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Smart Cities for Urban Planning: A Bibliometric-Conceptual Analysis

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Abstract

This article addresses the application of information and communication technologies in the development of smart cities with a focus on urban planning. With rapid urban growth, significant challenges arise, such as the need for efficient infrastructure, quality public services, and environmental sustainability. Smart cities aim to tackle these challenges by utilizing technologies such as sensors, big data, the Internet of Things (IoT), and artificial intelligence (AI) to optimize urban resources and improve the quality of life for citizens. The study conducted a bibliometric analysis to map the scientific production on smart cities and urban planning, identifying trends, focus areas, and the use of key concepts. Additionally, the study identifies the main research areas related to smart cities, such as environmental sciences, urban studies, engineering, and computer science. The analysis of keywords and emerging trends in the literature offers a detailed view of research priorities and the gaps that still need to be filled. The article concludes with recommendations for future research and smart urban planning practices, emphasizing the importance of integrated and collaborative public policies.

Keywords: Urban Infrastructure, Participatory Governance, Sustainability

1. Introduction

With rapid and continuous urbanization, cities have become vital centers of economic, social, and cultural activities. According to UN-Habitat (2014), by 2050, approximately 70% of the world's population will live in urban areas. This urban growth brings significant challenges, such as the need for efficient infrastructure, quality public services, and environmental sustainability. At the heart of these challenges is urban planning, essential for the organization and development of modern cities.

In this context, smart cities emerge as an innovative solution to address urban challenges. Angelidou (2015) defines smart cities as those that use information and communication technologies to improve the efficiency of urban services and the quality of life for citizens. Urban planning plays a role in integrating these technologies, ensuring they are implemented cohesively and effectively (Batty, 2013).

Smart cities seek to optimize the use of urban resources through technologies, promoting connectivity between different urban systems. Bibri and Krogstie (2017) highlight that these technologies include sensors, big data, the Internet of Things (IoT), and artificial intelligence (AI), which are used to collect and analyze data in real-time, enabling more efficient city management. Urban planning is necessary to coordinate these technologies so that they contribute to sustainable urban development (Kitchin, 2014).

The implementation of these two concepts involves a paradigmatic shift in how public services are delivered and managed. As Albino, Berardi, and Dangelico (2015) state, the adoption of smart technologies can result in more resilient, sustainable, and inclusive cities, providing a better quality of life for their inhabitants. Thus, urban planning must anticipate these changes and adapt to integrate new technologies in a way that maximizes their

benefits (Harrison & Donnelly, 2011).

However, the transition to smart cities is not without challenges. Among the main obstacles are the need for investments in technological infrastructure, data management, and ensuring privacy and security for citizens (Caragliu, Del Bo, & Nijkamp, 2011). Urban planning must proactively address these challenges, developing strategies that balance technological innovation and citizen protection (Nam & Pardo, 2011).

Smart cities are tools for creating more sustainable, efficient, and livable urban environments, promoting economic and social development, with planning necessary to ensure that these technologies are implemented in an integrated manner, maximizing their benefits for the city as a whole (Sharma, Joshi, & Sharma, 2016).

The conceptual study of smart cities is necessary to understand how the integration of ICT can transform urban infrastructure and public services. Albino, Berardi, and Dangelico (2015) emphasize that research in this field allows for the identification of best practices and challenges associated with the implementation of smart technologies, facilitating the replication of successful solutions in different urban contexts. Urban planning needs to be informed by this research to develop effective and adaptable strategies (Kunzmann, 2014).

Moreover, the analysis of smart cities can provide valuable insights into urban governance and citizen participation. According to Chourabi et al. (2012), the adoption of smart technologies can promote more transparent and participatory governance, involving citizens in the decision-making process. Urban planning must incorporate citizen participation mechanisms to ensure that smart technologies respond to the real needs of the population (Cardullo & Kitchin, 2018).

This study aims to fill this gap by conducting a comprehensive bibliometric analysis of the literature on smart cities. The objective is to identify the main trends, focus areas, and collaboration networks among researchers and institutions (Yigitcanlar et al., 2018). Urban planning plays a central role in applying this knowledge, ensuring that urban development strategies are based on solid evidence (Vanolo, 2014).

Bibliometric analysis is a powerful tool for mapping scientific production in a specific field and identifying publication patterns, collaborations among authors and institutions, and emerging themes. As Vanolo (2014) and Kitchin (2014) state, this approach allows for a deeper understanding of the field's evolution and the dynamics driving it. Urban planning can use this information to develop more effective policies and practices (Kitchin, 2015).

By focusing on bibliometric analysis, this study also seeks to reveal the main challenges and opportunities in smart cities research. According to Nam and Pardo (2011), understanding collaboration networks and research trends can help guide future studies and policies, promoting more efficient and sustainable urban development. Urban planning must be attentive to these trends to adapt its strategies (Komninos, 2015).

The relevance of smart cities is associated with their ability to attract investments and talent. Hollands (2015) suggests that cities successful in implementing smart technologies can become hubs of innovation and economic development, attracting technology companies and qualified professionals. Urban planning must create an environment conducive to innovation and economic development, integrating smart technologies strategically (Bakıcı, Almirall, & Wareham, 2013).

Furthermore, this study intends to identify gaps in literature and suggest research areas that have not yet been adequately explored. As discussed by Komninos (2015), identifying these gaps seeks elements to advance knowledge about smart cities and develop innovative solutions that meet the specific needs of cities. Urban planning must be flexible and adaptable, incorporating new findings and innovations (Harrison & Donnelly, 2011). By mapping collaboration networks among researchers and institutions, this study aims to promote cooperation and knowledge exchange. According to Bibri and Krogstie (2017), interdisciplinary collaboration is essential to address the complex challenges of smart cities and develop integrated and effective solutions. Urban planning must foster this collaboration, creating an environment conducive to innovation and development (Neirotti et al., 2014).

The objectives of this study are: (1) to map the scientific production on smart cities focused on urban planning; (2) to identify the main themes and trends in research; and (3) to provide recommendations for future research and smart urban planning practices (Kummitha & Crutzen, 2017). Urban planning is the guiding thread that integrates these objectives, ensuring that scientific findings are translated into practical actions (Kitchin, 2014).

The first objective involves the collection and analysis of bibliometric data to map the scientific production on smart cities. This includes identifying the most cited articles, the leading journals, and the most prominent research areas. As Cocchia (2014) and Caragliu, Del Bo, and Nijkamp (2011) state, this analysis provides a comprehensive view of the field and highlights the most influential contributions. Urban planning can use this

information to guide its priorities and strategies (Sharma, Joshi, & Sharma, 2016).

The second objective is to identify the main themes and trends in smart cities research. This involves a thematic analysis to categorize research topics and identify the most common focus areas. According to Hollands (2015) and Dameri and Rosenthal-Sabroux (2014), this approach allows for a more detailed understanding of research priorities and the gaps that still need to be filled. Urban planning must align with these trends to remain relevant and effective (Kunzmann, 2014).

The third objective is to provide recommendations for future research and smart urban planning practices. This involves synthesizing the results of the bibliometric analysis and identifying future directions for research and practice. As Vanolo (2014) and Kitchin (2014) state, these recommendations are essential for guiding the development of more effective and sustainable public policies and urban practices. Urban planning must incorporate these recommendations to ensure that smart cities meet the needs of all citizens (Schaffers et al., 2011).

The article is organized as follows: the next section presents the theoretical framework used to support the article, followed by the methodology used for the bibliometric analysis, the results are presented and discussed in detail. Finally, the article concludes with the main findings, implications for practice, and suggestions for future research (Vanolo, 2014).

This research can contribute to the development of more effective and integrated public policies. As Komninos (2015) and Dameri and Rosenthal-Sabroux (2014) state, urban policies that incorporate smart technologies can improve coordination between different sectors and levels of government, promoting a more holistic and efficient approach to urban development. Urban planning is key to implementing these policies in a coherent and effective manner (Schaffers et al., 2011).

2. Literature Review

2.1 Smart City Concept

In recent years, the concept of smart cities has been extensively discussed in academic literature, with various authors exploring its definition, characteristics, and implications for urban planning and city development. Smart cities are often described as urban environments that utilize information and communication technologies (ICT) to optimize infrastructure, improve the quality of public services, and promote sustainable development (Batty, 2013; Angelidou, 2015).

Numerous studies have explored different aspects of smart cities, including governance, technological infrastructure, sustainability, and citizen participation. Cocchia (2014) conducts a systematic review of the literature on smart cities, identifying key themes and research trends. The integration of these areas is crucial for the success of urban planning in smart cities (Allwinkle & Cruickshank, 2011). Conceptualizing smart cities requires an interdisciplinary approach, involving collaboration across different fields of knowledge, such as computer science, urban planning, and social sciences, to address the complex challenges of smart cities and develop effective solutions for urban planning (Yigitcanlar et al., 2018).

Smart cities are defined as those that employ a wide range of digital technologies to improve the lives of citizens, promote sustainability, and make urban processes more efficient. The implementation of smart cities necessitates the strategic integration of technologies, public policies, and urban planning to ensure that technological advancements are aligned with the population's needs (Angelidou, 2015). Harrison and Donnelly (2011) emphasize that the integration of ICT with existing urban infrastructure is vital for the development of smart cities, requiring a holistic approach to urban planning where technology is used not only to optimize processes but also to create more livable and resilient cities.

For this purpose, the collection and real-time analysis of data in smart cities, generated by sensors, IoT (Internet of Things) devices, and other sources, form the basis for efficient urban management. The use of this information allows urban planners to make more informed decisions, respond quickly to emerging problems, and adapt development strategies to the dynamic conditions of cities (Bibri and Krogstie, 2017).

This vast amount of data necessitates big data analysis, which can transform urban planning and provide valuable insights into citizen behavior patterns, resource use, and urban trends, enabling more precise and adaptable planning. However, it is crucial to understand the ethical and privacy challenges associated with the intensive use of this data (Kitchin, 2014).

These technologies should lead the city to economic development by creating spaces that are hubs of innovation, attracting technology companies, startups, and skilled labor. Therefore, urban planning must create conditions

that foster entrepreneurship, innovation, and collaboration across different sectors of the economy, which, in turn, drives sustainable economic development (Komninos, 2015). They should also improve the efficiency and quality of urban services, such as transportation, health, and education, considering social and economic aspects in smart city planning to ensure that the solutions adopted are inclusive and accessible to the entire population (Caragliu, Del Bo, & Nijkamp, 2011).

Another challenge to be incorporated into the concept of smart cities is the pursuit of urban sustainability, which can contribute to reducing energy consumption, improving public transportation efficiency, and managing waste sustainably. The integration of smart city technologies with sustainability policies must ensure that technological innovations result in real environmental benefits (Albino, Berardi, and Dangelico, 2015). Sustainability should facilitate the efficient management of resources, the reduction of carbon emissions, and the improvement of quality of life, guided by data and citizen-centered to achieve these goals (Sharma, Joshi, and Sharma, 2016).

The success of smart city implementation also depends on collaborative governance and citizen participation, with smart cities designed not only to be technologically advanced but also to promote social inclusion and active citizen participation in decision-making processes (Nam & Pardo, 2011).

Analyzing the different approaches adopted by cities worldwide to become "smart," Neirotti et al. (2014) identified two lines of action: some cities prioritize technological infrastructure, while others focus on sustainability or citizen participation. This duality reflects the need to adapt smart city solutions to local specificities, which is essential for the success of urban planning in different contexts.

Thus, this work aims to explain that smart cities can be conceived as a model of integrated urban planning, where the strategic application of information and communication technologies (ICT) is fundamental to optimizing infrastructure and should be tools to promote sustainability and improve citizens' quality of life. This concept encompasses not only the implementation of technological innovations but also the integration of these solutions with collaborative governance policies, social inclusion, and economic development.

The success of smart cities depends on urban planning that is both adaptable to local dynamics and data-driven, ensuring that technological transformations are aligned with the real needs of the population and contribute to sustainable and inclusive urban development.

2.2 Application of Smart City Concepts in the Urban Planning of Global Cities

Several cities globally have embraced the smart city paradigm, integrating advanced technologies into their urban planning to enhance sustainability, efficiency, and the quality of life for their residents. This discussion examines how cities like Singapore, Barcelona, Amsterdam, Copenhagen, Songdo, New York City, and Masdar City have operationalized smart city concepts within their urban planning frameworks, supported by scholarly literature.

Singapore is often cited as a leading example of a smart city due to its holistic approach to integrating technology into urban life. According to Woetzel et al. (2018), Singapore has implemented intelligent transportation systems that utilize real-time data analytics to manage traffic flow, reduce congestion, and enhance public transit efficiency. The government's e-services platform allows citizens to access public services online, promoting transparency and administrative efficiency (Townsend, 2013).

In terms of urban planning, Singapore's Urban Redevelopment Authority employs advanced modeling and data analysis tools to make informed decisions regarding land use, transportation networks, and environmental conservation (Yeh, 2017). The integration of Information and Communication Technologies (ICT) is evident at every planning stage, ensuring that technological innovations align with urban development goals.

Barcelona has implemented several smart city initiatives focusing on sustainability and improving residents' quality of life. Bakici, Almirall, and Wareham (2013) highlight Barcelona's deployment of smart lighting systems, where LED streetlights equipped with motion sensors reduce energy consumption in unoccupied areas. The city has also introduced smart waste management systems; sensors in waste bins notify authorities when they need emptying, optimizing collection routes and schedules (Ajuntament de Barcelona, 2019).

"Urban Labs" have been established as collaborative spaces for testing new technologies in real urban settings, fostering innovation and citizen engagement (March & Ribera-Fumaz, 2016). The redesign of public spaces to accommodate these smart systems demonstrates how technological upgrades are aligned with urban development plans, enhancing connectivity and sustainability.

Amsterdam focuses on sustainability, open data, and innovation within its smart city framework. The city has implemented smart energy grids and promotes renewable energy sources within neighborhoods, as noted by

Kanters and Horvat (2012). Smart parking systems have been developed to reduce emissions and traffic congestion, and the city encourages electric vehicle use through supportive infrastructure (Gemeente Amsterdam, 2020).

Citizen participation is a cornerstone of Amsterdam's approach. Platforms like "Amsterdam Smart City" allow residents to contribute ideas and participate in decision-making processes (Meijer & Bolívar, 2016). Collaborative pilot projects in designated districts inform broader urban planning strategies that prioritize sustainability and technological integration.

Copenhagen aims to become carbon-neutral by 2025 through comprehensive smart city initiatives. The city utilizes sensors and data analytics to optimize traffic flow, prioritizing bicycles and public transport (Kongens Lyngby et al., 2014). Extensive cycling infrastructure is supported by smart traffic signals that adjust based on real-time conditions, improving mobility and reducing emissions.

Urban planners in Copenhagen integrate environmental data into their designs, ensuring new developments contribute to the city's carbon-neutral objectives while enhancing livability (Beatley, 2012). The city's commitment to sustainability is embedded within its urban planning policies, aligning technological advancements with environmental goals.

Songdo International Business District, built from scratch on reclaimed land, is a master-planned smart city incorporating advanced ICT infrastructure into every aspect. Shin (2014) describes how all buildings in Songdo are interconnected through a centralized system managing energy use, security, and communication. An automated waste disposal system transports trash directly from homes to processing facilities via pneumatic tubes, reducing the need for garbage trucks and lowering emissions (Cugurullo, 2016).

The city's design emphasizes sustainability and convenience, with pedestrian-friendly layouts and smart transportation options that minimize car use. Songdo's urban planning showcases how ICT can be seamlessly integrated into the urban fabric to enhance sustainability (Halpern, LeCavalier, Calvillo, & Pietsch, 2013).

New York City leverages technology to improve urban living and resource management. The LinkNYC initiative replaces public payphones with kiosks providing free Wi-Fi, phone calls, and device charging stations (NYC Mayor's Office of Technology and Innovation, 2016). The city employs big data analytics to optimize public services such as sanitation schedules, emergency response times, and housing inspections (Kitchin, 2014).

Urban planning in New York integrates technological upgrades with existing infrastructure projects. Retrofitting buildings and public spaces to accommodate new smart systems allows for technological advancement without extensive overhauls, aligning with sustainability objectives (Viola, 2019).

Masdar City is designed to be one of the most sustainable cities globally. Powered primarily by solar and other renewable energy sources, the city incorporates sustainable architecture to reduce energy consumption (Reiche, 2010). The implementation of a driverless electric personal rapid transit system reduces the need for personal vehicles, contributing to lower emissions.

Planned with sustainability at its core, Masdar City integrates smart technologies into the urban fabric from inception, serving as a model for future eco-friendly urban developments (Cugurullo, 2013). The city's urban planning demonstrates a commitment to environmental stewardship and technological innovation.

These cities exemplify how the smart city concept is operationalized through the integration of technology and infrastructure, data-driven decision-making, sustainable development, and citizen engagement. Embedding ICT into physical infrastructure—such as smart grids, IoT devices, and sensor networks—enhances efficiency and resource management (Harrison et al., 2010). Urban planners utilize big data analytics to inform decisions, optimize resource allocation, and improve service delivery (Kitchin, 2014).

Sustainable development is prioritized in urban design, incorporating energy-efficient buildings and green public spaces to reduce environmental impact (Yigitcanlar & Kamruzzaman, 2018). Citizen engagement is facilitated through digital platforms and participatory processes, ensuring that developments meet community needs and promote inclusivity (Cardullo & Kitchin, 2019).

By integrating smart technologies into urban planning, these cities aim to create more efficient, sustainable, and livable environments. The application of the smart city concept involves rethinking urban design to prioritize connectivity, sustainability, and inclusivity. Technological infrastructure is considered a fundamental component, with advancements in ICT directly contributing to improving the quality of life for all residents.

3. Method

Given the objectives of this article, a bibliometric analysis was chosen as it is a research method used to

investigate scientific progress. This technique involves the quantitative analysis of scientific publications to conduct qualitative evaluations of the number of publications, the dissemination of knowledge, techniques, and technologies adopted for problem-solving in a specific scientific field, authorship patterns of publications, among others.

3.1 Data Collection

A bibliometric study was conducted to examine the scientific production on smart cities in correlation with urban planning. This approach allowed the identification of the researchers behind these investigations and the funding agencies within the international scientific community.

The Web of Science database was chosen because it is considered one of the best databases for conducting systematic bibliometric research due to several reasons: Comprehensive and Multidisciplinary Coverage as it offers extensive coverage of various scientific disciplines, including social sciences, natural sciences, engineering, humanities, among others; Quality and Relevance of Publications given that the journals indexed in the Web of Science undergo rigorous evaluation and selection processes, ensuring the high quality and relevance of the publications. This guarantees that the data used in the bibliometric analysis comes from reliable sources (Web of Science, 2024).

For the bibliometric analysis, the advanced analysis tools offered by the platform were utilized. These tools provide various functionalities for bibliometric analysis, such as citation identification, impact factor calculation, co-authorship, and co-citation network analysis, as well as knowledge mapping. Additionally, the platform facilitates standardized access to the metadata of articles.

The exclusive use of the Web of Science database was chosen for its high reliability and reputation in the academic field, ensuring that the publications analyzed meet rigorous quality and scientific relevance criteria. Although this choice may result in a selection bias, the advantage lies in the guarantee that only the most impactful and peer-reviewed studies are included, avoiding the inclusion of works with lesser academic rigor. Similarly, the decision to include only articles was made to focus on publications that represent the most recent advances in the field, considering that scientific articles are often more up-to-date and reviewed than other types of publications, such as book chapters and technical reports. This provides a more condensed and objective view of the topics analyzed.

3.2 Keyword Analysis

For the keyword analysis, a keyword co-occurrence graph was employed. The data extraction and preparation were carried out using an Excel spreadsheet containing bibliographic records. The keywords were tokenized and vectorized, resulting in a binary occurrence matrix. From this matrix, a co-occurrence matrix was calculated, where each entry represented the frequency of co-occurrence between two keywords. The 50 most frequent keywords were filtered to focus on the most relevant keywords. The filtered co-occurrence matrix was then used to construct a graph, where the nodes represent keywords, and the edges represent their co-occurrences. The node sizes were adjusted according to the frequency of the keywords, visually highlighting the most important ones.

We used the Matplotlib library to plot the graph, configuring node sizes and labels for better interpretation. This methodology combined text mining techniques and network analysis, providing an intuitive visualization of the relationships between keywords, enabling the identification of central themes, emerging topics, and research gaps.

Furthermore, the choice of the K-means algorithm for cluster analysis was driven by its computational efficiency and ease of implementation in large datasets. This algorithm allows for the identification of patterns and groupings within the dataset quickly, making it especially advantageous for numerical and well-structured data, as used in this research. While other techniques could have been considered, K-means offers a balanced approach between precision and computational cost.

Finally, the decision to use keyword co-occurrence analysis was motivated by the ability to quickly identify recurring and emerging themes in the literature, which is essential for bibliometric studies. Although this may, in some cases, result in a superficial analysis, this technique efficiently captures trends, offering an overview of the field of study. The consideration of publication biases is an ongoing concern in bibliometric studies, but the choice of sources and methodology aims to mitigate this factor as much as possible, providing reliable and relevant results.

3.2.1 Information Processing Using Big Data

For processing, the "Data Analysis & Report AI" model developed by Kenneth Bastian was utilized, employing the GPT-4 AI processing by OpenAI. To perform the cluster analysis, the articles were vectorized using the Term Frequency-Inverse Document Frequency (TF-IDF) technique, which transforms text into a numerical format that can be processed by the machine learning algorithm.

Initially, a Microsoft Excel file containing the metadata of the articles (title, abstract, keywords, year of publication, and citations) was used, which was retrieved from the Web of Science as described in the previous step. The text preprocessing involved cleaning and preparing the texts for analysis, including the removal of stopwords, normalization, and lemmatization. With the cleaned texts, NLP criteria were used to transform the texts into vectors. Subsequently, TF-IDF embeddings (Term Frequency-Inverse Document Frequency) were created.

Next, the K-means algorithm was applied to identify nine distinct clusters. Dimensionality reduction was performed for data visualization, facilitating the interpretation of the results. The representative articles of each cluster were reviewed to identify the predominant themes.

4. Results

4.1 Bibliometric Analysis

The data presented in the table summarize the results of research conducted in the Web of Science on the topic "Smart City" or "Smart Cities." The research was carried out in three stages, applying different filters to refine the results and obtain a more specific overview of the available articles.

Figure 1. Stages of analysis and exclusion criteria for bibliometric analysis

Source: Research Data.

In the first stage, the search string "Smart City" or "Smart Cities" was used without any restrictions on document type or language. This initial search returned a total of 43,654 articles, reflecting the popularity and broad scope of the "Smart Cities" topic in academic literature. In the second stage, an additional filter was applied using the search string "Smart City" or "Smart Cities" AND "Urban Planning" in all fields, maintaining the same collection period. This filter reduced the number of articles to 1,773, indicating that a smaller number of studies directly address the intersection between smart cities and urban planning.

Finally, in the third and fourth stages, the results were further refined to include only articles published between 2015 and 2024, written in English, and of the "Article" type. With these additional restrictions, the number of articles was reduced to 1,180. This final refinement highlights a collection of recent and high-quality academic works that are relevant to understanding the most current trends and developments in the field of smart cities and urban planning.

4.1.1 Researchers' Countries of Origin

By analyzing the origin of the researchers, regional trends in innovation and urban development can be identified. Countries and continents differ in their approaches to implementing smart cities. Asia, particularly China and South Korea, may stand out for their focus on emerging technologies and massive infrastructure, while Europe may be seen as a leader in sustainability policies and participatory governance. Understanding these trends allows other countries and cities to adopt best practices and adapt successful strategies to their own realities.

According to Asheim et al. (2016), the economic complexity and technological innovation of a region are often correlated with the diversity and specialization of its workforce. Therefore, knowing the researchers' origins helps map these trends and promote more effective public policies.

The origin of the researchers also demonstrates international fostering and collaboration, as collaborative research projects between different countries can benefit from the combination of resources and expertise. Wagner et al. (2015) emphasize that modern science is inherently collaborative and that international research networks are fundamental to scientific advancement. They argue that cross-cultural collaboration expands the

scientific horizon and accelerates innovation.

According to Healey (2015), understanding local conditions and incorporating regional perspectives are essential for effective urban planning. The integration of local knowledge with global practices helps create more resilient and sustainable solutions.

Thus, the origin of the researchers was surveyed, revealing that 3,379 researchers from 95 different countries contributed to the works, as shown in Table 1 below.

Table 1. Distribution of articles by researchers' country of origin

Nº	Country	Researchers	%	Nº	Country	Researchers	%
1	China	499	27,5%	11	Saudi Arabia	35	1,9%
2	USA	166	9,1%	12	Sweden	34	1,9%
3	South Korea	87	4,8%	13	Brazil	33	1,8%
4	Italy	74	4,1%	14	Netherlands	33	1,8%
5	England	68	3,7%	15	Canada	31	1,7%
6	Australia	62	3,4%	16	Norway	28	1,5%
7	Spain	57	3,1%	17	Iran	27	1,5%
8	Japan	49	2,7%	18	Portugal	25	1,4%
9	India	43	2,4%	19	Singapore	22	1,2%
10	Germany	39	2,1%		Others	-	22,2%

China leads scientific production with 499 researchers contributing 27.5% of the articles. This high number can be attributed to the country's significant investments in technology and urban infrastructure, as well as the rapid urbanization and development of cities. The USA is the second-largest contributor with 166 researchers (9.1%), with a focus on technological innovation and the presence of several renowned universities and research institutions contributing to this significant scientific output. South Korea, known for its technologically advanced cities like Seoul, ranks third with 87 researchers (4.8%), as the country places strong emphasis on technology and smart cities.

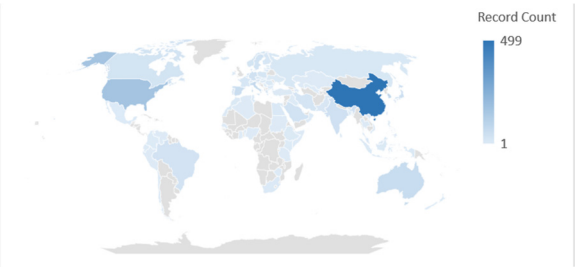

Figure 2. Distribution of article production by country

Asia is the most prominent continent, contributing the most to scientific production in smart cities and urban planning, with a total of 937 researchers, representing 78.08% of the total. This impressive number is mainly driven by China, which alone accounts for 499 researchers (41.58%). Besides China, other Asian countries such as South Korea (87 researchers, 7.25%), Japan (49 researchers, 4.08%), and India (43 researchers, 3.58%) also have a significant presence. The strong emphasis on technology, rapid urbanization, and substantial investments in smart infrastructure are factors contributing to this high production.

North America, with 201 researchers, represents 16.75% of the total article production. The United States is the main contributor in the region, with 166 researchers (13.83%). The high number of researchers in the U.S. reflects a strong focus on technological innovation and sustainable urban development, driven by prestigious universities and leading research institutions. Canada, with 31 researchers (2.58%), also makes a significant contribution to the region's scientific production.

Europe has 410 researchers, accounting for 34.17% of the total. The scientific production is distributed among

several countries, with notable contributions from Italy (74 researchers, 6.17%), England (68 researchers, 5.67%), Spain (57 researchers, 4.75%), and Germany (39 researchers, 3.25%). The diversity of contributions reflects Europe's strong tradition of research and innovation, with many countries investing in studies on sustainability, urban governance, and smart technology.

The analysis of the origin of researchers in smart cities and urban planning reveals the complexity and richness of global research. This understanding not only promotes diversity and inclusion in research but also facilitates the identification of regional trends, international collaboration, the development of effective public policies, resource allocation, and the appreciation of local research. Knowing the origin of researchers is, therefore, fundamental for the integrated and sustainable advancement of smart cities around the world.

3.1.2 Research Areas

The analysis of research areas related to smart cities and urban planning reveals a robust multidisciplinary approach, reflecting the complexity and breadth of this field. Below is a detailed description of the main research areas and the importance of multidisciplinary study.

The analyzed articles were divided into 70 research areas, with each article potentially classified in more than one area. This resulted in a total of 2,523 article entries.

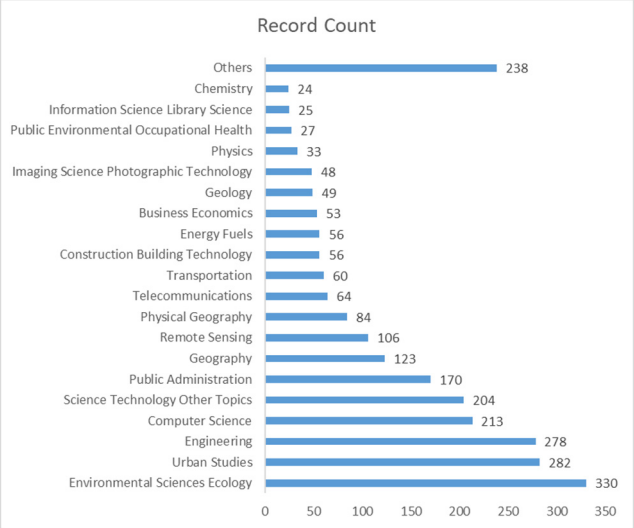

Figure 3. Distribution of research by Research Areas

The area of Environmental Sciences Ecology (330 articles, 27.97%) leads scientific production, highlighting concerns with environmental sustainability and the need to develop ecological solutions in urban environments. The research focuses on mitigating environmental impacts, developing green infrastructures, and conserving natural resources within the urban context.

Urban Studies (282 articles, 23.90%) concentrate on city planning and development, addressing issues such as urban growth, housing, infrastructure, and urban policies. The high representation in this area underscores the importance of understanding and resolving the complex challenges faced by modern cities.

Engineering (278 articles, 23.56%) is strongly represented, reflecting the need for technical and innovative solutions to urban problems. Urban engineering research often involves the development of new technologies, smart infrastructure systems, and sustainable construction methods.

Computer Science (213 articles, 18.05%) shows the growing integration of digital technologies in smart cities, evidenced by the strong presence of articles in this area. Research includes software development, big data analysis, artificial intelligence, and cybersecurity, all essential for the efficient operation of smart cities.

It should be noted that other research areas play a relevant role by offering complementary and specialized perspectives. The inclusion of these diverse areas ensures that the solutions developed are comprehensive, integrating technological, social, economic, and environmental aspects essential for the development of truly smart and sustainable cities.

3.2 Analysis of Key Themes and Trends

The keyword co-occurrence network graph provides a comprehensive view of the research landscape within the dataset, highlighting main themes, emerging topics, and potential research gaps. The quantitative analysis emphasizes the prominence and interconnection of central keywords, while the qualitative analysis offers insights into the thematic focus and evolutionary trends in smart cities research.

Thus, it visually demonstrates the relationships among the 50 most frequent keywords extracted from the dataset. The size of each node reflects the frequency with which a keyword appears in the dataset, while the edges denote the co-occurrence of keywords within the same documents. This network graph provides both qualitative and quantitative insights into the research themes and connections present within the dataset.

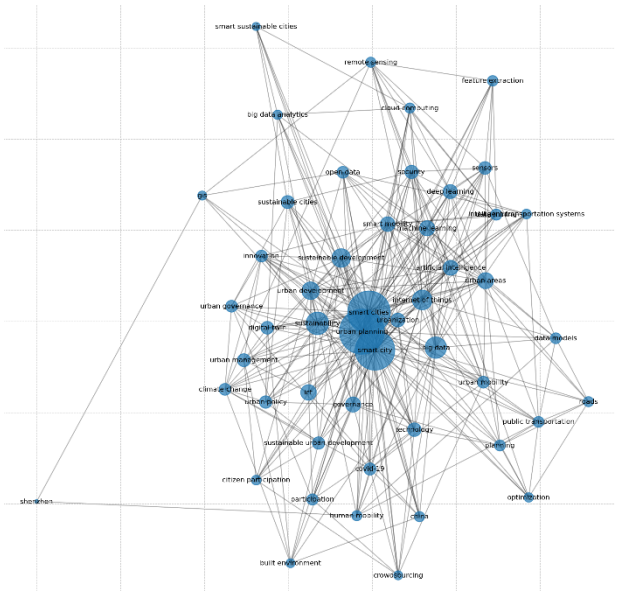

Figure 4. Network graph of co-occurrence of the 50 most relevant keywords

The size of the nodes in the graph is proportional to the frequency of the keywords. Larger nodes represent keywords that are mentioned more frequently in the dataset, indicating their prominence and relevance in the research domain. Keywords like "smart cities," "big data," "urban planning," and "sustainability" are among the largest nodes, suggesting they are central themes in the dataset.

The edges between the nodes represent the co-occurrence of keywords, with more connected nodes indicating higher degrees of co-occurrence. Keywords like "smart cities" and "big data" are not only large but also highly connected, indicating that they frequently appear together and are central in various research discussions.

The layout of the graph reveals clusters of closely connected keywords. These clusters indicate groups of related topics that are often discussed together in the literature. Themes such as "urban planning," "sustainability," "inclusiveness," and "digitalization" form a cluster, suggesting a thematic focus on how smart city concepts integrate with urban development and sustainable practices.

The central themes in the dataset revolve around smart city technologies and their applications. Keywords like "smart cities," "big data," and "urban planning" are central nodes, reflecting the main focus of the research. The frequent co-occurrence of these keywords suggests an interdisciplinary approach to studying smart cities, combining technology, data analysis, and urban development.

The presence of keywords like "inclusiveness," "social justice," and "participatory governance" indicates a growing interest in the social dimensions of smart cities. Researchers are not only focused on technological advancements but also on ensuring that these developments are inclusive and equitable. Keywords like "IoT" (Internet of Things) and "AI" (Artificial Intelligence) highlight the technological innovations driving smart city research, emphasizing the role of advanced technologies in urban management.

The analysis of less connected or smaller nodes may reveal potential research gaps. Keywords related to environmental sustainability or public health are less prominent, which may indicate areas where further research

could be valuable. The connections (or lack thereof) between clusters can also provide insights. If certain themes like "climate resilience" or "transportation infrastructure" are not well integrated into the main clusters, this could signal opportunities for more integrated research approaches.

The quantitative analysis of key emerging terms in recent research reveals that "smart cities" remains the most frequently used term, reinforcing its central role in contemporary research. Other terms like "big data," "urban planning," and "sustainability" also show significant frequencies, indicating their growing importance in research over the past few years. Among emerging terms, "big data" and "urban planning" stand out, reflecting the increasing integration of data analysis and strategic urban management in smart city initiatives. Additionally, "sustainability" and "decision-making" appear prominently, suggesting a focus on sustainable development and effective governance in urban planning.

Qualitatively, the continued prominence of "smart cities" underscores the ongoing interest and investment in research aimed at creating technologically advanced, efficient, and livable urban environments. The persistence of this term over the years indicates that it is not just a buzzword but a fundamental aspect of research and urban planning. The significant presence of "big data" highlights the trend towards data-driven decision-making in urban environments. Researchers and planners are increasingly relying on large datasets to inform and optimize city operations, reflecting broader technological advancements and the growing availability of data for urban analysis.

The emphasis on "urban planning" and "sustainability" points to a holistic approach to smart city development, where strategic planning and sustainable practices are prioritized. This suggests a shift towards creating cities that are not only smart but also resilient and environmentally responsible. Additionally, the presence of "decision-making" indicates a focus on governance and the processes involved in managing smart city initiatives, including the integration of participatory approaches and the use of data to support transparent and effective decision-making.

3.3 Problems and Trends for Future Studies

Urban planning and research related to smart cities are fundamental for the sustainable development of contemporary cities, and therefore, they will continue to grow in relevance in research (Karvonen, Cook & Haarstad, 2020). To identify the problems and future challenges for researchers and managers, an exploratory analysis was conducted, along with the development of a relevance analysis framework for various emerging topics in the context of urban planning and smart cities, providing an in-depth understanding of the challenges and opportunities present in this field.

The development of the relevance analysis framework was based on a detailed review of the main themes, titles, and keywords extracted from the dataset of this study related to smart cities. The topics were identified and classified according to their frequency and importance within the existing literature (Angelidou, 2014; Evans et al., 2019). Each topic was analyzed in terms of its relevance, potential impact, and practical applications, using both quantitative and qualitative approaches (Bélissent, 2010), as outlined in the table below.

Table 2. Outcomes

Topic	Importance	Potential Impact	Practical Application
Information and Communication Technology (ICT)	ICT modernizes and optimizes urban planning, enabling the collection and analysis of large volumes of data for more efficient urban management.	High precision in monitoring and forecasting urban needs, improving citizens' quality of life.	Implementation of IoT sensors for traffic monitoring, use of AI for optimizing public transport routes.
Sustainability and Green Infrastructure	Sustainability is important for long-term urban development, ensuring cities can face environmental and climatic challenges.	Reduction of carbon emissions, better management of natural resources, and increased urban resilience against extreme climatic events.	Development of urban parks, green roofs, and rainwater harvesting systems.
Urban Inclusion and Equity	Equity is essential to ensure all citizens benefit from urban development, regardless of their	Reduction of social inequalities, increased social cohesion, and improved	Affordable housing policies, digital inclusion programs, and participatory governance

	socioeconomic status.	quality of life in marginalized communities.	initiatives.
Public Health and Urban Planning	Integrating public health into urban planning is vital for creating urban environments that promote citizens' health and well-being.	Improved health conditions, disease prevention, and increased response capacity to health emergencies.	Planning of bike paths and green areas, air quality monitoring systems, and rapid response programs for public health emergencies.
Sustainable Mobility and Transport	Sustainable transport systems are essential for reducing the carbon footprint of cities and improving urban mobility.	Reduction of air pollution, decreased traffic congestion, and improved urban accessibility.	Infrastructure for bicycles and electric vehicles, efficient public transport, and vehicle sharing policies.
Water Resource Management	Efficient water resource management is relevant for ensuring the sustainability and resilience of cities.	Sustainable use of water, reduced risk of floods, and better water quality.	Water reuse systems, rainwater collection and storage infrastructure, and desalination technologies.
Land Use Planning	Efficient land use is essential for maximizing sustainable urban development and minimizing environmental impact.	Improved efficiency of urban space use, promotion of sustainable urban density, and preservation of natural areas.	Smart zoning policies, development of mixed-use zones, and urban densification strategies.
Urban Economy and Development	Sustainable economic development is fundamental for the vitality of cities and job creation.	Creation of new job opportunities, promotion of innovation, and increased urban competitiveness.	Innovation zones, incentives for startups, and circular economy programs.
Construction and Infrastructure Technologies	Innovative construction technologies are important for building sustainable and resilient urban infrastructure.	Reduction of resource consumption, increased durability of structures, and improved energy efficiency.	Use of sustainable materials, modular construction, and low-carbon construction technologies.
Urban Planning and Climate Change	Adapting urban planning to climate change is important to ensure the resilience of cities against extreme climatic events.	Reduction of risks associated with climate change, increased urban resilience, and protection of citizens and infrastructure.	Climate adaptation plans, carbon emission mitigation strategies, and development of resilient infrastructure.

In the quantitative analysis, the frequency of keyword occurrences and their correlation were mapped to understand the interconnection between the topics (Cai et al., 2020). Network analysis and data visualization tools were employed to identify the main clusters and their interrelationships (Karvonen, 2018), as demonstrated in the figure below.

Figure 5. Correlation Network Graph of Topics

The relevance analysis for emerging topics in urban planning highlights the importance of integrating innovative technologies, sustainable practices, and social considerations to address urban challenges (Karvonen, Cook & Haarstad, 2020). A deep understanding of future trends and current research problems provides a solid foundation for developing strategies that will promote more resilient, inclusive, and sustainable smart cities (Angelidou, 2014). The relevance analysis graph serves as an essential guide for researchers, urban planners, and policymakers who seek to innovate and improve urban life (Evans et al., 2019).

3.3.1 Main Research Challenges

The digital divide remains one of the biggest challenges in the implementation of smart cities. According to Bélissent (2010), overcoming this divide ensures that all citizens have equal access to smart city technologies. Digital inclusion should be addressed not only as a technical issue but also as a social and economic problem that requires effective public policies and a collaborative effort between the government, private sector, and civil society. Barriers to access include not only the lack of technological infrastructure but also the lack of digital skills and economic accessibility.

Developing effective strategies for urban adaptation to climate change is another pressing challenge. As highlighted by Angelidou (2014), cities need to adopt resilient urban planning practices to mitigate the impacts of climate change. This includes implementing green infrastructure, promoting energy efficiency, and adapting building codes to withstand extreme weather events. Urban resilience should also be integrated into long-term planning to ensure that cities can continually adapt to environmental changes.

Balancing urban growth with sustainable practices is essential to minimizing the environmental impact of cities, as discussed by Evans et al. (2019). Smart cities must incorporate sustainable development principles into their growth plans, including efficient resource utilization, promotion of sustainable transportation, and implementation of waste management systems. The integration of smart technologies, such as IoT sensors and data management platforms, can help monitor and optimize resource use, promoting more sustainable urban development.

Data security and privacy are central concerns in highly connected and monitored cities, as discussed by Karvonen (2018). The collection and use of large volumes of data in smart cities raise questions about who has access to this data and how it is protected from misuse. It is crucial to develop robust data governance policies that include data encryption, strict access control, and transparency about how the data is used. Additionally, educating citizens about digital security practices can strengthen trust in smart city initiatives.

Furthermore, as discussed by Karvonen et al. (2020), digitalization and technological innovation in cities should be seen as sociotechnical agendas, where social, political, and cultural changes are as important as technological advancements. This holistic understanding is essential to ensuring that smart cities not only improve efficiency and competitiveness but also promote social equity and environmental sustainability.

4. Conclusions

The bibliometric-conceptual analysis of smart and sustainable cities for urban planning revealed a wide range of challenges and opportunities that are essential for the development of future cities. This research provided valuable insights into the intersection of technology, sustainability, and social inclusion in the urban context.

First, the digital divide was identified as one of the main obstacles to the effective implementation of smart cities. Overcoming this divide aims to ensure that all citizens have equal access to emerging technologies, promoting a more just and equitable society (Bélissent, 2010). Effective public policies and multisectoral collaboration were necessary to address both technological and socioeconomic barriers.

Secondly, adaptation to climate change was highlighted as an urgent priority in urban planning. Urban resilience strategies, including green infrastructure and energy efficiency, were essential to mitigate the impacts of climate change and ensure the long-term sustainability of cities (Angelidou, 2014).

Additionally, balancing urban growth with sustainable practices was considered vital to minimizing the environmental impact of cities. The integration of smart technologies, such as IoT sensors and data management platforms, could optimize resource use and promote more sustainable urban development (Evans et al., 2019).

Data security and privacy emerged as central concerns in highly connected cities. Developing robust data governance policies was deemed essential to protect citizens from the misuse of personal information, thereby strengthening trust in smart city initiatives (Karvonen, 2018).

Another aspect was the need to understand smart cities not just as a technological agenda but as a sociotechnical agenda. Social, political, and cultural changes were as important as technological advances in promoting smart

cities that are efficient, competitive, equitable, and sustainable (Karvonen et al., 2020).

The analysis of research areas revealed a robust multidisciplinary approach, with emphasis on environmental sciences, urban studies, engineering, and computer science. This diversity was essential for developing integrated and effective solutions to contemporary urban challenges.

The study also highlighted the importance of inclusion and equity in the development of smart cities. Citizen participation was considered essential to ensure that all voices are heard and taken into account in urban planning, promoting more transparent and participatory governance (Cardullo & Kitchin, 2018).

Furthermore, the bibliometric analysis indicated that international collaboration was crucial for advancing research on smart cities. Collaboration networks between researchers and institutions from different countries could accelerate innovation and the implementation of global best practices.

It should be noted that this study presented some important limitations as the bibliometric analysis was based exclusively on data available in the Web of Science, which may have excluded other relevant sources of literature on smart cities and urban planning. Additionally, the analysis focused on publications in English, which may have led to an underrepresentation of relevant research conducted in other languages. This could have limited a full understanding of global practices and developments in smart cities, especially in regions where local language research is more prevalent.

In concluding the research, it was possible to identify some limitations inherent to the adopted methodology. Firstly, by opting to conduct a bibliometric analysis, the aim was to map the scientific production in the field of smart cities and urban planning. Although this methodology allowed for the identification of trends, collaboration networks, and gaps in the literature, a limitation was found in the lack of a more in-depth qualitative assessment of the analyzed studies. This resulted in restricting the understanding of the practical implications of emerging concepts, as well as limiting the analysis of the concrete implementation of smart city technologies in urban contexts. The justification for choosing bibliometric analysis lay in its capacity to analyze large volumes of data efficiently, enabling the detection of patterns and dynamics. However, it was observed that the approach did not allow for a more detailed examination of practical challenges in different urban realities.

A limitation was identified due to the dependence on the analysis of keywords and emerging trends in the literature to outline the focus areas of the research. While this strategy proved effective in detecting recurring themes, it ended up providing a partial view of the complexities involved in the adoption of technologies such as IoT, artificial intelligence, and big data in urban planning. The justification for this choice was based on the ability to provide a broad view of theoretical priorities and challenges; however, it was found that the absence of a deeper critical analysis of the concrete impacts of these technologies may have limited the applicability of the results in formulating public policies and developing more integrated and sustainable urban practices.

Nonetheless, the identification of emerging themes and gaps in the literature provided a solid foundation for future research. A deep understanding of current trends and research issues was important for developing strategies that promote more resilient, inclusive, and sustainable smart cities.

In summary, this bibliometric-conceptual analysis offered a comprehensive and detailed view of the challenges and opportunities in urban planning for smart cities. The integration of innovative technologies, sustainable practices, and social considerations was essential to addressing urban challenges and promoting the development of cities that truly improve the quality of life for citizens.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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