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Smart city in the context of mapping research fields

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Abstract. The aim of this study is to explore the conceptual structure of the research field as well as compare and contrast it with the findings of previous bibliometric smart city research. The study process has been focused on the following research questions (problems): (1) what are the leading themes in the smart city research field? (2) what are the emerging topics in the smart city research field? (3) what are the similarities and differences with the findings of other bibliometric studies regarding the conceptual structure of the field?

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1. Introduction

Cities are home to over 58% of the world's population, which explains the attention they attract among various specialists in most academic disciplines. Concern for the quality and conditions of life in cities and for the quality of the natural environment is expressed by numerous innovative, sometimes very surprising technological and technical solutions that relate to various spheres of activity and life in the city. These solutions touch upon issues of urban transport, housing construction, the introduction of domestic energy-saving and anti-emission solutions, and the appropriate spatial arrangement and composition of green areas. These issues are very important because the number of urban dwellers is constantly growing and the number of cities and large metropolises is increasing; it is estimated that, in less than three decades, i.e. by 2050, almost 68% of the population of our planet will live in cities.

We note both negative and positive consequences of urbanization. On the one hand, cities struggle with numerous problems, but, more importantly, they also witness progress and socio-economic development. It is here that new and diverse technical and technological solutions are created and introduced to optimize cities' capacity to function as organisms in which human activity interacts with the natural environment. Cities provide opportunities to alleviate and solve the problems of the modern world; they have enormous power. A rational way to solve the unfavorable consequences of management and life in the city is to implement the concept of smart cities (Szymańska, 2023). Szymańska in *Smart cities* discussed implementations of the smart city concept in numerous countries around the world, pointing to the diversity of approaches – from technological to socio-economic). Such undertakings capitalize on the city's energy savings and its healthy metabolism, attenuating, adapting to and, most importantly, mitigating climate change impacts (Szymańska, 2023).

When was the smart city concept born and what is it? There is no single definition of a smart city in the literature. Numerous researchers and practitioners have offered definitions, adopting different understandings depending on what element of city life they pay more attention to. This is reflected herein in the section in the context of mapping research fields.

Numerous publications show that the concept of smart cities appeared as early as 1974, when the city of Los Angeles attempted to create the world's first urban Big Data project (Community Analysis Bureau 1974; Sharifi et al., 2021a, 2021b, 2021c). Twenty years later (1994) in Amsterdam, in the pursuit of smart cities, the concept of a virtual "digital city" was created to promote the use of the Internet among the local population (Alberts et al. 2017). Since then, according to Sharifi (2020, 2021) and Sharifi et al. (2021a, 2021b, 2021c, 2024), there has been extensive research and attempts to create digital infrastructure for a smart city, with large ICT corporations such as IBM, Cisco and the business of smart cities (Swabey, 2012; Allam, & Newman, 2018), especially in terms of research and development. For example, in 2008, IBM launched the "IBM Smarter Planet" program, which aimed to explore and test how applying sensors, networks and analytics across various urban structures could increase efficiency and thereby identify business opportunities. The success of this program led to the corporation announcing, in 2009, a $50-million Smart Cities Campaign aimed at helping cities achieve efficiency and effectiveness while overcoming certain contextual urban challenges (IBM, 2010). Following widespread use of technology in various urban spheres, the concept gained acceptance in various cities in developed economies in 2011, with Barcelona at the forefront (Gascó-Hernandez, 2018) (see Szymańska, 2023).

Many researchers emphasize that the smart city concept first appeared in a scientific publication in 1992, marking the birth of a new era in urban innovation (Mora et al., 2018). Other authors point out that publications relating to the concept of smart cities can be divided into two periods, the first from 1991 to 2015 and the second from 2016 (Sharifi et al., 2021a, 2021b, 2021c). Since 2016, the literature discussing this concept has been growing steadily, as has the number of initiatives that cities around the world have launched to fulfil their ambitions to become smart (see Szymańska, 2023). In this regard, numerous researchers have conducted bibliometric analyses of publications on smart cities from 1990 to 2023 inclusive, based on the Scopus and Web of Science databases (Ingwersen & Serrano-López, 2018; Mora et al., 2018; Guo et al., 2019; Li, 2019; Mora et al., 2019; Wamba & Queiroz, 2019; Winkowska et al., 2019; Zhao et al., 2019; Martinez-Toro et al., 2020; Zheng et al., 2020; Bajdor & Starostka-Patyk, 2021; Sharifi et al., 2021a, 2021b, 2021c; Wang et al., 2021; Boulanger, 2022; Rejeb et al., 2022; Jebbar et al., 2024; Lundberg, 2024). The persistence of the interest in the smart city concept is also confirmed by the present study.

The smart city concept is still gaining popularity, as reflected in the growing number of publications on the topic and its various implementations in many countries around the world. Nevertheless, there remains no universally agreed definition of what makes a city "smart" (Szymańska, 2023). The research conducted and the scientific knowledge acquired still do not provide a clear answer as to what should be termed a "smart city". Numerous publications, including the works of Mora, Deakin and Reid (2018), show that we have one term – "smart city" – but that different interpretations of it exist. As those authors emphasize, based on the works of Hollands (2008), Paskalev (2011), Nam and Pardo (2011a, 2011b), Alkandari et al. (2012), Chourabi et al. (2012), Albino et al. (2015), Meijer and Bolivar (2016), Mora et al. (2017) Komninos and Mora (2018), and Appio et al. (2019), there is still no consensus as to what makes a city smart, and there are discrepancies in how the smart city is conceptualized and defined (Lundberg, 2024).

Some authors use the term "smart city" in relation to urban management approach and methods (Van der Meer & Van Winden, 2003); others use it to refer to applied solutions that combat social problems; others to applications that address environmental problems; and yet others use the term in relation to cities saturated with modern ICT infrastructure.

For example, Komninos (2002a; 2002b) defines a smart city as a space with high innovation and learning capacity, creativity, higher education and research and development centers, digital infrastructure and communication technologies, as well as a high level of management efficiency. Others recognize cities as smart if they invest in human and social capital (when they have such capital) and in traditional and modern communication infrastructure (ICT) to ensure sustainable economic development and a high quality of life (Caragliu Del Bo & Nijkamp, 2011: 70); still others when they manage their natural resources wisely and when they run a participatory governance system (Caragliu et al., 2009: 60; Caragliu, Del Bo & Nijkamp, 2011).

A relatively comprehensive definition of smart cities is included in the article entitled "Are 'smart cities' smart enough?", in which authors from the Senseable City Laboratory at the Massachusetts Institute of Technology presented a multi-faceted understanding of them based on a literature review (Roche et al., 2012). The researchers note that a smart city should be viewed as instantiating a complex aggregation of factors, with the following being analyzed: the condition of hard infrastructure and its consideration of care for the natural environment; the availability and use of information and communication technologies (ICT), both by residents and by public administration (Graham & Marvin, 1996; Roller & Waverman, 2001); the quality of human and social capital as expressed through such metrics as the presence of a creative class (Florida, 2002), residents' level of education (Berry & Glaeser, 2005; Glaeser & Berry, 2006), and the ability to generate knowledge spillover, i.e. the productive concentration and exchange of knowledge through intensive face-to-face contacts among city inhabitants (Breschi & Lissoni, 2001; Fu, 2007; Capello, 2009). Furthermore, the smartness of cities should be measured by their participatory governance, their smart economy, their smart urban mobility, and their smart strategies with regard to environmental protection and natural resource management. However, the decisive entity is an independent, self-reliant citizenry which consciously acts to improve the quality of life (Roche et al., 2012). Each of these aspects encourages residents to be active in creating a new, better social, economic and environmental space.

Attempts to comprehensively address the concept of the smart city have been undertaken by researchers (e.g., Giffinger & Haindlmaier, 2010; Cohen, 2011, 2012a, 2012b, 2015; Albino et al., 2015). Nevertheless, they also point out (along with many other authors) the lack of transparency and clarity as to what should be considered a smart city, what a smart city is, and what the components of a modern smart city are in reality. They emphasize that some people still understand them very narrowly, seeing them only as cities that make extensive use of information and communication technologies (ICT). Such a narrow understanding does not reflect the multiplicity of the aspects of a city's life and development. The above-mentioned researchers have organized and analyzed the existing definitions and concepts of smart cities and have proposed a theoretical framework identifying six key dimensions that influence a city's designation as "smart", as well as having created an integrated conceptual model reflecting which city sectors work to afford a city the label of "smart city".

Giffinger and Haindlmaier (2010), Cohen (2011, 2012a, 2012b, 2012c, 2015) and Albino et al. (2015) (based on the work of Giffinger & Haindlmaier, 2010) propose a broad definition (or understanding) of a smart city as the manifestation of an integrated approach to improving the efficiency of the city, improving the quality of life of its inhabitants and growing the local economy (DeAngelis, 2013).

Inspired by many studies e.g., Cohen – studies by the Center for Regional Studies of the Vienna University of Technology, studies by the Siemens group in creating the Green City Index and studies and experiments in creating the Territorial Model of Buenos Aires (Modelo Territorial Buenos Aires 2010–2060), and many other works, they proposed six main dimensions that constitute the concept of a smart city. These have been widely accepted in the scientific discourse on the idea of the smart city. Slightly expanding the content or scope of the individual dimensions, these are (quoted after Szymańska, 2023: 93–94):

- smart people – a learning society; a society initiating changes; using ICT; an information society (johoka shakai) that strives to improve the functioning of the city and optimize living conditions; in other words, it fits into the concept of a "city of intelligent communities" ("intelligent city"). A city of smart communities is a city that has a highly educated society, a society that learns throughout life, an innovative society that is open and receptive to the implementation of modern technologies. A city of smart communities is a city that provides free Internet access to various government offices, city administration, cultural, e-learning and educational services (libraries, sound libraries and others). It is a city of civil society that participates in city management and making decisions regarding pro-development activities in the city.
- a smart economy – cities should demonstrate innovation, creativity, high productivity, flexibility of labor market, flexibility of business profile; a competitive and highly efficient economy that favors the creation of local and global connections and the open exchange of goods, services and knowledge; advanced use of ICT, delivering new products and services and implementing optimal business models;
- a smart environment – a smart city manages natural resources rationally and sustainably, cares for the quality of the natural environment, minimizes pollutant emissions, optimizes energy consumption, introduces passive buildings, uses renewable energy sources; environmental and financial costs are optimized using ICT to control and monitor the state of the environment – air, water, housing, heating, street lighting, municipal waste, etc.; management is based on sustainable development principles and applies sustainable spatial planning;
- smart governance – a smart city creates an effective and transparent city management system based on cooperation and collaboration among the authorities, residents and local economic entities and uses modern communication and management technologies (e-governance) in the functioning of the city. Therefore, smart public management has the following factors playing a fundamental role: transparency of management, quality and availability of public services (Nam & Pardo, 2014) and social participation in decision-making. As many researchers emphasize, it is smart management that creates the conditions for integrating and implementing the remaining five dimensions of a smart city (Giffinger et al., 2007; Caragliu, Del Bo & Nijkamp, 2011; Manville et al., 2014; Cohen, 2015);
- quality of life (smart living) – a smart city creates an optimal living environment for its inhabitants through: integrated, extensive access to ICT infrastructure; high-quality public services relating to health, safety, cultural life, sports and recreation; and a high-quality natural environment;
- smart mobility (transport and communication) – a smart city implements integrated transport and logistics systems, creates intelligent transport systems, uses zero-emission transport, introduces integrated traffic management and introduces advanced information and ICT to electronically process, collect and transmit information. ICT makes a huge network of connections among the city's resources.

Over the last decade or so, the smart city concept has become a key tool for finding optimal, effective solutions to the challenges posed by modern cities, i.e., reducing energy needs and addressing environmental, social and economic challenges.

The broader idea of smart cities has always encompassed earlier concepts and implementations, e.g. the eco-city, the green city, the smart sustainable city, the innovation city, the city of intelligent communities, etc. (Szymańska & Korolko, 2015; Szymańska, 2023).

Pursuing the smart city idea involves using and implementing various eco-innovative concepts and applications as a manifestation of the sustainable development of cities and regions, bearing in mind that sustainable development covers all aspects and areas of human activity. As mentioned earlier, the city of the future is a smart city that rationally manages natural resources, cares for the quality of the natural environment, minimizes pollutant emissions, optimizes energy consumption, introduces passive construction, uses renewable energy sources, etc.

The above discussion has addressed the general conceptual model of the smart city and has shown what components should be considered in deciding that a city is "smart" – a city implementing smart solutions. However, it should be remembered that the components must work together to create a positive synergy. As the ThinkTank group researchers emphasize, it is not enough to fill urban spaces with intelligent traffic management systems, monitor safety and invest in modern public transport and public wireless Internet access points; rather, smart cities must also be a joint venture by residents, city authorities and local entrepreneurs (Bendyk et al., 2013).

It should be clearly emphasized that smart cities are cities that implement the principles of sustainable development in all dimensions: social, economic, urban, spatial, environmental, ecological, etc. Therefore, the concept of the smart city should be understood in a multi-faceted way. Each of these aspects encourages residents to be active in creating a new quality of the city – the city of the future. Contemporary cities, as well as cities of the future, should be pro-ecological and operate in accordance with the principles of sustainable development in order to improve the quality of life on our planet (Szymańska, 2023).

Defining the smart city (Szymańska & Korolko, 2015; Szymańska, 2023), it should be clearly emphasized that it is not only – as many believe – smart mobility, smart transport systems and advanced ICT technologies; it is, above all, a society that learns and initiates changes (smart people), runs a smart economy (smart economy), wisely manages and cares for the natural environment (smart environment), creates an optimal socio-economic environment with all kinds of services for its life (smart living), and creates and uses effective, transparent and modern communication and city management systems (smart governance) based on cooperation among authorities, residents and local economic entities. Smart cities are not just cities built from scratch, but rather, and most importantly, existing cities that, to various extents, are being transformed in the spirit of smart cities.

It is therefore obvious that "smartness" is a multidimensional concept in which both hard infrastructure (i.e., that based on modern technologies) and soft infrastructure (i.e., regulations, knowledge-based economy, citizen participation, diversity of social and institutional innovations, data management, etc.) coexist (Sharifi et al., 2021a, 2021b, 2021c).

The above indicates that the smart city literature needs periodic reviews in order to update our understanding of its evolution and reveal the trends therein (Mora et al, 2018; Boulanger, 2022, 2024). The growing number of publications demand a systematic and comprehensive analysis of the smart city research (Appio et al., 2019; Wamba & Queiroz, 2019; Sharifi et al., 2021a, 2021b, 2021c; Rejeb et al., 2022).

The present study is extremely important for attempting to show how the idea of a smart city is reflected in the scientific literature (indexed in Scopus), what topics are dominant in scientific studies, what issues researchers pay attention to, and what new research fields are emerging on the issue of the smart city.

Growing scholarly interest in exploring the smart city concept has resulted in an increasing number of research publications in the field. As of 31 December 2024, more than 19,000 items including the phrase "smart cit*" in their titles were retrieved from the Scopus database. Extending the query to the topic search (including titles, keywords and abstracts) yielded nearly 55,000 publications. The rapid growth of the research field has raised questions about its intellectual and conceptual structure. This increasing research productivity has resulted in the development of literature reviews and bibliometric studies. Nevertheless, most bibliometric studies related to the smart city concept focus on its relationship with other variables or are limited to a certain geographic area. Analyzing the publications that adopt bibliometric methodologies and a holistic approach to studying the smart city concept, it becomes apparent that one niche area of research covers the conceptual structure of the field. This is due to the scope of the previous bibliometric studies, their limitations and rapidly amassing research output in recent years. In light of the research field's very rapid expansion, mapping its conceptual structure seems to be of paramount importance for both theoretical development and business practice.

Therefore, the aim of this study is to explore the conceptual structure of the research field and to compare and contrast it with the findings of previous bibliometric research. The study process has been focused on the following research questions: (1) What are the leading themes in the smart city research field? (2) What are the emerging topics in the smart city research field? (3) What are the similarities and differences with the findings of other bibliometric studies regarding the conceptual structure of the field? To achieve the study objective and answer the research questions, a combination of literature reviews and bibliometric methods was employed. In the theoretical part of the study, a narrative review has been used to outline the smart city concept. In the empirical part of the study, previous bibliometric studies in the smart city research field were analyzed in a systematic review procedure (Tranfield et al., 2003; Czakon, 2011; Booth et al., 2012; Mazur & Orłowska, 2018). Moreover, keyword co-occurrence analysis, a type of co-word analysis (Callon et al., 1983, 1991; He, 1999; Zupic & Čater, 2015), was implemented to map the conceptual structure of the smart city research field. The remaining part of the article includes a methodology section, presentation of the findings, discussion and conclusions.

2. Methodology

2.1. Systematic literature review

Previous bibliometric studies analysing the conceptual structure of the smart city research field have been identified and discussed with the use of the systematic literature review methodology. The sampling process, conducted on 31 December 2024, employed the Scopus database and followed the model typical of the systematic literature review, recommended by Moher et al. (2009), consisting of three steps (Fig. 1).

The query for the conjunction of phrases 'smart cit*' (title search) and 'bibliometric' or 'scientometric' (topic search) retrieved 178 items. Nevertheless, the majority of bibliometric studies related to the smart city concept focuses on its relationship with other variables (e.g. sustainability, sustainable development, sustainable urban planning, land use, urban management and governance, public administration, circular economy, waste management, emerging and disruptive technologies, innovation, energy, healthcare, mobility, resilience, migration, social and cultural impacts, privacy, social equity, crowdsourcing, tourism, decarbonization, climate change) or is limited to a certain geographic area (e.g. China, India, Indonesia, developing countries).

In order to identify the sample of publications employing bibliometric methodologies to explore the whole smart city research field, the analysis of titles and abstracts of all 178 retrieved items has been conducted. The following criteria have been employed: (1) inclusion criteria: scope of research covering the whole smart city research field and unlimited geographically, (2) exclusion criteria: scope of research limited to relationship between the smart city concept and other variables, and geographic limitations to a certain country/territory of a category of nations. Finally, 156 items have been removed from the sample and 22 publications have been accepted for systematic literature review and analysis.

2.2. Bibliometric analysis

Bibliometric data for analysis have been sourced from the Scopus database. Together, Web of Science and Scopus are considered as the largest and most reliable databases of quality research publications (Aghaei Chadegani et al., 2013; Schotten et al., 2017; Zhu & Liu, 2020). The search in the Scopus database, conducted on 31 December 2024, retrieved 19,051 documents containing the phrase 'smart cit*' in their titles, published between 1997 and 2024. Most of them are indexed in such subject areas as Computer Science (12,096 items), Engineering (8,365) and Social Sciences (5,317). Publications selected for analysis are mainly conference papers (7,504 items), articles (7,286) and book chapters (2,349). Journals and conference proceedings are the most often represented source types. English remains the dominant language of publication. Detailed parameters of the sample are presented in Table 1.

Co-word analysis (Callon et al., 1983, 1991; He, 1999), representing science mapping methods (Zupic & Čater, 2015), has been employed to discover and explore the conceptual structure of the field. Co-word analysis is "a content analysis technique that uses the words in documents to establish relationships and build conceptual structure of the domain. The idea underlying the method is that, when words frequently co-occur in documents, it means that the concepts behind those words are closely related. (…) The output of co-word analysis is a network of themes and their relations that represent the conceptual space of a field. The semantic map helps to understand

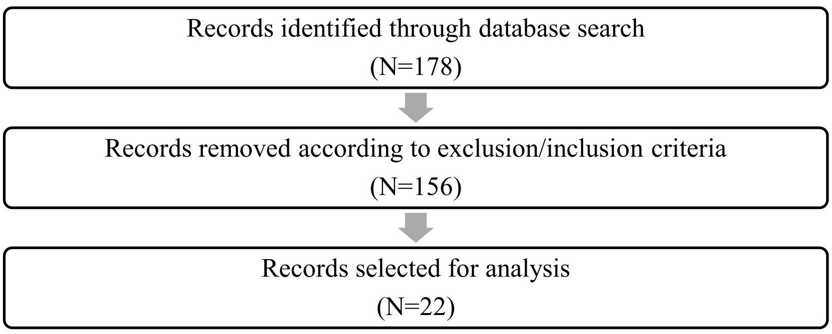

Fig. 1. Research sampling process
Source: own study

its cognitive structure (Börner et al., 2003)" (Zupic & Čater, 2015: 435). For the purpose of the study, co-occurrence analysis of high frequency keywords has been conducted. Bibliometric analysis has been supported and visualized with the use of VOSviewer software (van Eck & Waltman, 2010, 2023). Detailed parameters of VOSviewer employed for analysis are presented in Table 2.

3. Research

3.1. Reviewing smart city bibliometric studies

The process of review and analysis has included 22 publications aimed at mapping the smart city research field. Analysed items (in an alphabetical order) are presented in Table 3. As an outcome of the systematic review of smart city bibliometric studies, some of the publications (Janik & Ryszko, 2018; Komninos & Mora, 2018; Mora et al., 2017; Moradi, 2020; Pérez et al., 2020), focused mainly on profiling the research field, have been considered as of limited usefulness for conducting a comparative analysis of the research field conceptual structure. However, they will be briefly outlined as they contribute to mapping the research field. The second category of publications, considered as useful for building up a greater picture for understanding the conceptual structure of the field includes the studies authored by Bajdor and Starostka-Patyk (2021), Jebbar et al. (2024), Li (2019), Mora et al. (2018), and Mora et al. (2019). The third category consists of the works of Boulanger (2022), Y. M. Guo et al. (2019), Ingwersen and Serrano-López (2018), Lundberg (2024), Martinez-Toro et al. (2020), Rejeb et al. (2022), Sharifi et al. (2021a, 2021b, 2021c), Wamba and Queiroz (2019), Wang et al. (2021), Winkowska et al. (2019), Zhao et al. (2019), and Zheng et al. (2020). The findings of these studies may be used for direct comparative analysis with the outcomes of our bibliometric analysis.

Exploring and profiling the research field

Janik and Ryszko (2018) analyse research productivity in the field between 1991 and 2018 (number of publications and citations, distribution of the output among research areas and Web of Science categories). They identify the most cited publications, leading journals and the most productive countries. The study indicates research gaps and topics recommended for further exploration. Although keyword co-occurrence visualisation has been conducted, the analysis of the conceptual structure of the field is confined to identification of nodes (most frequent keywords).

Table 1. Parameters of the research sample

Category	Items (N)
Subject area	Computer Science (12,096); Engineering (8,365); Social Sciences (5,317); Energy (2,602); Mathematics (2,432); Environmental Science (2,252); Business, Management and Accounting (1,756); Decision Sciences (1,741); Physics and Astronomy (1,287); Material Science (813); Economics, Econometrics and Finance (751); Earth and Planetary Sciences (748); Medicine (477); Arts and Humanities (383), Biochemistry, Genetics and Molecular Biology (315), Chemistry (297), Chemical Engineering (227); Multidisciplinary (149); Psychology (132); Agricultural and Biological Sciences (129); Neuroscience (45); Health Professions (22); Pharmacology, Toxicology and Pharmaceutics (16); Veterinary (10); Immunology and Microbiology (10); Nursing (8)
Document type	Conference Paper (7,504); Article (7,286); Book Chapter (2,349); Review (531); Erratum (478); Editorial (316); Conference Review (241); Book (172); Note (83); Retracted (46); Short Survey (29); Letter (10), Data Paper (5); Undefined (1)
Source type	Journal (8,256); Conference Proceeding (6,699); Book Series (2,260); Book (1,686); Trade Journal (150)
Language	English (18,686); Spanish (89); Portuguese (68); German (64); Chinese (64); Italian (32); French (22); Russian (16); Korean (15); Hungarian (10); Japanese (9); Turkish (6); Polish (5); Croatian (3); Slovak (2); Lithuanian (2); Arabic (2); Swedish (1); Persian (1); Malay (1); Icelandic (1); Bosnian (1)

Source: own study based on data retrieved from Scopus (31 December 2024)

Table 2. VOSviewer parameters used for analysis

Parameters	Value/ characteristic
Unit of analysis	All keywords
Counting method	Full counting
Method of normalization of strength of the links between items	Association strength method
Layout	
Attraction	2 (default value)
Repulsion	0 (default value)
Clustering	
Resolution parameter (detail of clustering)	1 (default value)
Minimum cluster size (N)	10
Merging small clusters	Switched on
High frequency keywords used for analysis (N)	274
Minimum occurrences of a keyword / minimum number of citations of a document to be included for analysis (N)	86

Source: own study based on VOSviewer parameters (31 December 2024

Therefore, the article shows limited usefulness for being used in a further comparative analysis.

Komninos and Mora (2018) explore the research output in the smart city research field in the emerging phase of its lifecycle (1992-2012). Their study covers 1,067 publications retrieved from 8 scholarly databases. The analysis covers cumulative productivity and a growing community of scholars cultivating the field, including distribution of effort among geographic regions and research institutions. Their study presents also the findings regarding the intellectual structure of the field, analysed with the use of citation analysis. They review the literature and discuss structural axes of the smart city research production (technology-driven vs. human driven approach, top-down vs. bottom-up planning, collective intelligence vs. data driven intelligence). Nevertheless, the study does not provide the analysis of the conceptual structure of the field and will not be used in further discussion of our findings.

Mora et al. (2017) provide a very comprehensive profiling of smart city research. Their analysis includes distribution of source documents by type and date of publication, type and location of organizations conducting research in the field, cumulative growth of the number of publications and scholars cultivating the field, geography of knowledge production. The study also employs a citation analysis to explore the intellectual structure of the research field. As the conceptual structure is not investigated, the publication will be excluded from further comparative analysis.

The study by Moradi (2020) aims at analysing "the research trends in smart cities […] in order to demonstrate the most and the least active fields, researchers, institutions, frontier active centers/ authors and funding institutions, as well as drawing the map of the most active countries in this scope". As the main attention of the article is given to research profiling, it will not be used for comparative of the research field conceptual structure.

Pérez et al. (2020) provide a thorough and comprehensive profiling of the research output. They analyse the annual number of publications and received citations, the most productive and influential countries, research institutions, authors and journals. As mapping of the conceptual structure has not been discussed, the article will not contribute to our study.

Building a context for analysing the conceptual structure of the field

Bajdor and Starostka-Patyk (2021) conduct general profiling of research on the smart city concept and analyse the conceptual (thematic) structure of the field, covering publications issued in 2000-2020. The scope of their study includes the analysis of research productivity, sources (journals) profiling, author profiling, research institution profiling, country profiling, identification of core references, core journals and leading authors (with the use of citation analysis), identification of leading research themes (through keyword co-occurrence analysis). The study, based on the Scopus sample (N=1,354), categorizes

Table 3. Characteristics of selected bibliometric studies in the Smart City research field

Publication	Source of data	Period covered by analysis	Sample [N]	Employed methods / instruments	Remarks and limitations
Bajdor and Starostka-Patyk (2021)	Scopus	2000-2020	1,354	General research profiling; Keyword co-occurrence analysis; VOSviewer	Subject area limited to Business, Management and Accounting; Document type limited to articles, conference papers, books, book chapters and reviews; Language limited to English
Boulanger (2022)	Web of Science	2017-2022	4,289	Keyword co-occurrence analysis; VOSviewer	Language limited to English
Y.M. Guo et al. (2019)	Web of Science	1998-2019	4,409	Keyword co-occurrence analysis; Keyword citation burst analysis; VOSviewer; CiteSpace	Document type limited to articles, letters, reviews, book reviews, book chapters; Language limited to English
Ingwersen and Serrano-López (2018)	Web of Science	1990-2016	4,725	Social network analysis; Web of Science embedded analytical tools; DIVA (Database Information Visualization and Analysis system)	
Janik and Ryszko (2018)	Web of Science	1991-2018	6,462	Research profiling; Keyword co-occurrence analysis; VOSviewer	Limited discussion of the findings of keyword co-occurrence analysis (clusters' structure analysis omitted)
Jebbar et al. (2024)	Scopus; Web of Science	2017-2023	6,073; 6,500	Research profiling; Keyword co-occurrence analysis; Citation analysis; VOSviewer	Document type limited to articles, conference papers, book chapters and reviews; Language limited to English
Komninos and Mora (2018)	Google Scholar; ISI Web of Science; IEEE Xplore; Scopus; Springer Link; Engineering Village; Science Direct; Taylor and Francis Online	1992-2012	1,067	Research profiling; Citation analysis	Language limited to English
Li (2019)	Web of Science	1998-2017	4,667	Research profiling; Co-word analysis; Bibliographic coupling	The study employs a two-dimensional perspective, including Science, Technology & Engineering (STE) and Social Science and Humanities (SSH)
Lundberg (2024)	Scopus	2014-2023	46,937	Research profiling; Clustering; Python	Clustering based on expert-defined taxonomy
Martinez-Toro et al. (2020)	Web of Science	2001-2019	2,833	Social network analysis; Co-word analysis; VOSviewer	Full text available only is Spanish
Mora et al. (2017)	Google Scholar; ISI Web of Science; IEEE Xplore; Scopus; Springer Link; Engineering Village; Science Direct; Taylor and Francis Online	1992-2012	1,067	Research profiling; Citation analysis; Gephi software	Language limited to English
Mora et al. (2018)Mora et al. (2019)	Google Scholar; ISI Web of Science; IEEE Xplore; Scopus; Springer Link; Engineering Village; Science Direct; Taylor and Francis Online	1992-2012	1,067	Citation analysis; Word profiles; Gephi software; WordStat Software	Language limited to English
Moradi (2020)	Web of Science	1970-2018	4,696	Research profiling	
Pérez et al. (2020)	Web of Science	1991-2019	10,357	Research profiling; Web of Science embedded analytical tools	Document type limited to articles, book and reviews; Language limited to English
Rejeb et al. (2022)	Web of Science	1987-2021	4,760	Co-citation analysis; Keyword co-occurrence analysis; VOSViewer; HistCite; Pajek	Document type limited to articles and reviews; Language limited to English

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Publication	Source of data	Period covered by analysis	Sample [N]	Employed methods / instruments	Remarks and limitations
Sharifi et al. (2021)	Web of Science	1991-2021	5,722	Keyword co-occurrence analysis; VOSviewer; CiteSpace	Physics, Material Sciences, Mathematics areas excluded
Wamba and Queiroz (2019)	Web of Science	2000-2018	1,226	Keyword co-occurrence analysis; VOSviewer	Language limited to English
Wang et al. (2021)	Web of Science	2009-2020	10,000	Research profiling; Latent Dirichlet Allocation (LDA)	
Winkowska et al. (2019)	Scopus; Web of Science	2009-2019	15,744	Research profiling; Keyword co-occurrence analysis; VOSviewer	
Zhao et al. (2019)	Web of Science	1999-2018	2,920	Research profiling; Co-citation analysis; Keyword co-occurrence analysis; VOSviewer; CiteSpace	
Zheng et al. (2020)	Web of Science	1990-2019	7,840	Co-occurrence analysis; Co-word analysis; Co-citation analysis; CiteSpace	

Source: own study based on data retrieved from Scopus (31 Dec. 2024)

research on smart city in 16 thematic clusters. 'Internet of Things', 'blockchain', 'entrepreneurship', 'economy' and the 'environment' are found to be the strongest correlates of 'smart city'. 'Information and communication technologies' and 'sustainable development' are recognised as variables indirectly linked to 'smart city'.

Jebbar et al. (2024) conduct a bibliometric analysis of smart city related research works, indexed in Scopus and Web of Science, published between 2017 and 2023. They present some elements of research profiling (distribution of research output among subject areas and countries, research collaboration among the countries). Thematic analysis of the field is based on the clustering technique and may be used for increasing awareness of the context of mapping the conceptual structure of the research field.

Li (2019) employs a two-dimensional perspective (including Science, Technology & Engineering (STE) and Social Science and Humanities (SSH)) to explore the smart city research field in 1998-2017. The study briefly analyses productivity and profiles research output (by research area and country). Regarding the conceptual structure of the field, the co-word analysis supported with CiteSpace software provides visualization of thematic clusters from the perspective of STE and SSH. The study is complemented with bibliographic coupling aimed at analysing the intellectual structure of the field. Employing a different research approach (two-dimensional perspective) the study cannot be used directly for comparative analysis. However, it shows some potential to be included in discussing the cognitive structure of the research field.

The studies by Mora et al. (2018) and Mora et al. (2019) focus on the intellectual structure of the smart city research field, identified through citation analysis. However, what is of great importance from the perspective of our study, word profiles identified for leading clusters as a supplement of citation analysis offer value for indirect comparative analysis with the outcomes of the science mapping of the conceptual structure of the field, employing a co-word analysis. Consequently, it may contribute to better understanding of a greater picture for studying the conceptual structure of the smart city research field.

Identifying bibliometric studies for comparative analysis

Boulanger (2022) discusses the thematic structure of the smart city research field, comparing and contrasting the period prior to the COVID-19 pandemic (2017-2019) and the one during/after the pandemic (2020-2022). She employs keyword co-occurrence analysis, supported by VOSviewer software. The study, based on the Web of Science sample (N=4,329), explores 4 thematic clusters, focusing on: (1) governance, political agendas and implementation, (2) cloud computing and big data, (3) the operational part of the Internet of Things, (4) the monitoring of the world.

Guo et al. (2019) analyze research productivity in the field between 1998 and 2019, the most productive sources, authors, research institutions and countries. They explore the conceptual structure of smart city related research with the use of keyword co-occurrence and keyword citation burst methods. Their study covers analysis of collaborative relationships among authors, countries and research institutions as well as source titles (journals). The study by Guo et al. (2019), based on the Web of Science sample (N=4,409), discovers and discusses the following thematic areas in the research field: (1) smart development, (2) telecommunications and computer science, (3) smart strategy for sustainable development, (4) public administration.

Ingwersen and Serrano-López (2018) analyse how the smart city research field was developing between 1990 and 2016, including research productivity, document types, top contributors (countries, universities, subject categories). From the perspective of our study the most interesting is thematic mapping through clustering of Web of Science categories, accomplished with the use of the Social Network Analysis technique. This part of their research is to be compared and contrasted with the findings from our keyword co-occurrence analysis. The study, based on the Web of Science sample (N=4,725), identifies the following clusters: (1) ICT, including electrical/electronic engineering, telecom, information and communication technology, (2) energy, covering topics of energy and construction/building, (3) urbanization, including the issues of urbanization, sustainability and the environment, (4) eco-management, covering management and economics, (5) instrumentation.

Lundberg (2024) identifies 21 bibliometric studies within the smart city research field. Then, he presents the findings of the research profiling focused on the number of publications, the number of received citations, and geographic distribution. The most interesting part of the study is the expert-defined taxonomy with six research directions in the field, used to support the research profiling analysis. In spite of a different approach to identify research themes, the study is recommended for comparative analysis. The identified thematic areas are: (1) Internet of Things, (2) machine learning and artificial intelligence, (3) edge and cloud technologies, (4) big data and data mining, (5) security and privacy, (6) sustainability.

Martinez-Toro et al. (2020) focus on analysing the conceptual structure of the smart city research field. They employ keyword co-occurrence analysis supported by VOSviewer software. General findings from the study will be useful for comparative analysis. The study by Martinez-Toro et al. (2020), based on the Web of Science sample (N=2,833), points out the three following themes within the research field: (1) "(d)evelopment of cities based on innovation and sustainability", (2) "design and administration of cities by means of Internet and the Internet of Things", (3) "frameworks based on bigdata aimed at governance".

Rejeb et al. (2022) conduct a comprehensive profiling as well as analysis of the intellectual and conceptual structure of the smart city research field. The research profiling encompasses distribution of publications by year and citations, analysis of collaboration among nations, institutions and authors, distribution of publications by countries, academic institutions, journals, and scholars as well as the core references (those with the highest number of received citations). Keyword co-occurrence network analysis is supplemented with co-citation analysis used to identify thematic subfields and measure research potential for the future. Thematic clusters identified through keyword co-occurrence analysis are: (1) sustainability and governance, (2) he interplay between IoT, blockchain and computing technologies, (3) artificial intelligence tools, (4) smart energy and transport, (5) interaction applications. Co-citations analysis discovers the following clusters: (1) Industry 4.0 technologies, (2) sustainability, (3) smart city governance, (4) smart tourism, (5) mart city conceptualization and implementation, and (6) digital twin technologies. The study, based on the Web of Science sample (N=4,760), shows a very high potential for comparative analysis due to using a different database for the sampling process and combining keyword co-occurrence network analysis with co-citation analysis.

Sharifi et al. (2021a, 2021b, 2021c, 2024) employ keyword co-occurrence analysis to map thematic clusters within the research field and identify transitions of thematic focus over time. The identified thematic clusters are: (1) the smart city concept, (2) big data analytics, (3) technological aspects. Moreover, the study analyses the most influential sources (journals), leading contributing countries and research institutions, authors and core (most influential) publications. The study, based on the Web o Science sample (N=5,722), presents a high potential for the comparative analysis of the research field conceptual structure.

Wamba and Queiroz (2019) identify annual distribution of research production, the most influential journals, authors, publications and countries. The study, based on the Web of Science sample (N=1,226), employs co-citation analysis to explore thematic clusters within the field, which may be a useful contribution to further comparative analysis. Such an approach has been successfully tested in earlier publications (Lis et al., 2023). The identified thematic clusters are: (1) concepts, definitions and understanding of smart cities, (2) frameworks to describe the integration of smart cities with technologies, (3) smart city governance and big data analytics.

Wang et al. (2021) perform the analysis of geographic distribution of the smart city research output and the stages in the field's lifecycle. With the use of Latent Dirichlet Allocation (LDA) topic model, the study identifies research topics in the field, which may contribute to comparative analysis. Wang et al. (2021) notice that "Latent Dirichlet Allocation (LDA) topic model results revealed that research topics could be categorized into five aspects: (1) policy research on the status quo of smart cities, (2) data analysis and application, (3) infrastructure construction, (4) urban governance, and (5) network security".

Winkowska et al. (2019) profile the research output (document types, annual distribution of publications, distribution of subject areas) and identify thematic clusters within the field through keyword co-occurrence analysis. The study, based on the Scopus and Web of Science sample (N=15,744), points out the following thematic areas: (1) smart technology, (2) socio-economic aspects, (3) environmental aspects, (4) urban logistics.

Zhao et al. (2019) conduct the profiling of smart city research published between 1999 and 2018 and indexed by Web of Science. The study combines co-citation analysis and keyword co-occurrence analysis to map thematic clusters defining the conceptual structure of the field, what makes it very suitable for further comparative analysis. The thematic clusters identified with the use of co-citation analysis are: (1) the concepts and the elements of smart city, (2) smart city and the Internet of Things, (3) the smart city of the future. The themes indicated in the keyword co-occurrence analysis are: (1) research objectives and development-strategy research direction, (2) technical support research direction, (3) data processing and applied research direction, (4) management and applied research direction.

Zheng et al. (2020) conduct "a scientometric review of the progressively synthesized network derived from 7,840 bibliographic records from a topic search on (smart city) in the period 1990–2019. Using CiteSpace, co-occurrence analysis of categories is conducted to explore the evolution of the disciplines engaged in (smart city) research; co-word analysis of the keywords and document co-citation analysis associated with cluster analysis are further performed to reveal the development paths and research topics in terms of burst terms, text and citation-based clusters, citation structure, and pivotal points in the field".

3.2. Mapping the conceptual structure of the research field

Exploring leading thematic areas

All the publications included in the research sample provide 56,102 keywords. Among them there are 37,808 keywords with only one occurrence. The top 10 keywords with the highest number of occurrences are: 'smart city' (12,915 occurrences), 'smart cities' (4,565), 'internet of things' (3,445), 'IoT' (1,128), 'sustainable development' (1,127), 'big data' (1,050), 'urban growth' (938), 'artificial intelligence' (874), 'decision making' (871), and 'internet of things (IoT)' (864). According to the formula provided by Donohue (1974; as cited in: Guo et al., 2017), the minimum number of high frequency keywords included into co-word analysis is 274, which corresponds to keywords of minimum 86 occurrences. The network visualization of analysis outcomes is presented in Figure 2, and the detailed composition of thematic clusters representing the conceptual structure of the field in – Table 2. In network maps of research fields, visualized with the use of VOSviewer, the distance between two items corresponds to strength of relationship between them i.e. the closer two keywords are located to each other, the stronger relationship is reported. The size of a frame (or a circle) represents the number of keyword's occurrences i.e. the more occurrences received by a keyword, the bigger size of a frame (circle).

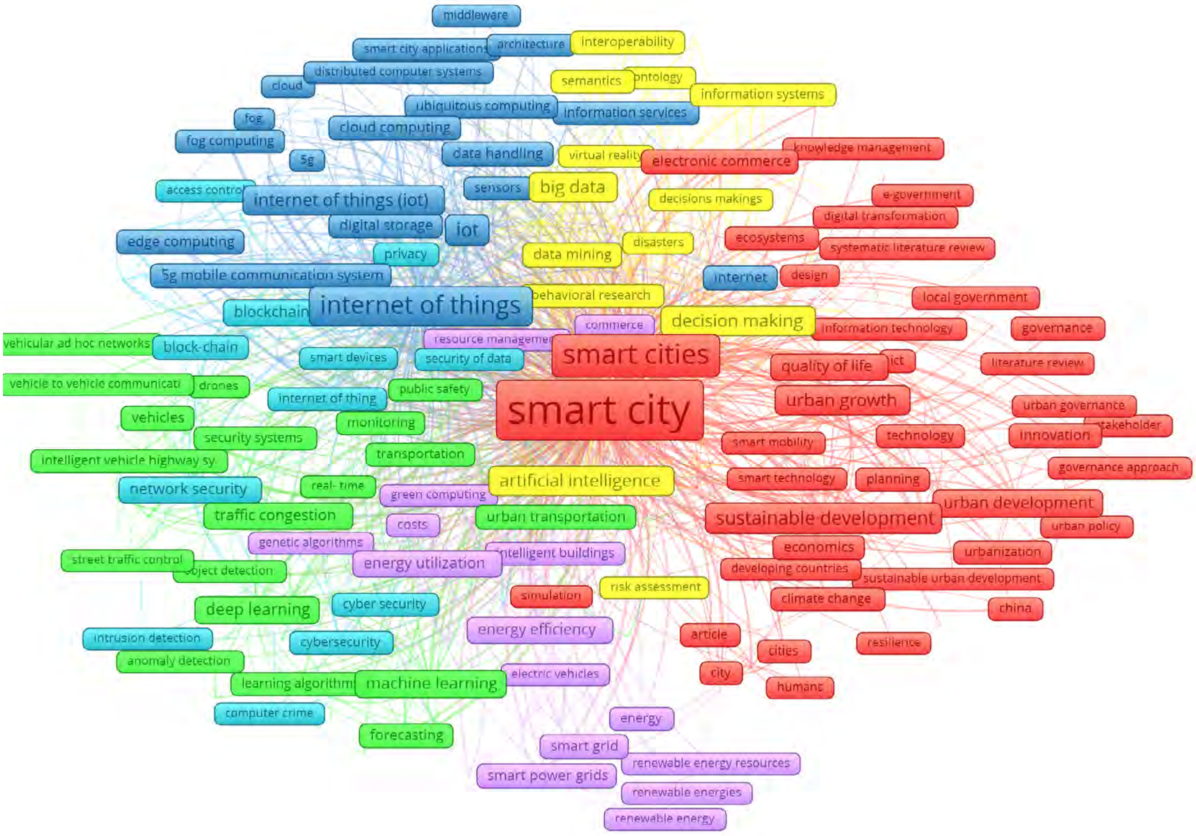

Fig. 2. Network visualization of co-word analysis of smart city research

Source: own study based on data retrieved from Scopus and analyzed with VOSviewer (31 December 2024)

Discovering emerging topics

Analysis of the average publication year allows us to identify the keywords representing emerging ('hot') topics in the research field. Among research on the smart city concept, the following keywords may be considered as manifestations of such 'hot' topics: 'machine-learning' (2022.88), 'optimisations' (2022.68), 'sustainable city' (2022.54), 'block-chain' (2022.51), 'digital twin' (2022.49), 'real time' (2022.43), 'energy consumption' (2022.29), 'long short-term memory' (2022.22), 'convolution neural networks' (2022.22), 'cyber security' (2022.21), 'convolution neural network' (2022.17), 'current' (2022.17), 'Internet of Thing' (2022.16), 'decision makings' (2022.12), 'China' (2022.10), 'cloud computing' (2022.09), 'deep learning' (2021.87), 'COVID-19' (2021.83), 'performance' (2021.80), 'block chain' (2021.60). Visualization of the average year of publication for analyzed high-frequency keywords included in smart city publications is presented in Figure 3.

4. Summary and conclusions

The research conducted shows that we have six basic thematic clusters in smart city research (co-word analysis). The analysis outcomes are presented visually as a network in Figure 2, and the detailed composition of thematic clusters representing the conceptual structure of the field in is presented in Table 4.

Cluster one is called "Smart Cities and Sustainable Urban Development: Technologies, Governance, and Citizen Participation" and reflects the literature whose main emphasis is on smart cities, sustainable development, sustainable urban development, or urbanization. The keywords with the highest number of occurrences in the cluster are: 'smart city' (12,915); 'smart cities' (4,565), 'sustainable development' (1,127), 'urban growth' (938), 'sustainability' (724), 'urban development' (646) and the implementation of various information and communication technologies (849) in city management, for inclusive development that contributes to the improvement of the quality of

Table 4. Composition of thematic clusters in smart city research (co-word analysis)

Clusters	Items (number of occurrences)
Cluster 1 (Red) / Smart Cities and Sustainable Urban Development: Technologies, Governance, and Citizen Participation / 89 items	‘current (235); advanced technology (90); algorithm (116); article (187); benchmarking (125); case studies (164); China (221); cities (197); citizen participation (120); city (263); city construction (178); city management (147); climate change (202); conceptual framework (90); covid-19 (130); crowdsourcing (136); design (111); developing countries (143); digital technologies (153); digital transformation (130); e-government (158); economic and social effects (265); economic development (102); economics (312); ecosystem (177), electronic commerce (350); environmental technology (150); governance (182); governance approach (158); human (210); human computer interaction (100); humans (92); ICT (209); India (134); information and communication technologies (522); information and communication technology (199); information technology (128); infrastructure (122); innovation (328); investments (167); knowledge management (107); literature review (116); literature reviews (161); local government (174); metadata (101); mobility (111); open data (204); planning (233); policy making (88); population statistics (281); public administration (135); public policy (98); public services (116); public transport (86); quality of life (586); rapid urbanizations (87); resilience (98); simulation (104); smart cities (4,565); smart city (12,915); smart environment (146); smart governance (116); smart mobility (147); smart services (112); smart technology (134); stakeholder (94); surveys (193); sustainability (724); sustainable cities (186); sustainable city (155); sustainable development (1,127); sustainable urban development (88); systematic literature review (127); systematic review (88); technological development (140); technology (211); technology adoption (100); urban area (136); urban areas (210); urban development (646); urban environments (246); urban governance (105); urban growth (938); urban infrastructure (107); urban management (99); urban planning (663); urban policy (156); urban population (101); urbanization (207)
Cluster 2 (Green) / Machine Learning in Intelligent Transportation Systems: Real-Time Monitoring, Autonomous Vehicles, and Urban Traffic Management / 50 items	accidents (120); air pollution (112); air quality (269); anomaly detection (89); antennas (181); autonomous vehicles (127); cameras (92); classification of information (131); convolutional neural network (103); convolutional neural networks (120); decision trees (101); deep learning (642); deep neural networks (95); drones (113); emergency services (99); forecasting (309); intelligent systems (315); intelligent transportation systems (247); intelligent vehicles highway systems (219); learning algorithms (201); learning systems (454); location (90); long short-term memory (103); machine learning (735); machine-learning (295); monitoring (237); motor transportation (174); multi agent systems (106); neural networks (149); object detection (109); performance (176); quality control (137); real time systems (153); real-time (149); reinforcement learning (133); roads and streets (235); security systems (236); state of the art (106); street traffic control (149); support vector machines (86); traffic congestion (525); traffic control (163); traffic management (189); transportation (186); transportation system (149); unmanned aerial vehicles (UAV) (138); urban transportation (345); vehicle to vehicle communications (139); vehicles (342); vehicular as hoc networks (121)
Cluster 3 (Blue) / Next-Generation Communication Architectures for Smart City Applications: Integrating 5G, IoT, and Edge Computing in Intelligent Distributed Systems / 49 items	5G (119); 5G mobile communication systems (289); application programs (146); architecture (151); cloud (91); cloud computing (379); cloud-computing (165); communication technologies (92); complex networks (124); computation theory (99); computer architecture (149); data acquisition (231); data collection (147); data communication systems (97); data handling (409); data transfer (96); digital storage (430); distributed computer systems (161); edge computing (306); fog (154); fog computing (226); gateways (computer networks) (99); health care (150); information services (172); Internet (302); Internet of Thing (IoT) (287); Internet of Thing (3,445); Internet of Things (IoT) (864), IoT (1,128), middleware (112); mobile applications (159); mobile computing (107); mobile telecommunication systems (154); network architecture (328); quality of service (245); resource allocation (147); resource management (104); scheduling (94); sensor (100); sensor networks (191); sensor nodes (190); sensors (233); smart city applications (89); smart parking (112); smartphones (125); ubiquitous computing (191); web services (107); wireless sensor networks (331); wireless telecommunication systems (95)

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Cluster 4 (Yellow) / Artificial Intelligence and Big Data in Decision Support Systems: Integrating Digital Technologies for Information and Risk Management / 35 items	architectural design (90); artificial intelligence (874); behavioral research (216); Big Data (1050); data analytics (308); data integration (102); data mining (284); data visualization (156); decision making (871); decision support systems (162); decision makings (108); digital twin (142); disaster prevention (106); disasters (161); e-learning (89); environmental management (103); environmental monitoring (103); geographic information systems (110); GIS (100); Industry 4.0 (87); information management (743); information systems (246); information use (257); interoperability (214); life cycle (111); ontology (122); public safety (89);
Cluster 5 (Purple) / Sustainable Energy and Resource Management in Intelligent Systems: Optimization, Automation, and Green Technologies / 28 items	automation (338); budget control (87); commerce (98); cost effectiveness (140); costs (166); electric power transmission networks (275); electric vehicles (151); energy (228); energy conservation (148); energy efficiency (599); energy harvesting (90); energy management (188); energy utilization (545); energy-consumption (104); genetic algorithms (118); green computing 125; intelligent building (218); management systems (90); optimisations (158); optimization (282); renewable energies (133); renewable energy (126); renewable energy resources (103); smart grid (328); smart homes (116); smart power grids (333); waste management (337); water management (88)
Cluster 6 (Light Blue) / Cybersecurity and Privacy in Emerging IoT Ecosystems: Blockchain, Cryptography, and Access Control in Cyber-Physical Systems / 23 items	access control (88); authentication (170); block chain (288); block-chain (572); computer crime (88); crime (135); cryptography (193); cyber physical system (110); cyber security (222); cybersecurity (239); data privacy (286); efficiency (181); embedded systems (235); emerging technologies (99); Internet of Thing (189); Internet of Things technologies (137); intrusion detection (104); network security (517); privacy (265); security (393); security and privacy (128); security of data (124); smart devices (108)

Source: own study based on data retrieved from Scopus and analyzed with VOSviewer (31 December 2024)

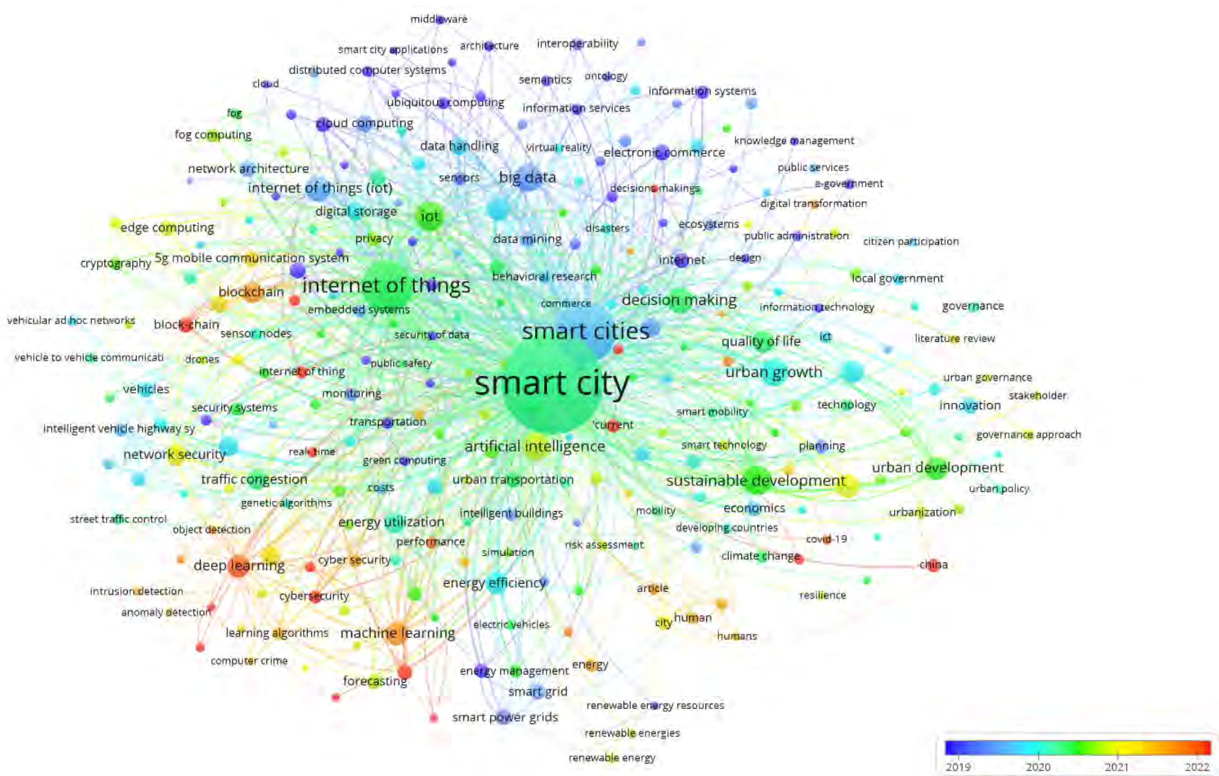

Fig. 3. Overlay visualization of co-word analysis of smart city research
Source: own study based on data retrieved from Scopus and analyzed with VOSviewer (31 December 2024)

life in cities. Generally, this cluster includes literature that concerns modern smart cities and their impact on society, the environment and the economy.

Cluster two is "Machine Learning in Intelligent Transportation Systems: Real-Time Monitoring, Autonomous Vehicles, and Urban Traffic Management". The thematic scope of this cluster reflects how the rapid development of machine learning (ML) and artificial intelligence (AI) technologies has significantly changed the urban transportation landscape significantly. It demonstrates the integration of intelligent systems into urban mobility infrastructure, with a focus on real-time traffic management, autonomous vehicles and predictive analytics. A comprehensive overview is presented of state-of-the-art learning algorithms, including deep learning, reinforcement learning and support vector machines, which are used for traffic prediction, object detection and decision-making in dynamic environments. It also illustrates the role of intelligent transportation systems (ITS), vehicular ad-hoc networks (VANETs) and unmanned aerial vehicles (UAVs) in enhancing traffic flow, safety, and emergency response. Recent case studies and comparative data have been taken into account to highlight the performance, challenges and future directions of AI-based urban mobility solutions. The cluster also highlights the potential of ML-based approaches to improve efficiency, reduce congestion and support sustainable urban development.

Cluster three is "Next-Generation Communication Architectures for Smart City Applications: Integrating 5G, IoT, and Edge Computing in Intelligent Distributed Systems". This cluster showcases the impact and convergence of 5G, the Internet of Things (IoT) and cloud-fog-edge computing architectures on the development of applications in smart cities and the healthcare sector. It shows how these technologies enable the efficient acquisition, communication and processing of data in distributed systems to support real-time, large-scale services. Modern architectures provide high quality of service (QoS) and responsiveness through the use of wireless sensor networks, middleware and advanced resource management strategies. The cluster provides an overview of key technologies, architectural models and data processing mechanisms, highlighting current challenges and directions for further research in communication systems and ubiquitous computing.

Cluster 4 is "Artificial Intelligence and Big Data in Decision Support Systems: Integrating Digital Technologies for Information and Risk Management". In an era of increasing complexity in information and environmental systems, this cluster demonstrates that the integration of technologies such as AI, big data, digital twins, geographic information systems (GIS) and semantic technologies is crucial for supporting decision-making processes. Intelligent, modern decision-support systems use advanced data analysis and visualization, ontologies and interoperable architectures to effectively manage risk, monitor the environment and support public safety and emergency management operations. The cluster demonstrates an overview of current technological and methodological solutions with a particular focus on e-learning, virtual reality and digital twin applications.

Cluster five is "Sustainable Energy and Resource Management in Intelligent Systems: Optimization, Automation, and Green Technologies". This cluster demonstrates that, as demand for efficient and sustainable energy systems grows, modern resource management is coming to crucially reply on the integration of technologies such as automation, optimization, green technologies and renewable energy sources. The cluster illustrates how smart grids, smart buildings, electric vehicles and energy management systems are helping to enhance energy efficiency, reduce costs and manage budgets more effectively. It also highlights the use of genetic algorithms and other optimization methods in decision-making processes for waste and water management, as well as energy harvesting. Overall, it identifies the key areas of research into intelligent and sustainable energy use in urban environments.

Cluster six is "Cybersecurity and Privacy in Emerging IoT Ecosystems: Blockchain, Cryptography, and Access Control in Cyber-Physical Systems". This cluster does not address the Internet of Things (IoT) era as a whole, but it specifically addresses IoT systems used in smart cities. This cluster shows that, with the rapid development and expansion of IoT and cyber-physical systems, the importance of effective cybersecurity and privacy protection mechanisms is growing. It demonstrates the application of modern technologies such as blockchain, cryptography, access control and authentication in the context of securing data and infrastructure in complex and distributed environments. Particular attention is paid to intrusion detection, network security and embedded systems, which form the basis for smart devices and services. The cluster identifies challenges related to efficiency, interoperability and data privacy, proposing directions for further research on secure and resilient IoT ecosystems.

Firstly, our research shows that the issue of smart cities is still very relevant; it is attracting the interest of many researchers, and the number of publications on the topic continues to grow. Secondly, in recent years, the concept of the smart city has evolved into a dynamic and interdisciplinary field, driven by rapid technological advancements and the urgent need for sustainable urban development. But what are the new topics in the field of smart city research? The emerging (the latest trends) trends in smart city research are: the technological perspective and sustainable development.

Within the analyzed studies on the smart city concept, the following can be considered as manifestations of such "hot" emerging topics: 'machine-learning', 'optimizations', 'sustainable city', 'block-chain', 'digital twin', 'real time', 'energy consumption', 'long short-term memory', 'convolution neural networks', 'cyber security', 'current', 'Internet of Things', 'decision makings', 'China', 'cloud computing', 'deep learning', 'COVID-19' and 'performance'.

What are the emerging topics in smart city research? Firstly, our research shows that the issue of smart cities is still very relevant, that it attracts the interest of many researchers, and that the number of publications is constantly increasing. Secondly, in recent years, the smart city concept has evolved into a dynamic and interdisciplinary field, driven by rapid technological advances and the urgent need for sustainable urban development. The most prominent of the emerging "hot" topics include technologies such as machine learning, deep learning and blockchain, which are increasingly being integrated into urban infrastructures to enhance real-time decision-making, energy consumption optimization, and cybersecurity. This is also confirmed by other researchers, such as Boulanger (2022) and Rejeb et al. (2022), who emphasize that research on smart cities focuses primarily on sustainable development and management, new technologies (e.g., IoT, blockchain, new computing paradigms, and AI), smart energy, transportation, and interactive applications (Boulanger, 2022; Rejeb et al., 2022).

It should be noted that the emerging "hot" topics also include the use of digital twins and IoT devices, which enable cities to simulate and monitor complex systems, providing actionable insights for urban planners and policymakers. Techniques like long short-term memory (LSTM) and convolutional neural networks (CNNs) are being applied to forecast traffic patterns, manage resources and improve public services.

These aspects were also highlighted by Boulanger (2022, 2024). Martinez-Toro et al. (2020) emphasize that research on smart cities focuses on three areas: (1) urban development based on innovation and sustainable development, (2) city design and administration using the Internet and IoT, and (3) big-data-based management. Similar conclusions are drawn by Sharifi et al. (2021a, 2021b), who point out that the existing literature can be divided into three major clusters focused on smart city concepts, IoT and big data analytics.

Furthermore, our bibliometric analysis shows that the COVID-19 pandemic further accelerated the adoption of cloud computing (which is also reflected in emerging topics – Figure 3) and AI-driven analytics, highlighting the importance of resilience and adaptability in urban systems. This was also demonstrated in Boulanger's (2022) research. In fact, the COVID-19 pandemic gave even more momentum to smart city initiatives around the world, and many cities relied on smart solutions to combat the pandemic (Sharifi & Khavarian-Garmsir, 2020; Sharifi et al., 2021c).

The pandemic occurred relatively recently, so it is too early to observe its significant impact on scientific output, and this aspect will likely be more reflected in scientific literature on smart cities in the coming years. However, more detailed and extensive research is needed to observe its impact on smart city research.

It is worth noting that, in recent years, a fairly large research area (listed in the bibliography) has focused on China, which is becoming a leader in implementing large-scale smart city initiatives, demonstrating the potential of integrated technologies in transforming urban life.

In recent years, the scholarly literature has begun to feature the issue of smart cities in the context of climate change and sustainable urban development and urbanization, but our bibliometric analysis shows that it still occupies too little space. It is expected that, in the coming years, as also emphasized by Sharifi et al. (2021a, 2021b), interest in sustainable development and climate change will continue to grow, along with increasing hope that smart cities will enhance the ability to overcome social challenges. Given the importance of combating climate change, further research is needed to better understand the actual and/or potential contribution of smart cities to achieving climate change adaptation and/or mitigation goals.

Our literature analyses show that interest in smart city issues in the context of security and privacy, and the number of related publications, are also increasing (Cluster 6 – Table 4, Fig. 3). These aspects will probably continue to be addressed and developed in the coming years.

Moreover, in the light of the bibliometric analysis, we note that increasing attention is being paid to the use of technological innovations in civic participation, e-government and e-management. This indicates a certain optimism, as these technologies can be and are being used to make cities less crowded and polluted (e.g., more matters can be dealt with online without having to leave home and use private or public transport), thereby increasing the comfort and quality of life of city dwellers and reducing our ecological footprint. This has been reflected in, among others, cluster 1 entitled "Technologies, Governance, and Citizen Participation".

Our analysis of publications showed them to cover a wide spectrum of issues related to the smart city concept and that they reflect, to various extents, all the components that make a city smart, i.e. smart people, smart economy, smart environment, smart governance, smart living, smart mobility. As research evolves, the performance of smart city solutions is increasingly being assessed through the lens of sustainability, efficiency and citizen-centric design, making them fertile ground for innovation and interdisciplinary collaboration.

However, some researchers (Winkowska et al., 2019) state that implementations of the smart city concept are poorly embedded in a multi-sphere and multi-variant vision of the future. In their opinion, "foresight" (which is successfully used in building visions of the future for countries, regions and enterprises) could be used in developing a vision of the future of the smart city involving a wide range of local community stakeholders, and a foresight methodology should be developed for planning the future of smart cities in which citizens are both users and co-creators of smart cities (Winkowska et al., 2019).

Finally, in agreement with many researchers (e.g., Sharifi et al., 2021a, 2021b, 2021c), given the rapid increase in the number of publications, regular literature updates and analyses are needed to keep up with the huge explosion in knowledge on smart cities.

Moreover, it would appear useful to conduct more detailed analyses of each of the six clusters identified in our study, as this may provide more detailed information on the longer-term evolution of the smart city concept (in terms both of content, i.e. individual components, and of their importance in identifying what a smart city is).

The mapping of the research areas shows that the concept of a smart city is understood very broadly and variously – and we should not expect a universal concept of the smart city to emerge. The creativity and innovation of human thought are inexhaustible, and new ideas will emerge regarding how to ensure that life in cities and on planet Earth is in line with the principles of sustainable development.

The presented literature studies show that there is no single, clear definition of what constitutes a smart city. Rather, the concept of smart cities should be understood multidimensionally. When using the term "smart", various aspects of the city's functioning should be taken into account: technical and technological (e.g., smart homes, smart lighting, smart heating, intelligent transport systems) or purely urban planning or organizational (appropriate management and administration), as well as the very important environmental aspect. However, in each case, the aim is for cities to consume as little energy as possible, to pollute the natural environment as little as possible, to be passable and to make optimal use of resources, and to create favorable living conditions for residents and other users (plants and animals). The idea of smart cities thus aims to optimize their development (Szymańska, 2007: 343). Smart cities are therefore a way to reduce the negative effects of cities and urbanization. Their implementation involves factors that are new in the development of cities (e.g., advanced technologies that allow for the saving of both energy and time and for better use of social and infrastructural capital).

Therefore, smart cities are cities that, among other things, use renewable energy sources, reduce noise and air pollution, conduct sustainable waste management, introduce efficient and effective transport systems and city planning and implement a circular economy (Szymańska, 2007: 343). They are ecological cities in which public transport uses eco-friendly propulsion and digital technologies, and satellite technologies facilitate traffic management. They are cities that care about the quality of the natural environment and create large, green areas. In smart cities, ecological (i.e. energy-efficient and intelligent – passive) houses are built that consume minimal amounts of energy, and the systems and installations allow the house to be managed from any corner of the Earth. The heating can be turned on – or a fire lit in the fireplace – remotely. Cities with smart homes consume minimal energy, which has both economic and environmental implications. Smart city concepts can apply to cities built from scratch and to existing cities where various "smart" solutions are being implemented to improve the quality of life of their residents and economic development. The idea of "smart" and "smarter" cities is seen in various parts of the world, and this applies to the construction of new cities and to the refurbishing of old, existing ones or individual urban districts, etc., either to the integrated overall implementation of the full technological and organizational package or to only a limited set of activities (Szymańska, 2013: 344; Szymańska, 2023). To ensure optimal development conditions, city authorities are constantly looking for increasingly effective methods for analyzing data, anticipating problems and coordinating urban resources.

Numerous concepts related to the idea of smart cities have begun to be implemented for both purely ecological and purely economic reasons, as implementing these concepts has been seen as a new mechanism for the development of the cities in question. As already mentioned, many institutions and research offices create and publish annual reports classifying cities (according to various methodologies) according to which is the most ecological, smart, innovative, green, sustainable, etc. These rankings are often used as magnets to attract new residents, tourists, new investors and new businesses.

It is important that the movement that has coalesced around the concept of smart cities is not just a passing enthusiasm but that it brings together many groups: researchers and scientists, residents, authorities, social organizations, businessmen, politicians and economic entities. It is also important that support for smart city initiatives continue; that city authorities and residents remember to cooperate with each other in this area; that this, one of the most fashionable concepts – the smart city and related concepts – be implemented all around the world and point all inhabitants of our planet towards the future.

Smart cities present a lesson for the urbanized world. The most important problems of the modern world, alongside the nuclear threat, terrorism, wars and hunger, are global warming, environmental pollution, the ecological crisis and the growth of cities. In this context, the key issues for the global community, politicians and authorities are: increasing energy efficiency and reducing greenhouse gas emissions; limiting excessive private transport; the availability and conservation of water and the availability of freshwater resources; waste disposal and management; water and sewage management; and many others. Implementing ideas and concepts relating to smart cities helps to solve and mitigate these problems. It is not the only panacea for the ills of modern cities, but it is probably among the best.

The success and sustainable and integrated development of cities require not only the latest (often very expensive) technologies but also innovative and creative communities, and often the vision of city leaders and social activists. The city is a puzzle that can only be solved using out-of-the-box thinking and an integrated approach that takes into account all aspects of city life. It should be approached multi-dimensionally, so that all the pieces are found, scrutinized and fitted together in the fullest manner. At the same time, it is important to remember that much can be achieved by directing urban policy and improving what already exists, such as by raising environmental awareness and amending building regulations to require greater energy efficiency of buildings (e.g., through improved insulation) and appropriate colors of buildings and roofs.

All actions, even those taken by individuals, are highly recommended. It is not always necessary to build new, expensive cities; we have many cities on our planet. Certainly, building new, ecological, ultra-modern cities is one of the paths to developing cities of the future. However, it is more advisable and probably more effective (as indicated by numerous examples discussed in *Inteligentne miasta* (*Smart cities*) by Szymańska (2023) to modernize and transform existing cities to be more environmentally friendly and less costly for residents. Often, it is enough to modernize cities, improve their layout to make them more airy, construct new buildings, orient them optimally to the cardinal directions, optimize urban transport, and plant new areas with trees to make them more ecological and reduce their pressure on the environment. These do not always have to be expensive ventures. Sometimes imagination, creativity and out-of-the-box thinking are required. The potential of a smart city lies in its inhabitants, authorities and economic entities – and their co-participatory, responsible problem-solving in implementing the smart city idea.

A smart city is not only – as some people think – a city that is highly networked and packed with ICT systems; a smart city is a city that broadly understands the idea of smart city, one that engages the community, authorities and economic entities, that includes ecological solutions, care for the natural environment, optimal planning, management and many other elements (as reflected by the bibliometric analysis in six thematic clusters related to smart cities).

The biggest task that awaits residents and city authorities is therefore to improve the fabric of existing cities. The 15-minute city concept is an opportunity and a challenge that the 21st century is presenting to humanity and our entire planet. This is all even more important because the number of urban inhabitants is constantly growing, as is the number of cities and large metropolises (Szymańska, 2023). It has been estimated that, by 2050, almost 68% of the world's population will live in cities. If we do not implement various development programs that include sustainable and integrated development, including the concept of smart cities, are not implemented, it may significantly worsen the condition of the natural environment and the comfort of life.

Humanity always faces enormous new challenges, but the functioning of newly established cities and the modernization of existing ones provide some optimism. Moreover, the population gathering in cities, in developed, developing and underdeveloped countries alike, has the creative power to develop new technologies and solutions to optimize life in cities and their functioning in space (Glaeser, 2011a: 36–41). It is even said that a wealth of thought, creativity and inspiration is born in cities. Cities around the world attract people whose collective effort determines progress. According to Glaeser (2011b), creativity, an abundance of ideas, and inspirations arise in crowded streets and interpersonal contacts, which emanate creative energy and have brought great achievements in the history of mankind.

We should not oppose the city as a civilizational phenomenon, but we must mitigate the problems that urbanization brings. It is cities that have proven that they can solve these problems. It is in cities that, for hundreds of years, bold ideas and courageous actions have been born – solutions to our biggest problems, and the examples discussed prove that they can be overcome.

As shown in this bibliometric analysis, the concept of the smart city should not be limited to one aspect of life and activity in a city. It is good that the idea itself has appeared and is attracting the attention of the world community (as eco-development, the eco-city and ecological once did); it is developmental and has no end point. However we name it, the important thing is that we want to implement it, and as numerous examples highlighted by Szymańska (2023) show, we are indeed implementing it. Thanks to the smart city idea, many cities have responded to this challenge and are trying to implement it and show by example (which other cities can follow) that it can be done. And if, in even the smallest way, this idea helps a city to be considered in all its complexity, then that in itself is already a lot.

Everything must be done to make life in present-day and future cities cleaner, healthier, cheaper and more comfortable, with the least possible pressure on the environment. Whether we achieve this depends only on us. Therefore, projects are being developed for modern cities of the future, as well as for the reconstruction and modernization of existing ones; where there will be no industrial pollution, illegal garbage dumps, dirty tap water or old, smoking cars; where there will be efficient and effective transport and places for recreation; where it will be quiet and comfortable. These are not only visions, but, as indicated in this article, projects that have already been implemented. Unfortunately, the smart city concept has not been widely implemented and most city dwellers (and the number of city dwellers is constantly growing globally) are experiencing the negative effects of runaway urbanization and enormous pressure on the environment. It is our moral duty to do everything we can to improve, through various actions (including implementing the smart city idea), the quality of life on our planet and to ensure that planet Earth is a permanent habitat for us, one which we should take care of, before it becomes too late to reverse the negative consequences of our actions. Regardless of where we work and where we live, at what geographical latitude, we can all, to a greater or lesser extent, influence the sustainable and integrated development of cities and urbanization. It is therefore important to remember that implementing the smart city idea should serve good social goals and ensure the security of our planet, so that it will ensure sustainable development and that the inhabitants of the green planet feel good and comfortable on it. We must implement all possible initiatives to make this happen.

Finally it is important to emphasize that the smart city concept should be implemented with the goal of achieving concrete goals and improving the quality of social and economic life, as well as the "health" of our planet. Implementing the idea and concept of the smart city is not a “race” among “projects for projects’ sake” (examples of such “megalomaniacal” projects include ghost towns in China); it is intended to serve specific purposes and to be socially and economically useful.

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