

ARTIFICIAL INTELLIGENCE IN SHAPING THE SMART SUSTAINABLE CITY

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Abstract: In recent years, there has been an increased interest in artificial intelligence (AI) and its various applications in many sectors of the economy, in education and in people's everyday lives. The study of the application of artificial intelligence is also evident in many articles on smart cities. The aim of this study is to reveal new trends in the evolution of the Smart City and the formation of conceptual assumptions and practical applications of the technology in the Smart Sustainable City. The research focuses on literature analysis and content analysis.

Keywords: Smart City, Smart Sustainable City, Artificial Intelligence

1. INTRODUCTION

In recent years, there has been an increased interest in artificial intelligence (AI) and its various applications in many sectors of the economy, in education and in people's everyday lives. The study of the application of artificial intelligence is also evident in many articles on smart cities. The practical application of AI in city management is also developing rapidly, both in the area of ICT application and in the management of many city functions.

Artificial intelligence is a very common term not only in exact sciences, technical sciences, but is also increasingly appearing in humanities, social sciences and interdisciplinary research. The humanistic context of this research mainly focuses on ethical aspects. In fact, today artificial intelligence can be considered from the perspective of different scientific disciplines and used in a variety of research.

But cities are smart not because of artificial intelligence, but because of their inhabitants, i.e. the natural intelligence of humans. Modern technologies based on artificial intelligence algorithms only support the various processes of city functioning in the areas of city management, waste management, traffic management, security management, crisis management, etc. Smart cities should not be associated only with artificial intelligence and modern information and communication technologies, although this is also important in the functioning of modern cities and societies, but more with human intelligence, intellectual capital, social capital.

There are many definitions of Smart City and in these definitions we must pay attention to the different generations of their development. Referring to the concept of the Chilean researcher Boyd Cohen (2015), we can distinguish 3 generations or three phases of Smart City development:

- Smart City 1.0 - the initiator of the use of technology in cities was the ICT sector;
- Smart City 2.0 - the initiator of technology deployment was the local authority, the city government;
- Smart City 3.0 - the initiators of ICT solutions in the city are the citizens themselves, who consciously articulate their needs.

The tendency to number all successive phases of development (industry, network, society) is also revealed in the case of the Smart City. Smart City 4.0 and 5.0 concepts are emerging in research:

- Smart City 4.0 - cutting-edge technology, networking and knowledge sharing to meet the goals of sustainable urban development and its citizens (Kinelski, 2022, Głębocki, 2021),
- Smart City 5.0 - an ecosystem of intelligent services based on multi-agent technology, in which systems based on artificial intelligence algorithms interact with people. By design, it is an ecosystem that can harmoniously balance all spheres of life and the conflicting interests of different urban actors (Svítek et al., 2020).

One of the best-known definitions is that of W. Mitchell (2007). This definition is open-ended, that is, its author assumes its successive layers with the process of urban development and its 'smart dimension'. The smart city, as Mitchell calls it, is a combination of increasingly efficient digital telecommunication networks (compared to nerves), ubiquitous intelligence (compared to brains), sensors and tags (compared to sense organs) and software (compared to knowledge and cognitive competence). This system does not exist in isolation from other functioning urban systems (dimensions/intelligences), it combines with them to create a new quality of life for citizens. Therefore, it seems that - in line with the Smart City concept itself - the definition should be more in concert with the inhabitants - it should have a social dimension. Such a definition was proposed by N. Komninos (2008), which can be a kind of complement to the definition proposed by Michell. According to Komninos, a Smart City is an area (municipality, county, cluster, city, city-region) consisting of four key elements:

- an active population carrying out knowledge-intensive activities or a cluster of such activities;
- effective actors, institutions and procedures for knowledge production, enabling its acquisition, adaptation and development;
- developed broadband infrastructure, digital spaces, e-services and online tools for knowledge management
- innovation potential (Kuzior and Sobotka, 2021).

Methodologies and approaches developed in combining the concept of AI with methods of organizing Smart City can be widely used both in related fields of management: safety and security (Deja et al., 2021), lean management (Ulewicz and Ulewicz, 2020; Ulewicz et al., 2021) and controlling (Knop et al., 2019; Ulewicz et al., 2020). It also may be analytical approaches using methods different from the traditional one: bootstrap resampling (Pietraszek et al., 2016), dimensionality reduction (Pietraszek and Skrzypczak-Pietraszek, 2015), as well as in the so-called hard industrial fields (Radek et al., 2014; Pietraszek et al., 2017) that will encounter AI implementation problems. These

include: sustainable chemical technologies (Kozłowski et al., 2002; Ulewicz et al., 2003; Radzymińska-Lenarcik and Ulewicz, 2018), laser welding techniques (Radek et al., 2018), non-destructive testing (Patek et al., 2014), special technological coatings (Radek and Konstanty, 2012; Radek et al., 2019), as well as biotechnological production (Skrzypczak-Pietraszek and Pietraszek, 2014).

2. METHODOLOGY OF RESEARCH

The aim of the study is to reveal new trends in the evolution of the Smart City and the formation of conceptual assumptions and practical applications of technology in the Smart Sustainable City. The research focuses on literature analysis, content analysis. The Scopus, Google Scholar and WoS databases were used to investigate the growing trends of interest in Smart City and Smart Sustainable City topics. Titles, abstracts and keywords of the entire content of the indicated bibliometric databases from the beginning of indexing to April 7, 2024 were used to search for the above terms.

3. RESULTS

During the development of the Smart City concept, researchers and practitioners in the implementation of ICT and AI solutions quickly realised that technology alone was not enough to shape better living conditions for communities. Therefore, the evolution of the Smart City has moved towards the rational, optimal use of technology and the shaping of a Smart Sustainable City (SSC). SSC is defined as an "...innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" (UNECE).

Among the aforementioned Smart City generations, the concept of Smart City 4.0 is close to the understanding of the Smart Sustainable City, which refers to sustainable development and therefore has generational and intergenerational responsibility at its axiological basis. It focuses on improving the quality of life and stimulating economic growth, but also on protecting the environment and its resources for future generations. The main task for the current generation is to improve living conditions, safety, air quality, noise reduction, etc. Within the framework of public consultation, deliberation or dialogue, city residents co-determine the implementation of new technologies in the city. It is the task of the city authorities to implement and ensure that these solutions work well.

An analysis of bibliometric databases allows us to conclude that interest in Smart City issues has increased significantly in recent years. The Scopus database identifies 49,366 records in titles, abstracts and keywords. The oldest indexed publication dates back to 1997 (Shetty, 1997). As of 2024, 1,247 publications are already dated (accessed: 07.04.2024). WoS finds 16,163 scientific papers, with only 244 dated to 2024 (accessed: 07.04.2024).

The Google Scholar database for the query "Smart City" finds 465,000 records, including 13900 dated 2024 (accessed: 07.04.2024). In each database, an increase in interest in this topic can be observed (cf. Figure 1 - list for 2015-2023) with small fluctuations between 2022 and 2023, in which a downward trend can be observed, mainly in the Google Scholar database.

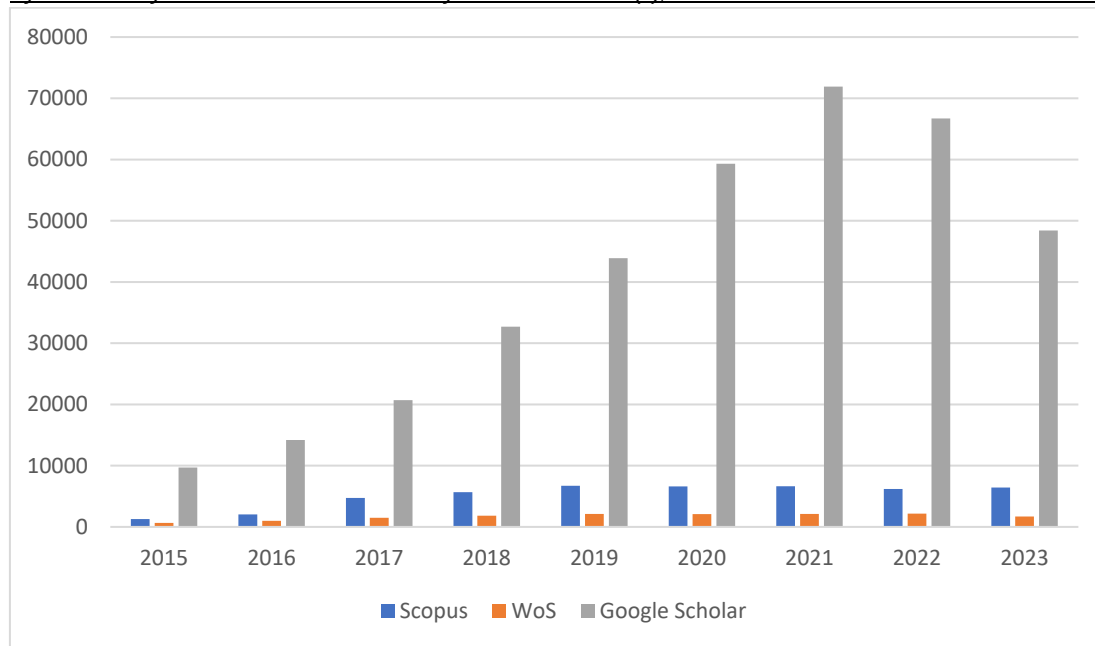


Fig. 1. "Smart City" in bibliometrics

Source: own study based on data from Scopus, WoS and Google Scholar

Table 1. "Smart City" in bibliometrics

Year	Scopus	WoS	Google Scholar
2015	1275	661	9700
2016	2034	1007	14200
2017	4727	1491	20700
2018	5682	1824	32700
2019	6725	2115	43900
2020	6607	2083	59300
2021	6647	2122	71900
2022	6206	2172	66700
2023	6431	1692	48400

Source: own study based on data from Scopus, WoS and Google Scholar

There are far fewer publications directly dedicated to the "Smart Sustainable City". A search in titles, abstracts and keywords showed that the Scopus database contains 429 publications, WoS – 107, Google Scholar – 4,000.

4. DISCUSSION

The primary objectives of a Smart Sustainable City are to improve the quality of life, the efficiency of urban services and the protection of the environment. Modern technologies, including artificial intelligence algorithms, are tools in shaping SSCs. We can use different models to design an SSC. The design of such a city must be based on the collaboration of different actors. The key to operationalising the assumptions of sustainable urban development is knowledge, its diffusion, distribution and application in the processes of generating and implementing innovations that serve economic and social development, increase people's quality of life and protect the environment. Properly targeted innovation can serve to solve the problems of civilisation. Universities and research institutes are the

most predestined places for the creation and subsequent sharing and distribution of knowledge. From there, knowledge spreads to all actors in social, economic and political life. The optimisation of knowledge diffusion and distribution processes for the realisation of sustainable development principles must take into account the feedback of the various actors. A model of knowledge diffusion and distribution, taking into account feedback and multi-directional information flows, can be helpful in designing and planning the development of SSCs (Kuzior and Kuzior, 2020; Kuzior et al. 2024).

There are relatively few academic studies on the use of artificial intelligence in shaping the Smart Sustainable City. The Scopus database finds only 28 publications in titles, keywords and abstracts.

Saleh et al. (2024) point to the importance of using artificial intelligence (AI), building information modelling (BIM) and the Internet of Things (IoT) in shaping smart sustainable cities. They describe the application of these solutions in architecture, engineering and construction. They point to the performance and sustainability of materials, life cycle and operational efficiency and environmental impact. They describe the integration of renewable energy, sustainable material selection and intelligent building control. Kim et al. (2024) point to a potential new era of SSC, the 6G era, in which devices and machines, vehicles, sensors and robots, will be connected to communicate, respond and operate in real time. This will result in more efficient urban operations and services through non-terrestrial networks, advanced mobile edge computing, vision-aided wireless communication, artificial intelligence (AI)-based wireless communication, and integrated sensing and communication. Kommey et al. (2024) points to the use of artificial intelligence algorithms in optimising energy consumption in smart homes. A similar topic is addressed by Gualandri and Kuzior (2023). Marques et al. (2023) present a bibliometric analysis of the use of Artificial Intelligence in SSC services. Hasan et al. (2023) provide guidelines for the development of SSCs using the Internet of Things and AI in their publication. Assayed et al. (2023) reason that Smart Sustainable Cities must be based on smart technology and smart education. In education, they propose the use of a novel chatbot. Badidi (2022) points to the possibilities of using edge artificial intelligence (edge AI) and Blockchain in SSCs. Many articles on Smart City and Smart Sustainable City refer to Pandemic Covid-19 (Fatewar and Vaishali, 2021; Kuzior et al., 2022; 2021; Vasilyeva et al., 2021; Sadjadi, 2024). The issue of modern technologies in the formation of Smart Sustainable City and Smart City is shown in different development contexts (Deja et al., 2023; Kwilinski, 2023; Nurbatsin et al., 2024; Yigitcanlar, 2024; Mazon, 2024; Tutak and Brodny, 2023; Mańka-Szulik and Krawczyk, 2022, Kuzior et al., 2023). Modern technologies, including those based on artificial intelligence algorithms, can be helpful in designing and implementing a Smart Sustainable City. However, it is also important to bear in mind the negative consequences that may become apparent when using them (Goyal and Gnanasigamani, 2024; Tok and Chattopadhyay, 2023, Turoń et al., 2020).

5. CONCLUSION

Smart Sustainable Cities utilize Information and Communication Technologies and Artificial Intelligence to improve quality of life and operational efficiency while ensuring sustainable development these technologies are integral in meeting the needs of current and future generations without exceeding environmental limits at local global and planetary levels. The development of SSCs relies on a solid foundation of knowledge that promotes rational technology use and supports democratic processes this framework

helps in shaping a civil society that is well informed and engaged in the governance of urban spaces. SSCs focus on nurturing human and social capital recognizing that technology alone is insufficient for sustainable urban development the success of these cities hinges on the development of environmental awareness and a environmental culture that supports sustainable practices technological tools in SSCs serve to bolster societal and economic development while safeguarding the environment these tools need to be effectively integrated within the urban framework to maximize benefits and minimize potential negative impacts the concept and implementation of SSCs are continuously evolving urban planners and policymakers must remain adaptable to integrate new technologies and innovations that could further enhance the quality of life and sustainability of urban environments.

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