart cities as it provides the highly skilled workforce needed to develop, implement, and maintain advanced technological solutions. Individuals with tertiary education often possess strong technical and engineering skills, enabling them to design and manage smart city systems effectively. Therefore, V4 countries with well-developed higher education systems hold an advantage in constructing smart cities.

Conversely, unemployment can present a barrier to smart city development. A lack of employment opportunities may limit residents' ability to utilize the new technologies and services offered by smart cities. Unemployment is often associated with reduced access to financial resources, making it more challenging to introduce innovative solutions in cities. Moreover, high unemployment rates can deter foreign investors and local entrepreneurs from investing in smart city infrastructure.

However, there exists a reciprocal relationship between smart city development and unemployment. Smart cities can generate new jobs in technology-related fields such as IT, telecommunications, energy management, and transportation. The implementation of smart solutions can foster the emergence of innovative businesses and startups, creating employment opportunities and strengthening local economies.

In the V4 countries, there are variations in terms of tertiary education and unemployment. Countries like the Czech Republic and Poland have well-developed tertiary education systems and a higher percentage of individuals with tertiary education. However, unemployment remains a challenge across all V4 countries, particularly among young and less qualified individuals. Nevertheless, data indicates two trends: an increase

Table 1. Selected factors of economic and social development

	Warsaw					**Prague**					**Bratislava**					**Budapest**				
Years	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
Higher education	57	71,6	69,2	68,7	64,9	56,1	57,3	60,9	57,2	59,9	51,8	59,9	62,1	54,9	54,7	45,7	54,9	57,7	54,2	61,1
Unemployment rate	2,6	2,4	2,4	2,5	2,1	1,7	1,3	1,8	2,3	2,3	4,2	2,9	3	3,4	2,6	2,7	3,1	3,2	3,3	2,9
internet users	78	78	79	80	82	80	88	89	93	88	70	70	75	85	90	75	81	83	89	92
e-banking	49	52	54	57	60	67,4	72,9	74,6	79	80	54,8	59,7	63,2	68	71	51,2	56,7	61,3	68	76
e-government	24,3	24,8	27,2	29,3	31	43,5	50	51,5	53	57,9	45,1	45,6	47,2	51,3	51,8	42,7	48,2	50	59,5	72,1
Rate of emergence of new ICT enterprises	11	11.9	12,3	13,4	12,7	9,5	9,8	10,2	10,7	10,7	11, 6	12	12,6	11,6	11	11,2	11,5	14,1	13,9	12,5
Intensity of research and development	1,74	2,19	2,40	2,44	2,56	2,97	2,32	2,42	2,68	2,54	1,84	1,4	1,4	1,42	1,42	1,88	1,77	2,12	2,53	2,41
R&D expenditures per capita	590	620	646	698	786	800	1020	1050	1110	1194	520	510	550	554	568	663	651	684	706	747
Human resources in science and technology	52,2	67,4	70,7	66,5	68,7	60,2	60,4	63,7	65,9	67,8	58,1	57,4	59,8	62,3	63,5	48,3	58,9	55, 6	57,9	67,1

Source: Eurostat

in education and a decrease or stable level of unemployment, which fosters greater social engagement among the population. Educated individuals are more aware of their rights and responsibilities and actively participate in social and political life. In the context of the smart city concept, this translates to increased citizen involvement in decision-making processes regarding city development. Educated citizens are more knowledgeable about the benefits of smart solutions and are therefore more receptive to innovation and willing to collaborate with local authorities to implement changes aligned with the smart city concept.

Another factor that showcases the development of the smart city concept is the growing number of internet users, which drives the advancement of digital public services. V4 countries can utilize the internet to provide online access to information and services such as document filing, tax payment, vehicle registration, and healthcare services. This contributes to improved administrative efficiency, time savings for citizens, and eliminates the need for physical presence in offices. The high number of internet users also increases the demand for telecommunications infrastructure, including fiber-optic networks and 5G, necessitating investments in network expansion and upgrades. The greater the number of internet users, the higher the demand for developed infrastructure capable of handling the growing data traffic. The number of daily internet users also influences the development of digital services and resident participation in the smart city concept. Access to the internet enables residents to utilize mobile applications, social media platforms, transportation services, and solutions for healthcare and education. A larger number of internet users creates more opportunities to develop digital services and involve residents in the decision-making processes of the city.

Additional areas that play a significant role in driving smart city development include e-government and e-banking, which leverage digital technologies to enhance administrative processes and services for residents. These areas also experience growth in digital services.

Within the smart city concept, e-government plays a crucial role in improving access to public services, administrative processes, and communication with authorities. Through web portals, mobile applications, and digital platforms, residents in V4 countries can easily and efficiently

complete formalities, submit documents, access services, pay taxes, and track the status of their affairs. E-government promotes efficiency, transparency, and convenience for residents.

The second area driving the development of the digital economy is digital financial services. Through mobile apps, online platforms, and innovative payment solutions, residents of V4 countries can conveniently manage their finances, make payments, transfer money, and access various banking services. E-banking contributes to transactional efficiency, financial security, and simplifies daily financial operations for residents.

The implementation of e-government and e-banking within the smart city concept brings numerous benefits. It improves access to public and financial services, reduces bureaucracy, enhances communication between residents and administration, and increases convenience and time savings. Moreover, e-government and e-banking contribute to the digitalization of society and the development of digital skills among residents, which are crucial for fully harnessing the potential of smart cities.

The development of smart cities also fosters the emergence of new companies and startups that create innovative technological solutions and services tailored to the needs of the smart city environment. The introduction of advanced technologies creates an attractive environment for startups to utilize these resources and develop innovative products and services. Additionally, the presence of robust innovation ecosystems, including startup accelerators, R&D centers, and technology clusters, attracts entrepreneurs and encourages the formation of new companies.

Each of the V4 countries is committed to establishing a favorable innovation ecosystem and providing access to finance and education to promote the growth of new companies and the development of smart cities. All V4 countries have startup incubators and accelerators that provide support through mentoring, business advice, infrastructure, and funding. These institutions assist young entrepreneurs in developing their ideas, testing innovative solutions, and preparing for market entry. In the context of smart cities, incubators and accelerators often focus on projects related to digital technologies, the Internet of Things (IoT), data analytics, and renewable energy.

The V4 capitals offer various forms of financial support for startups, including research and development grants, equity investments, and dedicated

investment funds. These financial resources enable entrepreneurs to further develop their ideas, invest in technological advancements, and scale their businesses. Supporting such ventures stimulates the development of innovative solutions for smart cities.

However, the pace of development may vary between national capitals due to differing economic and legal conditions, as well as varying levels of financial investment in the knowledge economy. Another set of factors that drive smart city development is scientific research. The V4 countries collaborate with universities, research institutes, and innovation centers to bridge the gap between academia and business. Such partnerships facilitate technology transfer, the commercialization of research, and the creation of innovative businesses. Within the framework of smart cities, this cooperation enables the practical implementation of the latest scientific and technological advancements.

High intensity of research and development (R&D) and R&D spending serve as important tools for fostering innovation and technological advancements. Companies, research institutions, and universities that invest in R&D contribute to the development of new technologies, services, and solutions in the context of smart cities. As mentioned earlier, smart cities increasingly utilize advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, blockchain, and more. Cities that prioritize research and development are better positioned to develop and implement these technologies. A strong focus on research and innovation facilitates the implementation of smart city solutions, including smart transportation systems, energy grids, waste management, healthcare services, education, and security.

It is important to note that governments and local authorities in the Visegrad Group, by investing in technical, scientific, and engineering education, are nurturing a pool of skilled professionals capable of creating, implementing, and managing smart city solutions. However, effective implementation of smart city concepts still faces challenges. The main obstacle, as can be inferred, is not the lack of appropriate skills and human resources in the technology field, but the inability to retain highly qualified IT professionals within public institutions. The region as a whole struggles with low salaries for such specialists, which makes the private sector more attractive in terms of employment conditions.

It should be emphasized that while individual V4 capitals are making efforts to develop smart cities, they also face various challenges. These challenges include the integration of different systems and data, ensuring digital privacy and security, engaging the public, and ensuring equal access to technology for all residents.

The level of smart city advancement varies among the V4 capitals, influenced by specific measures taken by individual cities, such as urban policies, investments, technological infrastructure, and community involvement. Several common factors contribute to success, including domain integration, collaboration with the private sector and community organizations, monitoring of technological advancements, and effective data management. Further investment in these areas can accelerate progress and foster the creation of sustainable, innovative, and citizen-friendly cities.

In summary, Prague stands out as one of the most advanced smart cities in the region. The city is implementing numerous ICT-based initiatives in areas such as transportation, energy, waste management, and civic participation. Prague leads in smart parking, traffic monitoring systems, e-health, and has a well-developed telecommunications infrastructure. Bratislava is also actively pursuing smart city development and introducing innovative solutions in transportation, energy, resource management, and citizen services. The city has projects related to smart street lighting, e-services for citizens, a well-established public transport system, and digital solutions for residents. Warsaw is a leading smart city in Poland, focusing on digital infrastructure, intelligent transport management, air quality monitoring, energy efficiency of buildings, and digital services for citizens. Warsaw is also involved in smart grid projects, smart charging stations for electric vehicles, and mobile applications for residents. Budapest is also making efforts to become a smart city, with a focus on smart transportation, digital public services, e-services for citizens, and the development of digital infrastructure. Budapest is actively involved in various smart city projects, including smart parking, traffic management systems, air quality monitoring, and the development of mobile applications for residents.

The study findings indicate that policy makers in the V4 countries, at both the local and governmental levels, are committed to fostering innovation and technological development. They recognize the importance of human resources in science and technology and the collaboration between sectors

for the effective implementation of smart city solutions. The V4 countries understand that education, technical skills, and the ability to innovate are crucial success factors. Therefore, they are investing in the development of technical education, specialist training programs, and scholarships in science and technology. Establishing specialized research centers, technology parks, and startup incubators is also a priority to foster collaboration between science, business, and innovation.

In the context of the smart city concept, the V4 countries are pursuing several benefits. These include improving the quality of life for citizens, enhancing the efficiency of public services, preserving the environment, promoting sustainable economic development, and attracting investments. The smart city concept has become a strategic goal for the V4 countries, as they aim to leverage technological and innovative potential to create modern and citizen-friendly cities.

Conclusions

Research oriented towards the problem of digital development in conjunction with urban development needs to draw from various disciplines, particularly those that allow for a comprehensive exploration of the relationship between governance, public policy, and the application of cybertechnology.

The issue of policy coherence and multi-level governance is increasingly significant in urban policy debates and practices. To ensure the success of this process, several barriers must be overcome, including political discrepancies between different levels of governance, national regulations that assign sole responsibility for implementing sustainable development and its follow-up to national governments, a lack of expertise in local administrations, and a gap between public policy institutions and the private sector.

The analysis demonstrates that the application of digital innovation can significantly accelerate development in many crucial aspects of contemporary urban spaces. However, establishing policy coherence among multiple public sectors and aligning budgets with urban development is a considerably complex issue.

Fostering social inclusion is of great importance for the development of smart cities. This can be achieved by creating new participatory mechanisms

that are transformed into systematic and institutional channels for consultation and exchange between communities and public administrations. It is therefore crucial to involve the public in the design of new long-term strategic plans, characterized by partnership and multi-level coordination.

The scope and sustainable development goals outlined in Agenda 2030 present significant challenges to the V4 countries. This article examines the role of the V4 capitals (Prague, Bratislava, Warsaw, and Budapest) in the processes related to the national adaptation of Agenda 2030. The selected V4 countries do not differ in terms of the challenges associated with the implementation of Agenda 2030.

The V4 capitals – Prague, Bratislava, Warsaw, and Budapest – are the largest and most significant cities in their respective countries and hold substantial influence over the progress towards achieving sustainable development goals. The authorities of these cities often prioritize sustainability aspects such as public transport, energy efficiency, air quality, environmental protection, education, and community development. Their urban policies and actions have the potential to impact a wide range of sustainability goals. However, it is notable that in the four cases studied, local authorities do not conduct a sufficiently comprehensive analysis of their progress towards the Sustainable Development Goals. Conducting such an analysis would aid them in identifying areas where they face challenges and taking appropriate actions to improve their performance.

Factors that focus on the local aspects of digital capacity development are expected to influence or correlate with the commitment of local governments to the goals of Agenda 2030. In the case of the V4 countries, it is expected that the cities play an influential role in achieving the sustainable development goals.

From a policy perspective, the study suggests the need to further strengthen the role of local governments in the context of Agenda 2030. It is also reasonable to anticipate that political institutions will continue to grapple with the challenges posed by the goals outlined in Agenda 2030, particularly considering the existing divergence of views on the best approach towards a more sustainable world.

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