SMART INNOVATIONS AND SMART COMMUNICATIONS IN SMART CITIES

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Abstract

The concept of a smart city is a technologically modern urban area focused on its citizens, in which contemporary technologies, electronics and sensors are applied with the aim of collecting specific data and using them for assets and resource management, as well as improving the efficiency of local services and reducing energy, operating and other costs. As such, it encompasses a wide range of initiatives, from more advanced urban transport networks and communal services, through more efficient lighting, all the way to more interactive and responsive city administration and the development of integrated infrastructure. The goal of this article is to determine the relevance and importance of the most common smart innovations and intelligent communications related to the modern concept of a smart city, by applying the desk research method. In addition to the analysis of the smart cities' global market, the article also provides a detailed overview of the most significant smart innovations and intelligent communications on which the functioning of modern smart cities rests. The authors conclude that smart cities represent our imminent future, especially in light of ongoing climate change, the threat of new pandemics and natural disasters, and the need for sustainable development.

Keywords: *smart city, smart innovations, intelligent communications, digital technologies, climate change, environment.*
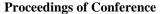
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Introduction

The European Commission defines smart cities as places where traditional networks and services are improved using digital technologies with the aim of enhancing benefits of their citizens and businesses. A smart city goes beyond the simple, trivial use of modern digital technological solutions with the aim of efficient use of resources and reduction of harmful greenhouse gas (GHG) emissions. The concept of smart cities includes a wide range of initiatives, from advanced urban transportation networks and utility services, through more efficient lighting and energy supply, all the way to more interactive and responsible city administration and integrated infrastructure [1].

A smart city is a modern, technologically rounded urban area focused on its citizens, in which modern technologies, electronics and sensors are applied with the aim of collecting specific data and using them to manage assets and resources, as well as improving the efficiency of local services and operating processes. This concept, among other things, includes the use of the most advanced digital tools and analytical visualization with the aim of collecting data, the application of digital geographic information systems for identifying problems and needs of city districts, but also the use of data-driven decision-making process in a wide range of urban administrative areas. The goal of the smart cities development is to improve the services and functioning of local administration and utility services, especially in the field of providing tax, financial, hospitality, educational, social, consulting, health and many other local urban services [2].

The contemporary world is subject to growing urbanization, while the United Nations (UN) estimates that today more than half of the global population (55%) lives in cities. The UN also roughly calculates that by 2050, two-thirds of the global population (about 68%) will live in urban areas, creating a need for much better organization of future cities. The expected growth of urbanization will require a much smarter approach to managing sustainable urban growth with the aim of creating and developing sustainable cities, both in developed and in developing countries [3, p. 1].

In 2018, the rate of urbanization was highest in North America with 82% of the urban population, in regions of South America and the Caribbean (81%), Europe (74%) and Oceania (68%). Unlike these areas, Africa is still dominated by rural populations. Along with accelerated urbanization, the successful management of urban growth, especially in poorer areas, increasingly can determine sustainable development. At the same time, the economic, social, environmental and technological dimensions of sustainable development gradually more condition the sustainable urban growth itself. Sustainable urbanization, among other things, requires the integration of urban and rural developmental policies, achieving growth while minimizing harmful environmental effects, as well as access to appropriate infrastructure and social services. Hence, it is particularly focused on the poor and vulnerable social groups [3, p. 1], leading us to the very concept of smart city used as a means for the realization of these goals.

The concept of smart cities implies the implementation of environmentally friendly initiatives and practices that improve the citizens' quality and standard of life. Smart cities perform this by using modern innovative information and communication technologies (ICTs) to collect data, optimize business operations, and improve the management of city utility and administrative services. These cities can specifically influence sustainable growth and development by encouraging recycling, circular economy and wastewater management, as

well as developing smart governance, mobility, green building, and smart economy. The ultimate goal of this concept is to encourage sustainable growth, protect the environment, improve the quality of life and urban services, and reduce operating costs. Smart cities bring with themselves numerous public benefits such as energy savings, reduction of pollution, improved air quality, infrastructure development, increased safety, and optimization of traffic and transportation of goods, services and people [4]. All these facts represent an exemplary argument for delving into the relation among smart innovations, intelligent communications, and smart cities.

The idea of smart cities boils down to a comprehensive holistic approach dominated by the use of modern innovative ICTs. The modern vision of the smart city development requires the active role of ICTs in the management, control, supervision, and communication of local urban services aimed at improving quality of life and the needs of its inhabitants. The concept of a smart city is usually accompanied by technological, human and institutional elements that represent the basis of its development. On the other hand, relevant literature sources usually highlight its economic, humane, managerial, mobility, ecological, and life dimensions [5, pp. 510-514]. Wahab et al. [6, p. 3] reviewed the sources of literature on smart cities and identified as many as their 11 dimensions, among which stand out smart economy, smart administration, smart people, smart environment, smart infrastructure, smart technology, smart living, smart mobility, smart utility services, smart security and smart agriculture.

This article consists of six sections. After the introductory part, the second section reports the used research methodology. The third section is devoted to the description of the most significant trends in the global smart cities market. While the article's fourth section provides a detailed overview of smart digital innovations, the fifth one is devoted to the analysis of the role of the most common intelligent communications used in smart cities today. The last section concludes the paper with the indication that smart cities represent our inevitable future, but also a means for achieving sustainable urban development goals.

Used Research Methodology

The article uses the desk research methodology based on available reports of relevant international organizations and data, together with a review of existing relevant sources of literature and published articles on the importance, role, advantages and disadvantages of smart cities in the contemporary world. This analysis covers all the major types of smart innovations and the role of intelligent communications that underpin the development and functioning of smart cities using available secondary data sources. More precisely, the article uses data sources from various agencies such as Statista and Gitnux, as well as published scientific papers and articles from relevant web portals with its intention of systematizing the most significant applications of modern innovative and communication technology solutions in smart towns. In addition to the desk research method, the article also uses the method of description, analysis and synthesis, historical method, and comparative method in its ultimate attempt to evoke the most significant current smart trends in smart cities.

Smart Cities in Numbers

In the dynamic landscape of contemporary urbanization, smart cities represent the crescendo of the use of digital innovations, integrating modern technological solutions and urban

infrastructure with the aim of improving the quality of life of their residents. During 2024, the global smart cities market is expected to achieve an impressive revenue growth of US\$ 10.4 billion, with its projected increased value of US\$ 165.8 billion at a compound annual growth rate (CAGR) by 2028. Although today Singapore and South Korea have primacy in the development and implementation of the smart city strategies, the highest revenue growth in the smart city market is still expected in the United States of America (USA), China, Japan, Germany and India [7].

Contrary to previous projections, the Gitnux agency expects that by the next, year 2025, the world market of smart cities will reach a value of as much as 820.7 billion US\$, signaling the accelerated global adoption of this concept. This expected jump indicates the dominant role of advanced technologies and intelligent urban planning initiatives in encouraging sustainable growth and quality of life for smart urban areas citizens. It is expected that by 2050, 60% of the global population will live in smart cities, and that by 2026, smart lighting will take precedence in the applications of this concept. Today, Amsterdam is considered the city with the largest number (170) of smart city initiatives in Europe, insisting on digital transformation and innovations in the aspects of urban life through modern ICTs solutions. While 66% of US cities are currently actively investing in smart city projects and technologies, 93% of cities globally are still in their infancy in developing their smart city strategy [8].

Smart cities can influence the decrease of income inequalities and development gaps, computerization of administrative services, further urbanization and industrialization, and thus solving the problems of transport systems, improving the quality of health and administrative services, and enhancing environmental protection. In 2021, only China (48%) had the largest number of emerging smart cities, followed by Europe (23%), India (11%), USA (7%), Oceania (5%), Japan and South Korea (2%) and Canada (2%) [9, p. 7]. Smart cities today represent complex urban ecosystems consisting of a mix of technological, social, organizational and business dimensions. In the period from 2012 to 2017, the total global consumption of smart cities was mostly directed to the administration and education sector (24.6%), the smart energy sector (15.8%), smart healthcare (14.6%), smart security (13.5%), smart infrastructure (13.1%), smart mobility (8.7%), and smart building and housing (9.7%) [10]. Finally yet importantly, smart cities today are witnessing an accelerated CAGR of Internet of Things (IoT) adoption rate from US\$ 130.6 billion in 2021 to an expected US\$ 312.2 billion in 2026, highlighting the importance of investments in their direct digital transformation [11].

Smart Innovations for Smart Cities

Digital technologies are networking people. They collect data and connect urban processes in their intention to improve the quality of local services and the living standard of the urban population. The need for innovative technological applications is all the greater if one takes into account the numerous urban challenges of climate change, as well as the danger of new pandemics and natural disasters outbreak. In addition, with the growing threat of attacks in urban areas, the emergence of infectious diseases and misuse of digitalization, there is an urgent need for the development of smart cities since they provide predictability, security, surveillance and control, thus improving the quality of life and enabling the sustainable urban development [12, p. 554].

As already discussed, technology-driven innovations can minimize energy consumption, optimize mobility, urban planning and waste management, as well as improve the quality of education, health services and general safety of citizens. At the same time, these initiatives raise the transparency of the urban infrastructure itself, encouraging networking, collaborative innovation, inclusiveness and creativity [13]. Smart cities rely on various digital technologies, specially favoring the collection of data through modern sensors and Internet of Things (IoT) technologies, which are further processed through Artificial Intelligence (AI) systems. Today, among the most significant innovation efforts and initiatives in smart cities, smart mobility, the digital citizen concept, smart energy, e-government, green urban planning, improved waste and water resources management, smart buildings and intelligent digital agriculture stand out. While some of them are already well known from our everyday life, in the following text we describe some of the most interesting and latest smart innovations enhancing the further development of smart cities.

Smart mobility is a mix of different transport methods that is integrated with the latest technological solutions such as sensors, big data analytics, IoT, AI and telematics. This innovation represents a true revolution in the urban transportation ecosystems, going beyond improvements to traditional traffic flow [14]. Smart mobility driven by modern technologies is an innovative response that aims to improve the efficiency, resilience and sustainability of modern urban transportation networks and systems. In this process, a special role belongs to environmentally friendly forms of transportation, supported by the appropriate infrastructure for smart charging of electric vehicles (EVs). Autonomous vehicles, robot taxis, and water taxi services are just some of the innovative transportation possibilities that are expected to develop in the near future. Smart mobility, among other things, implies the public availability of traffic information with the aim of saving time, money and harmful GHG emissions, as well as improving the travel experience. Therefore, this innovation appears as a basic prerequisite for the smart transformation of modern cities [15, p. 5].

Smart energy can be described as a flexible intelligent innovative system of energy production and consumption optimization that relies on innovative technologies in the building of sustainable energy management systems. The concept of smart energy represents the integration of AI systems, machine learning, data analytics technologies, and IoT solutions in increasing the efficiency of contemporary energy systems [16]. A smart energy system represents a kind of combination of smart electricity, smart heating networks, smart gas networks, and modern production and storage technologies, which is aimed at optimizing the entire energy system [17, pp. 323-350]. Smart cities have a special need for smart energy systems as they provide reliable, efficient and environmentally friendly energy supply. Based on interconnected IoT solutions, it is possible to improve the decision-making process on production, storage and distribution of energy. On the other hand, smart networks enable the monitoring of these processes in real time. At the same time, based on machine learning techniques, it is possible to predict the demand for energy, as well as potential collapses of the energy system itself. While virtual power plants help in the efficient distribution of electricity, big data analytics and machine learning ensure the reliability and efficiency of the power system through its predictive maintenance [13].

The concept of *green urbanism* refers to the attempt of creating ecologically suitable and cleaner cities through the application and development of electric public transport, the construction of energy-efficient buildings, the use of renewable energy sources and, in general, the greening of public areas. Green urbanism can also be seen as an approach to

building the new identity of cities that creates environmentally friendly urban neighborhoods by reducing waste and harmful GHG emissions, expanding green urban areas and encouraging the electrification of mobility. The goal of green urbanism is to reduce the consumption of energy, water, and raw materials in every phase of the smart city life cycle, while this innovative concept especially insists on optimizing energy consumption, green building, recycling, circular economy, etc. [18]. In addition to environmental protection, green urbanism is also aimed at favoring social sustainability and healthy communities, encouraging the process of greening, expanding green areas, creating new parks, afforestation, and purifying water and air. In this way, *green urban planning* helps to mitigate the effects of climate change, reduce traffic GHG emissions, improve the health of the population, encourage social inclusion and integration, reduce waste and use clean energy, etc. In this sense, green urban planning, in its confrontations with the negative effects of climate change, targets the sustainability and resilience of smart cities. The imperative of decarbonization is shaping the design of green urban environments, with the ultimate need for expanding green spaces, public parks, private gardens and biodiversity, as well as cleaner air. Green urban planning also insists on the application of innovative architectural solutions that use environmentally friendly building materials, adequate wastewater storage and management techniques, and energy-efficient design with the aim of reducing the undesirable carbon footprint [13].

Although not entirely new, the idea of *smart buildings* is gaining importance in many cities around the world. Intelligent buildings also enable use of resources more efficiently and smarter development of processes, expanding the capacities of modern buildings, their functionality, efficiency, reliability, flexibility, interactivity, and sustainability. Today, the concept of smart buildings is increasingly linked to the development of technologies in the direction of automation and integration with their users, as well as to connectivity, mobility, health and safety, well-being, efficient use of resources, reduction of pollution, and encouragement of green sustainable development. Smart buildings are based on the intensive use of ICTs that enable the connection of physical infrastructure aimed at optimizing public services, availability of information, participation in public life, integration of intelligence aspects, sustainability, improvement of quality of life, and automation of systems. As such, smart buildings influence the development of smart cities, contributing to their favorable interaction with the living environment, smarter flow of energy, matter and information, smarter decision-making in real time, smarter management of energy production and consumption, etc. [19, pp. 1-3]. In the conditions of the climate change challenges and the danger of the outbreak of new pandemics and infectious diseases, the modern construction industry creates flexible automated living spaces, using technologies of remote control and automated control of buildings. The emergence of high-tech building materials, smart sensors, IoT technologies, cloud computing, AI, and wireless Internet access can also collectively facilitate real-time monitoring, predict and optimize energy use, identify security threats, and optimize the use of resources [13].

Last but not least, *intelligent digital agriculture* is based on smart innovations in robotics, big data analytics, AI and IoT technologies that have made a big step towards managing modern agricultural systems and optimizing the workforce. Smart agriculture today uses applications of wireless sensors with the aim of monitoring the condition of soil, plants, livestock and infectious diseases. Smart agriculture increasingly relies on automation of food production, integration of vertical indoor farming systems, smart greenhouses, renewable energy sources,

smart nanomaterials, as well as AI-driven systems. Today, AI is increasingly used to analyze data, optimize decisions, fine-tune lighting and control air parameters, which further leads to waste reduction, increased yields and improved quality of agricultural products [20]. Thus, intelligent urban agriculture has a special role in smart cities due to their need for sustainable agricultural production. Urban agriculture includes various imaginative and innovative practices such as community gardens, rooftop farming, smart greenhouses, controlled environmental agriculture (CEA) in greenhouses, and futuristic vertical farms, thus also contributing to the sustainable development of smart cities themselves [13].

Smart Communications for Smart Cities

The importance of communication is undeniable in all segments of our daily life. Communication is a process in which information is transmitted and received. Through communication, people try to reach an agreement by conveying symbolic messages, while it consists of spreading stimuli and their perception, influence, use and action. In communication, the following two factors have a dominant role: a) the sender's factor and b) the receiver's factor. In this way, communication takes place in two spatial locations, where the sender (source) and receiver (user) are located, while exchanging messages with each other [21]. Through the process of communication, the way of treatment and construction of the smart cities themselves can also be observed. Thanks to modern digital technologies, this connection and way of communication among people is reflected in the building of smart cities. While a person using digital technologies appears as its sender, the smart city is the receiver of the transmitted information.

Seen through the prism of contemporary communications, the smart city can be identified with the human body. A smart city consists of blocks of smart buildings (human muscles), parks and green areas that, by analogy with human lungs, help purify the air and provide oxygen. The concept of a smart city also consists of streets and avenues that can be identified with human veins and arteries. Human being also has his/her senses through which information reaches his/her brain. The senses further send information to its brain about what is happening in the environment and signal it how to adapt the body to the given situation. If the same strategy were to be applied to a smart city, its built-in sensors would collect data from the environment, so that based on all the collected data, smart practical applications would be created for the daily life of its citizens. In addition, all that collected data helps the city to constantly learn and adapt, which rightfully gives it the epithet of a smart city [22, p. 99].

In recent times, communication and technological innovations have gained great importance in terms of ensuring connectivity in smart cities. Connectivity plays a huge role in smart towns since it enables the collection, processing and distribution of data with the aim of increasing the operational efficiency of urban services and making better decisions at the local level. In smart cities, a smart telecommunications infrastructure can achieve these goals, relying on a large number of digital devices and various communication technologies that include wireless sensor networks, machine-to-machine (M2M) communications, vehicle-to-vehicle (V2V) communications, network virtualization, gateways and business automation processes [23, pp. 1-2].

Smart cities also use smart communication infrastructure to deliver a variety of local services such as waste management, water storage, parking and other utility services management. Through a network of interconnected sensors and devices, smart cities can optimize the use of resources, reduce business costs, improve the quality of life of citizens, and lead to an increase in their general comfort. The importance of communication infrastructure in smart cities is reflected in the exchange of data in real time, improved efficiency of resource use, improved mobility and connectivity, as well as in the personalization and efficiency of smart public services aimed at the needs of their residents. Such technological and smart solutions further promote connectivity, sustainable development, public safety, more efficient transportation, and the overall safety of their residents [24].

The development of smart communications has led to the rise of intelligent communication systems intended for a large number of applications in smart cities. These systems are based on the close interaction of sensors, modular devices and actuators, paving the way for a large number of disruptive innovations and smart applications with a huge impact on contemporary society. Current smart communication systems are based on autonomous architectural schemes such as IoT, smart grids, smart cities, smart economy, smart industry, big data analytics, and comprehensive global connections that have great social impact and create services with great value added for individuals [25, p. 1]. Modern communication networks further support complex communication services that require smart network management techniques based on the synthesis of embedded intelligence and the delivery of performance information [26, p. 415].

Finally, considering the noticeable growth of urbanization in the modern world and the huge role of ICTs in the sustainable development of urban neighborhoods, it is a huge challenge to realize their sustainable urbanization of the desired level and scope. Networks that are designed for the needs of smart cities have their own unique characteristics that distinguish them from traditional, general-aimed network and communication systems. An extremely high density of smart devices primarily determines these intelligent networks, followed by unusual traffic patterns, unstructured wireless typology, heterogeneity of the technologies used, high security and the simultaneous use of several different technologies. However, smart cities are also associated with a large number of particular challenges, such as the lack of standardized solutions, difficulties in interconnecting independent networks, M2M and V2V interactions and the development of commercially successful products, such as real-time parking monitoring, internet of water and other smart city-wide integrated solutions [27, pp. 1-3].

Conclusion

A smart city is a modern, technologically rounded urban entity that uses contemporary technology, sensors and various digital-technological innovations to collect data, efficiently manage assets, resources and services, and thus to improve the quality of life of its citizens. By providing services and solving acute urban problems, a smart city leads to improved accessibility of transportation services, savings in energy use, improved quality of utility services, more interactive and responsible city administration, integrated infrastructure and environmentally friendly urban solutions, at the same time improving social services and encouraging sustainable development of urban neighborhoods. For this purpose, smart cities use a mix of communication networks, software and user interfaces, as well as a variety of

vivid digital innovations such as the Internet of Things, Artificial Intelligence, telematics, machine learning, big data analytics, etc. Given the fact that the contemporary world is subject to growing urbanization, as well as its expected further intensive growth, the emergence of the concept of smart cities represents a revolutionary trend in the urban development of contemporary global society.

During 2024 alone, the global smart cities market is projected to achieve an impressive revenue growth of US$ 10.4 billion, indicating the growing importance of smart cities in the world. Although today Singapore and South Korea have primacy in the development and implementation of the smart city strategy, the highest revenue growth in the smart city market is still expected in the USA, China, Japan, Germany and India. This article provides a detailed overview of the most important smart innovations and the role of intelligent communications that have accompanied and marked the development of smart cities in the world so far. The discussed smart digital innovations and intelligent modern urban communications unequivocally improve the quality of life and standard of living, enabling better integration of people with city infrastructures and more efficient urban service management. All these trends lay the foundations for the further development of smart cities around the world. In this sense, they represent our imminent future, especially in the light of ongoing climate changes, the risks of new pandemics and natural disasters outbreak, as well as the need for fostering sustainable urban development.

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