SMART CITIES AS DRIVERS OF TWIN TRANSITION - EVIDENCE FROM THE REPUBLIC OF SERBIA

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Abstract
United Nations sustainable development goal 11 "Sustainable cities and communities" emphasizes the importance of cities, viewing them as actors largely influenced by economic and population growth, modern consumption, and numerous environmental challenges. In urban areas, there are numerous challenges of modern life, which also imply major changes in the model of urban development. As extremely complex systems and hubs of various activities, cities that develop as "smart" get a key place in achieving the goals of economic and sustainable development, both in developed and developing countries. Undoubtedly, smart cities have a very important role in these processes and can facilitate the twin transition to a green and digital economy. This paper aims to analyze the role and importance of smart city development for the twin transition. Consequently, the paper is divided into three thematic parts. The first part refers to the basics and importance of the twin transition. The second part analyses how smart cities, as the concept of sustainable urban development, and twin transition are interconnected and contribute to each other, while the third part is about the situation and perspective of smart city development and twin transition in Serbia. Through the implemented digitalization and e-government development in Serbia, a strong base for smart cities was created. In certain local governments, successful projects that are important in creating resilient and smart cities are an incentive and a good example for the future. Some of these examples will be presented in the paper. In conclusion, final remarks are given. From a methodological point of view, this work presents a desk research analysis and synthesis of data from relevant sources, with the aim of a detailed presentation and concluding the subject. The research results contribute to the understanding and perception of this important topic.

Keywords*: twin transition, smart cities, sustainable development, Serbia*

Introduction

Cities serve as vital hubs for the exchange of ideas, trade, science, culture, and social progress, fundamentally driving social and economic advancement. As noted by Stefanou and Mitoula (2024), the intense dynamics propelling urban development result in cities attracting a significant portion of the global population, which currently stands at about 50% residing in

urban areas that comprise only 3% of the Earth's surface. This urbanization trend is projected to continue, but it brings with it pressing challenges, including high energy consumption—accounting for 60-80% of total usage—and substantial carbon emissions at 75% of global output. Urban residents commonly face issues such as traffic congestion, air pollution, waste management, and social inequality, necessitating innovative solutions to ensure sustainable urban living.

With the aim of enhancing urban sustainability, the United Nations' Sustainable Development Goal No. 11 emphasizes the need for safe and inclusive cities (Chatzifragkios Makrydakis, 2024). Ban Ki-Moon's assertion that *"Our fight for global sustainability will be won or lost in cities"* underscores the critical nature of addressing urban challenges through sustainable development frameworks that balance environmental, social, and economic needs.

Among the various concepts fostering sustainable urban development, the "smart city" paradigm stands out as a transformative approach. By leveraging information and communication technology (ICT), smart cities aim to create more inclusive and sustainable environments, responding to the urgent needs of their inhabitants while promoting economic growth and innovation. The role of advanced technologies in enhancing operational efficiency and residents' quality of life is undeniable (Chatzifragkios Makrydakis, 2024).

In this paper, it will be explored how the potential contributions of smart city applications to sustainable urban development, particularly regarding environmental sustainability. What is also of great importance and it is shown in the first part of this paperwork is analysis of the role and importance of smart city development for the twin transition. The second part of the paperwork is dedicated to the topic how smart cities, as the concept of sustainable urban development, and twin transition are interconnected and contribute to each other, while the third part is about the situation and perspective of smart city development and twin transition in Serbia. Various approaches in the context of how they tackle environmental issues, implement mitigation strategies, and utilize ICT, An under-researched aspect of smart city initiatives is their potential to achieve "zero vision" objectives (Angelidou et al., 2018). Furthermore, we will examine the concept of "smart spaces," characterized by their openness, connectedness, coordination, intelligence, and scope (Cearley and Burke, 2018), and their implications for urban settings.

Local governments play a crucial role in realizing the vision of sustainable cities. They face multifaceted challenges, such as pollution and overcrowding, while striving to raise public awareness and promote citizen engagement in urban sustainability efforts (Stefanou and Mitoula, 2024). By addressing these issues holistically, this research aims to enhance understanding among stakeholders about the sustainability of urban environments, highlighting the collective responsibility required to attain meaningful progress towards sustainable urban futures by enhancing twin transitions in Republic of Serbia.

Methodology

The subject of research is a complex topic, and the methodological framework includes numerous methods that, in their interdependence at a high level, enable the direct acquisition of knowledge. This systematic, clear, and goal-oriented research is based on data analysis and the synthesis of theoretical and empirical facts. The research methodology employs desk research analysis to investigate the concept of smart cities and the emerging phenomenon of the twin transition, which integrates digitalization and sustainability. Additional methods used include basic methods such as analysis and synthesis, deduction and induction in concluding, as well as general scientific methods like descriptive analysis. The starting hypothesis of the research is that the development of smart cities has a significant transformational potential for the green and digital transition. By gathering and synthesizing secondary data from relevant

sources, allowing data analysis of contemporary literature, peer-reviewed journals, reports, case studies, and publicly available documents related to the subject of the research, as well as systematizing the collected information according to the research objectives, the aim is to provide a detailed presentation and conclusion on the subject. For the research, sources of complete, combined, and related content were used. This approach is particularly relevant for exploring the intersection of smart cities and twin transition, as it provides access to a wide range of scholarly articles, policy papers, governmental reports, and industry publications. Reports from international organizations provided additional context on global trends in sustainable urban development and the role of emerging technologies. The desk research approach made it possible to compile a wide range of viewpoints on twin transition and smart cities, offering a strong basis for comprehending how they overlap and potential future development. The research results will contribute to the understanding and perception of this important topic.

Twin transition - a spot where digital amplifies sustainability

The topic of the twin transition has become a central focus in current literature, with increasing interest from researchers, managers, and policymakers in exploring this phenomenon. The concept of twin transition integrates of digital and green strategies, specifically its focus on harmonizing digital transformation with environmental sustainability goals. In essence, the twin transition framework refers to the simultaneous advancement and connection of two major economic and societal shifts:

1. *Digital (or smart) transition* is the dominant driver of transformation and refers to the adoption of advanced technologies and digital innovations.
2. *Green transition*, another major transformation driver of transformation, which focuses on environmental responsibility, adaptation to climate change and sustainability,

The first aspect is a digital transition that is not possible without so-called key enabling technologies (KET). These are advanced information and communication technologies that are characterized by high research and development intensity, fast innovation cycles, significant capital investment, and the creation of highly skilled jobs. Key enabling technologies include Internet of Things (IoT), Big Data & Analytics, Cloud Computing (CC), Simulation, Virtual Reality (VR) & Augmented Reality (AR), Artifical Intelligence (AI), Additive Manufacturing (AM), System Integration, Robotic and Cybersecurity (Ortega-Gras, et al. 2021). The second aspect is that green transition is not possible without digital transformation. These cutting-edge technologies are considered crucial tools for driving innovation and digital transformation across various industry sectors and society, including their key role in achieving sustainability goals. This is where we reach the core of the twin transition, which integrates both the green and digital transitions, offering a comprehensive approach to fostering sustainable development using digital innovations. In simple terms, digital transformation serves as a critical enabler and instrument for achieving green objectives. Both segments of twin transition have a significant systemic impact as they apply to the entire product life cycle and involve all parts of the value chain (Komninos, 2022). Even though the twin transition is gaining greater attention, there is an obvious shortage of research on the subject and scattered research in this field. The evaluation of SMEs and the analysis of shifts in competitive business advantages brought about by twin transitions are relatively recent responses to the implementation of the Green Deal and Sustainable Development Goals (Burinskienė and Nalivaikė, 2024). The pursuit of twin transition, which includes key enabling technologies, green human resource management, investment in environmental management strategies, and technological innovation, can significantly enhance a company's competitive advantage based on sustainability (Rehman, et al. 2023).

Based on a variety of theoretical frameworks, it is possible to assume that digital technologies will facilitate eco-innovation; nevertheless, it is anticipated that artificial intelligence and the combination of digital investments will have a more significant impact on eco-innovation. The findings demonstrate that investments in AI application areas are the primary driver of digital technology's contribution to a firm's eco-innovation, whereas expenditures in other digital technologies have a more selective effect (Montresor and Vezzani, 2023).

Accelerating the twin digital and green transitions has been prioritized at the European policy level, as this will be essential to creating sustained economic growth. To encourage green and digital transitions, the European Union has introduced many strategies, regulations, and directives. Some of the most significant ones are The European Green Deal, New Industrial Strategy for Europe, Digital Strategy (Shaping Europe's digital future), A new Circular Economy Action Plan-For a cleaner and more competitive Europe, etc. Implementation of these policies is supported with several EU funding instruments such as key R&D funding instrument the Horizon Europe Programme, then Programme for the Environment and Climate Action, known as LIFE Programme and Innovation Fund (Ortega-Gras et al. 2021). Achieving the UN Sustainable Development Goals depends heavily on the efficient implementation of digital and green transition. According to recent research, green technologies are crucial for digital transformation, particularly when it comes to solving business difficulties related to sustainable development. There are three complementary levels of recommendations for enhancing the twin transitions to support the circular economy by utilizing innovative technologies (Ortega-Gras et al. 2021):

1. At the industry level, establish clear objectives for digitalization and circularity in advanced sectors while developing new strategic plans and policies to promote the twin transition in underdeveloped sectors.

2. At the technological level, support research and development efforts focused on technologies that are already driving the circular transition and analyze how other emerging technologies could further support this shift.

3. At the knowledge level, develop the essential digital and green skills required for a twin transition, provide the necessary expertise to understand and implement it, and promote synergies among various training initiatives to enhance their effectiveness.

This approach can make significant contributions so that society achieves a successful twin transition and reaches a sustainable and smart industry model. Activity-based ecosystems are the most common type of ecosystems in cities, formed by people, companies, and organizations that share spaces, infrastructure, the labor market, and other urban externalities. Research papers focused on pathways toward a digital and green transition have shown that the transformation of activity-based ecosystems in cities and regions relies on processes such as “prioritisation”, “ecosystem perspective”, and “platform-based smart and green solutions” (Komninos, 2022). Pathways for activity-based ecosystems transformation are of high interest to all countries, regions, and cities. These pathways linked to digital and green transitions can “(a) connect digital and green technologies enabling a twin transition, (b) produce system innovation leading to a radical change of routines, and (c) transform economic activities and industry ecosystems” (Komninos, 2022). System innovation should be a direct transformative outcome of radical changes introduced by the digital and green transitions. There are two ways that change can take place: first, through state-led policies, innovative strategies change economic activities and their ecosystems; second, through state-led and market-driven processes, the twin transitions change the same activities (Komninos, 2022).

Transformational potential of smart cities for green and digital transition

A smart city is urban community that seeks to improve the well-being of its residents, businesses, visitors, organizations and administrators by providing digital services that contribute to a better quality of life. The utilization of information and communication technology (ICT) to transform the living and working environment within the city is the most essential aspect of smart cities. By bringing together ICT and inhabitants, as well as improving creativity and knowledge, smart cities are brought to life through the widespread deployment of digital technologies in communities and their incorporation into governance systems. It is impossible to create a smart city that is both sustainable and feasible without the deployment of cutting-edge technology. The component of the smart city concept that directly contributes to the acceleration of digital transformation is this. Most of the advanced ICT smart solutions implemented in cities are focused on addressing environmental concerns. One of the following groups best reflects the most widespread initiatives related to smart cities in urban settings: sustainable development, energy efficiency, decreases the energy footprint of buildings, enhancing business and citizen services, increasing quality of life, strengthening local democracy and transparency, public safety, cyber security, and bolstering digital infrastructures. A smart city should increase service accessibility and efficiency, reduce poverty, unemployment, and social isolation, and minimize pollution and its negative effects on the environment by gathering open, anonymous data and using it to formulate policies (Chatzifragkios Makrydakis, 2024). Smart city and twin transition are strongly interconnected and contribute to each other's goals. This combination of wide use of ICT for environmental issues and green solutions in urban areas are one of the most important aspects of a smart city. Twin transitions can be directly related to the development of smart cities since they aim to use technology that will improve urban living while tackling environmental problems. Data, digital infrastructure, connectivity, and sustainable practices are all essential to the idea of smart cities. Synergy and interdependence between socio-economic and ecological sustainability can be achieved by building cities with an emphasis on sustainable housing and urban area management. This approach can support and facilitate the double shift to a more digital and greener future. By developing cities with a focus on sustainable housing and urban area management, it is possible to create synergy and interdependence between socio-economic and ecological sustainability. This approach can help effectively implement and promote the twin transition toward a greener and more digital future.

The green transition in smart cities is primarily associated with smart energy, urban (circular) bioeconomy, sustainability, and carbon reduction. Smart cities aim to reduce their environmental impact by leveraging technology to optimize energy consumption, waste management, and transportation. These cities are incorporating renewable energy sources, such as solar and wind power, alongside energy-efficient buildings, smart grids, and storage systems to minimize carbon footprints and manage energy use effectively. Advanced technologies also enable better monitoring of waste production and recycling, promoting resource efficiency and supporting a circular economy, all of which contribute to a more sustainable urban environment. The concept of an urban bioeconomy, which can be viewed as the implementation of the bioeconomy within urban regions, is a new form of environmental value creation that offers a potential solution. Cities have traditionally been viewed as net consumers of ecological resources and producers of ecological waste. However, by viewing the city as an ecological resource that can be leveraged for profit, the concepts of urban metabolism, circular economy, and bioeconomy have attempted to rebalance this seemingly parasitic connection in recent years (Taylor Buck and While, 2020). Within the context of urban development, the European Commission therefore stated that ‘cities should become major circular bioeconomy hubs. Circular urban development plans could translate

into significant economic and environmental gains' (European Commission, 2018). "An urban bioeconomy describes an economic system within cities and their surroundings, ranging from semi-urban communities to megacities, that consists of bioeconomic components including green infrastructure, urban farming and the broader urban food system, biowaste valorisation, and any other elements that utilise bio-based processes or materials as well as ecosystem services in an urban environment with the aim of generating positive environmental, economic, social and health impacts on cities, their population and their environment as a whole in the present and future" (Yang, & Yang, 2022). Urban bioeconomy is a paradigm-shifting framework that acknowledges the interdependence of ecosystems, people, and climate. The key question is how can cities support and develop a thriving urban bioeconomy where nature-based solutions, circularity and land restoration are central to its operations? Meta-analysis of the systematic literature review results according to the predefined coding framework done by Yang and Yang (2022) show three potential bioeconomic components in urban bioeconomy namely 1) Green Infrastructure, 2) Urban Farming, and 3) Biowaste valorisation. For each of these components, the opportunities and challenges are outlined about their economic, environmental, social, and health implications (Yang and Yang, 2022). Bioeconomy businesses often focus on utilizing renewable resources and adopting circular economic principles. By promoting resource efficiency, bioeconomy businesses contribute to the sustainability of cities by minimizing their ecological footprint. The idea of an urban bioeconomy holds enormous potential to right-size the relationship between economic production and natural ecosystems.

The second aspect of smart cities is their transformative potential for digital transition. Fundamentally, smart cities drive the digital transformation of urban areas, or conversely, both directions show their strong connection. The technological revolution is reaching cities, making them an unstoppable global phenomenon. Massive amounts of digital data have been produced because of the information and communication technology's (ICT) extraordinary development. Digital transformation is the use of digital data analysis and ICT as key enabler that changes of an organization and provide a new or significantly better supply of products or services. One of the widely accepted ideas that primarily depends on ICT and digital transformation—both of which are necessary to achieve city smartness—is the smart city. Strategy orientation and technological aspects can be seen as key determinants of digital transformation, which are at the same time the leading factors in smart city initiatives (Tomičić Pupek et al. 2019). The key elements of digital transformation are not possible without key enabling technologies mentioned in the previous part, and most of them are building elements of smart city.

Smart cities are based on ICT and data-driven decisions attempting to efficiently and sustainably manage all facets of urban life, such as public areas, transportation, energy and water use, and contact with local residents. A smart city is a city that is fully connected, equipped with wireless, Bluetooth, and sensor technology to improve the lives of its residents. Every physical object can be equipped with advanced sensors and connectivity to become a smart object that generates a multitude of data. (Cvetković and Adamović, 2018). The Internet of Things refers to the massive use of advanced sensors and wireless communication in all types of physical objects. Big data analytics (BDA) is the process of obtaining insights and fact-based information from large amounts of data. Smart cities and BDA are very much connected, because using BDA to inform data-driven decisions is essential to smart city development. When raw data collected from various smart city domains is converted into useful information for smart city stakeholders that is where smart cities and BDA interact. Through sensors, cameras, and other IoT devices, smart cities rely on data collection and analysis to improve the management of urban services. This enables more informed, efficient decisions that contribute to both the green and digital transition. Research results by (Osman

et al. 2022) indicate that BDA, as a data-driven decision-making enabler, have positive influence on effectiveness of decision-making in smart cities. BDA provides services to a wide range of decision-makers and stakeholders, including residents, governors, mayors, and strategic planners (Osman et al. 2022). Technological tools like automation and artificial intelligence (AI) can greatly improve city operations. Artificial Intelligence is a technology designed to enable machines to perform tasks typically carried out by humans, aiming to replicate human development, learning, and memory. In this context, AI refers to problem-solving instructions that are programmatically implemented and customized to mimic human behavior (Shtepani and Kuzari, 2024). Technologies like blockchain can enhance smart city resilience, risk management, and readiness levels, while strengthening prevention and civil protection systems. This includes improving the ability to coordinate actions and provide necessary responses during urban crises caused by natural hazards or human-induced events (Christodoulou and Kalergis, 2024). By eliminating the need for manual labor, these cutting-edge technologies can increase productivity, decrease human error, and save energy. They also give cities the ability to make data-driven decisions instantly, which improves traffic flow, resource management, and creates more sustainable urban environments.

Twin transition and smart cities – state-of-art in Republic of Sebia

Smart cities have become feasible using contemporary technology like wireless networks and other internet-based applications, which have changed the way of life in metropolitan areas (Cvetković and Adamović, 2018). Smart cities, as part of the green and digital transformation, are typically viewed as a responsibility of local governments, given their role in ensuring a better quality of life for citizens. While some cities are still refining and expanding their plans to become smart, others have already seized the opportunities presented by the idea of smart cities, adding new value to all stakeholders engaging in the living city ecosystems and acting as models of best practices (Tomičić Pupek et al. 2019). Globally there are so many successful examples of the twin transition process in smart cities. Barcelona has smart city initiatives that link the digital and green transitions, like IoT sensors that monitor energy consumption and manage waste or the use of smart streetlights that help reduce energy use by adjusting brightness according to traffic and pedestrian activity. Copenhagen is a role model of sustainability and digital innovation that aims to be a carbon-neutral city. Its approaches involve the use of smart technologies in urban planning, like smart lighting, energy-efficient buildings, and an air quality monitoring system. Green mobility solutions, such as electric vehicles, shared bikes, and smart parking systems, enhanced by digital tools to streamline city operations, are widely used in many cities striving to achieve smart city status. A prime example of smart cities in world leverages real-time data to optimize energy consumption and reduce its carbon footprint, representing how the twin transition can be achieved in urban areas. These cases demonstrate how cities can influence both digital and green transitions to become more sustainable, efficient, and liveable while addressing global challenges.

There is no evidence from Serbia with smart city examples like this. Still, following global and European policies, as well as smart city development initiatives, this topic has gained increasing attention and relevance in recent years in Serbia, at multiple levels and from different types of actors in society - from citizens to business entities and local governments to the scientific research community. In terms of twin transitions, Serbia significantly lags when it comes to the green transition, while it has made some respectful progress in the field of digital transition. The initiative to develop smart cities in Serbia primarily comes from the central level of government. Digital transformation, supported by strong digitization of public administration, has been among the priorities of the Government of Serbia for years. The regulatory framework for this area has seen significant improvements (Mashovic et al. 2024).

As part of the digital infrastructure development necessary for smart city implementation, Serbia has been highly dedicated to the development of eGovernment, making significant progress in this area. Serbia is a leader Western Balkan region when it comes to digital transformation, and the development of eGovernment is one of the most important state projects, receiving big attention and yielding notable results. The Office for IT and eGovernment continuously improves the quantity and quality of electronic services offered to citizens and businesses to make public administration as accessible as possible at any time and from any place (Kisin et al. 2024). Official projects like one of the Ministry of State Administration and Local Self-Government's "Development of smart cities based on cloud infrastructure" have started to gain attention. These projects are centred on the advancement of eAdministration to provide the technical framework for the creation of smart city development. "The Road Map of Smart Cities in Serbia" was recently unveiled as part of the initiative "Journey to Smarter Future: Building Smarter and More Sustainable Communities in Serbia." The biggest towns in Serbia, including Kragujevac, Novi Sad and Belgrade, may have the best chance of being labelled as smart cities because of the excellent IT infrastructure (Mashovic et al. 2024).

Serbia has a chance to catch up and connect with developed countries. However, the concept of a smart city is much more than individual projects and solutions, and in this sense, research so far shows that there is still no smart city in Serbia in the full sense of this concept. With digital transformation and eGovernment in Serbia, some base for smart cities development is created, but that is not sufficient for "real" smart cities. For the continued development of smart cities in Serbia, it is essential to further enhance the strategic and regulatory framework, as well as develop the institutions required for their growth. This may involve establishing legal regulations for the sector, creating a national smart city development program, and adopting planning documents at the local government level. Additionally, further infrastructure development is required, which is essential for the development of smart cities, such as the continuation of electronic communication development and the establishment of modern digital infrastructure, with a special emphasis on the development of next-generation networks, key enabling technologies and ensuring broadband internet access throughout the entire territory of Serbia. Furthermore, there is a need to strengthen information security and continue developing services following EU standards (Kisin et al. 2024).

Conclusion

The significance of urban areas in the context of Sustainable Development Goal 11, "Sustainable Cities and Communities," highlights their pivotal role in navigating the challenges posed by rapid population growth, economic expansion, and pressing environmental issues. As cities evolve into "smart" entities—centers of complex systems and dynamic activities—they emerge as essential players in achieving both sustainable and economic development.

Smart cities are at the forefront of integrating creative, sustainable, and efficient solutions to enhance urban living conditions. The continuous technological revolution presents an unprecedented opportunity to address the socioeconomic and environmental repercussions of urbanization. By investing in modern technologies, cities can become greener and more efficient, effectively positioning themselves as leaders in innovation and sustainable transformation.

The framework of smart cities illustrates the symbiotic relationship between advanced digital technology and sustainability initiatives. By incorporating digital infrastructure, real-time data, and sustainable practices, smart cities aim to optimize urban functions while

simultaneously mitigating environmental impacts. This integration not only enhances the quality of life for residents but also fosters economic growth and reinforces community resilience.

Initiatives within the smart city paradigm encompass a broad spectrum of solutions that can transform nearly every facet of urban life, from improving public health and safety to facilitating cost savings and environmental protection. The adoption of tailored technologies that prioritize data protection is vital to ensuring that these advancements honor the privacy and security concerns of citizens.

In Serbia, the digital transformation represents a unique opportunity to tackle urban challenges, promote sustainable development, and elevate the quality of life for all residents. While significant progress has been made, there remains a need for collective action among government bodies, universities, the business community, and civil society to overcome existing obstacles. By harnessing innovation and technology, Serbia has the potential to cultivate thriving smart cities that drive sustainable development for future generations.

As a final remark, smart cities embody a critical intersection between technology and sustainability, providing an actionable pathway to address urban challenges. As the journey toward these transformative urban environments continues, a collaborative approach will be essential to maximizing the benefits of smart city initiatives and ensuring a sustainable urban future for all.

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