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Decadal Trends in Smart Healthcare: A Bibliometric Review of Smart City Innovations

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Abstract— **In recent years, the smart cities concept has witnessed significant expansion globally, with particular attention given to the healthcare sector. This evolution is closely associated with the emergence and increasing integration of technologies such as artificial intelligence, the Internet of Medical Things(IoMT), cloud computing, and telemedicine. This study aims to analyze research trends in smart cities and healthcare over the past decade. To achieve this, we utilized the Scopus database to extract relevant information from a carefully curated corpus of 930 articles. Our analysis focuses on identifying key scientific journals, as well as the most cited articles. Our findings reveal a notable growth trend in publications and identify the top ten journals specialized in the selected field, such as IEEE Access, while also unveiling the most cited articles. Keyword co-occurrence analysis was conducted using the RStudio tool and the R programming language. This study offers valuable insights to encourage ongoing innovation in the field of healthcare.**

Keywords— Smart city; Healthcare delivery; Smart health; Internet of things (IoT); Telemedecine; Bibliometrix, LDA algorithm; RStudio

I. INTRODUCTION

In recent years, smart cities have become a focal point of global attention [1]–[4], especially in the realm of healthcare delivery innovations. The synergy between urban development and technological advancements has ignited a transformative discourse aimed at optimizing healthcare services in urban environments [5]. A comprehensive analysis of healthcare delivery innovations in smart urban settings over the past decade is crucial. This article presents a comprehensive review and bibliometric analysis to identify the primary scientific contributions and leading journals in the fields of healthcare innovation and smart cities.

We employed the Scopus database to gather pertinent information for descriptive and co-occurrence analysis, acknowledged as a significant academic resource for extracting relevant data from a diverse array of scientific publications. This bibliometric analysis strives to highlight the most impactful works and key journals in the field of healthcare innovation and smart cities over the studied period. Moreover, the utility of descriptive analysis lies in its ability to provide a detailed overview of research trends and key areas of interest in this burgeoning domain. Additionally, keyword co-occurrence analyses performed with RStudio facilitate an in-depth exploration of the interplay between key concepts.

The integration of digital technologies, such as data analytics, and urban infrastructure has accelerated the development of innovative healthcare delivery methods in urban contexts. From telemedicine to IoT-based surveillance systems [6], the fabric of healthcare in smart cities has undergone profound transformations. Nevertheless, a nuanced understanding of the prevailing trends, leading contributors, and seminal publications is imperative to contextualize the progress made and direct future research pathways.

Drawing from a wealth of academic literature and bibliometric data [7]–[15], this article elucidates emerging themes, influential studies, and scholarly networks shaping the discourse on innovations in healthcare delivery in smart cities. By synthesizing insights gleaned from a decade of research, this study aims to provide valuable perspectives to policymakers, practitioners, and researchers, thereby facilitating informed decision-making and fostering ongoing innovation in this dynamic field. The objectives of this study are as follows:

- Examine the increasing trend in the publication of articles over the last decade.
- Identify patterns, including the most prolific scientific journals and the most cited articles in the studied field.
- Analyze the dominant keywords in healthcare innovation and smart cities by conducting a keyword co-occurrence analysis.

The rest of the document is structured as follows: the second section details the methodology employed. The third section provides a comprehensive descriptive analysis. The fourth section presents an analysis of keyword co-occurrence. Finally, the last section engages

with a comprehensive discussion and outlines the study's limitations and future perspectives.

II. METHODOLOGY

The methodology adopted for this study involves several key steps in the collection and analysis of bibliometric data. Initially, an exhaustive search was conducted in the Scopus database to extract necessary information, including titles, keywords, abstracts, and publication years of relevant documents (see Fig. 1). This search yielded an initial dataset comprising 2,687 documents.

Subsequently, a filtering process was applied to these documents based on predefined criteria: publication years ranging from 2013 to 2023, document type restricted to articles, and the language of publication set to English. This filtering step was designed to ensure the quality and consistency of the data utilized for our bibliometric analysis [16]. After filtering, the dataset was narrowed down to 930 documents, resulting in a more targeted and relevant dataset for our study.

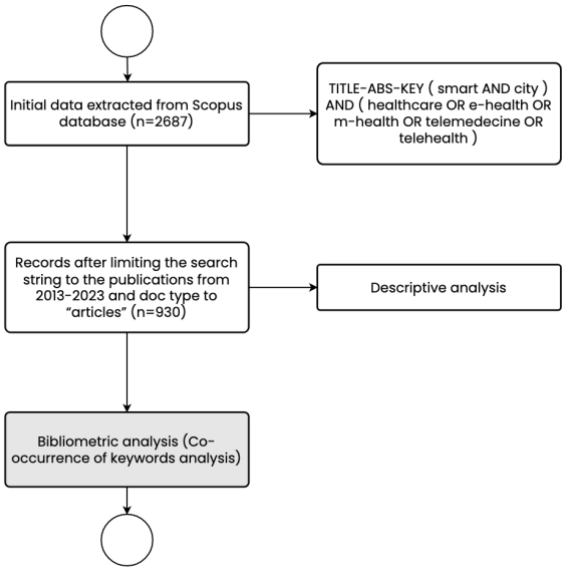

Figure 1. Flow chart of research methodology

To conduct the bibliometric analysis, we utilized the RStudio development environment and the R programming language, leveraging the advanced capabilities of the Shiny App for Bibliometrix [17]. This platform offers a suite of tools and techniques to explore and analyze bibliometric data efficiently and rigorously.

With the data prepared and the appropriate tools in place, we conducted a comprehensive descriptive analysis to discern general trends of publications in the studied field. This analysis encompassed studying the distribution of articles by year, identifying the most frequently cited documents, as well as the most frequently used words. In conjunction with the descriptive analysis, a keyword co-occurrence analysis was performed. This enabled the identification of relationships between key terms and the elucidation of central concepts in the studied scientific literature, thereby offering deeper insights into the research landscape of this field. Subsequently, topic modeling was conducted as a text analysis technique to uncover the primary themes within the document set. This method employs statistical algorithms to assign probabilities to each word in the documents, grouping them into coherent topics [18]–[22]. Our study's focus is a thorough analysis of the results from topic modeling applied to the relevant dataset using the Latent Dirichlet Allocation (LDA) algorithm and the LDAShiny [23].

III. DESCRIPTIVE ANALYSIS

A. Publication Output

The figure below depicts the trajectory of scientific publications related to innovations in healthcare and smart city domains over the past decade. This visualization highlights a significant increase in the number of publications, reflecting the growing interest of researchers in the intersections between smart cities and online healthcare.

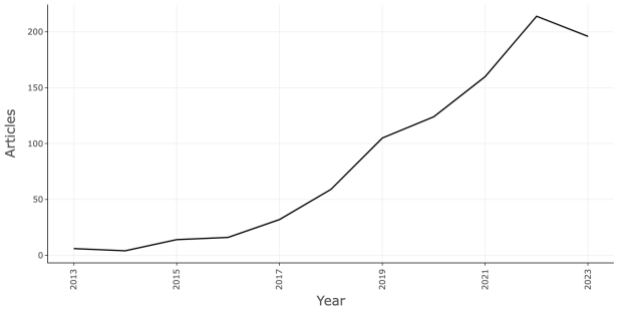

Figure 2. Annual Scientific Production

B. Sources' Local Impact

The most cited journals and articles are presented in Table 1 and Figure 3. IEEE Access (3477 citations), IEEE Internet of Things Journal (2322 citations), and Sustainable Cities and Society (2321 citations) are the most productive journals with 65, 31, and 28 publications respectively. IEEE Access had the highest H-index of 29. It is worth noting that "NP" stands for the total number of publications and "TC" denotes the total number of citations, as shown in Table 1.

TABLE I. TOP SOURCES' LOCAL IMPACT

Element	*H_i*	*TC*	*NP*	*PY_s*
IEEE access	29	3477	65	2016
Sustainable cities and society	22	2321	28	2018
IEEE internet of things journal	18	2322	31	2017
Future generation computer systems	15	2224	16	2017
Sensors (switzerland)	14	1504	17	2013
Sensors	9	278	24	2021
Wireless personal communications	9	396	16	2017
Computer communications	8	583	10	2015
Sustainability (switzerland)	8	294	23	2020
Applied sciences (switzerland)	7	171	17	2019

The number of citations an article receives is indicative of its value and influence in the scholarly domain. Accordingly, this study has highlighted the most cited articles, as presented in Figure 3 [24]–[33]. The relevance and impact of an article are positively correlated with its citation count. In other words, an article gains importance

as its number of citations increases, indicating its recognition and adoption by the scientific community. For example, the top-ranked article, published in IEEE, has accumulated an impressive total of 853 citations, attesting to its substantial impact on the scientific literature in the studied field.

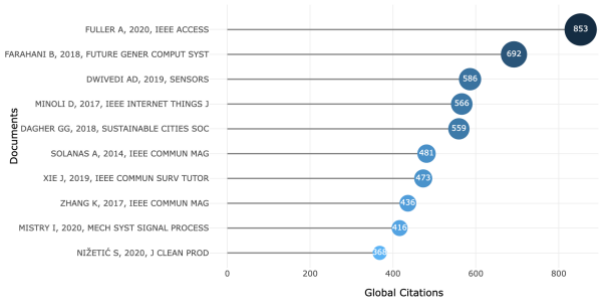

Figure 3. Most Global Cited Documents

C. *Most Frequent Words*

The word cloud analysis identifies dominant themes in the literature on smart cities and healthcare innovations (see Fig. 4). The terms “Internet of Things” and “smart city” are particularly prominent, mentioned 394 and 309 times respectively, indicating a strong emphasis on IoT’s role in smart urban development. Furthermore, the term “healthcare” appears frequently, with 194 occurrences, underscoring the critical focus on healthcare advancements in smart cities. This pattern points to a growing convergence between technological progress with the needs of healthcare delivery in smart urban environments.

Figure 4. Keywords frequency analysis

IV. BIBLIOMETRIC ANALYSIS

A. *Co-occurrence of keywords analysis*

Keyword co-occurrence analysis was conducted to study the most frequent keywords and themes across the selected documents. To achieve this, the minimum number of keyword occurrences was set to 10, meaning that only keywords appearing at least 10 times in the selected documents were retained. Among the most recurring keywords in the literature on smart cities and online healthcare are “health care”, “internet of things”, “smart city”, “human”, “m-health”, and “cloud computing”. This indicates that a significant amount of research has been conducted and continues to be conducted in the aforementioned domains.

Figure 5 presents a thematic map of research on smart cities and healthcare. The size of the bubbles in the graph reflects the frequency of occurrence of keywords in the analyzed publications. In the quadrant of driving themes, a significant concentration of subjects emerges, characterized by high density, notably the key term “Internet of Things”, along with a substantial set of associated keywords. In contrast, the quadrant of core themes harbors themes with low density but marked centrality, such as “smart city” and “healthcare”. The quadrant of niche themes groups subjects with strong internal links but less prominent external links. Finally, the quadrant of emerging themes lists themes characterized by weak internal and external links, accompanied by relatively low density and centrality.

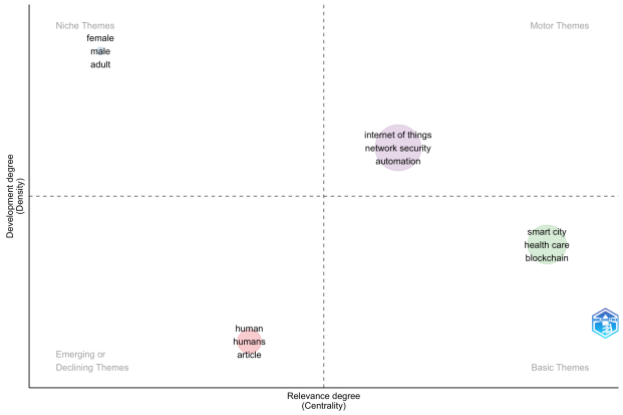

Figure 5. Thematic Map

B. *Topic Modeling using LDA Algorithm*

The initial stages of the topic modeling analysis involved text preprocessing, including the removal of elements deemed irrelevant. An effective lexicon was constructed to decipher the themes within the texts. Subsequently, the LDAShiny tool was utilized to build the LDA model and determine the optimal number of topics that enhance the quality of our topic modeling model using the topic coherence score (see Fig. 6).

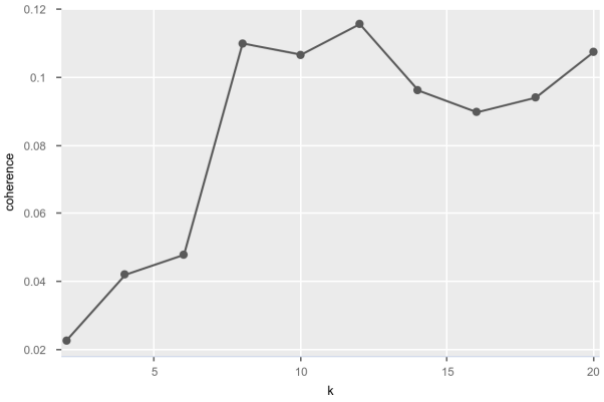

Figure 6. Topic coherence scores

The results from the LDAShiny tool revealed a high frequency of the following terms across all topics: healthcare, time, cities, reality, sensors, real-time, health, applications, and technology. These findings suggest a strong interest in technological advancements and innovative strategies in real-time urban healthcare delivery, emphasizing efficient time management, the use of sensors

for real-time monitoring, and the significance of technological solutions such as mobile applications and connected medical devices.

V. DISCUSSION

The present study has provided an in-depth examination of trends, relationships, and emerging themes in research on smart cities and healthcare innovations, with a particular focus on the role of telemedicine and online healthcare. The results revealed a significant concentration of research on key subjects such as the Internet of Things (IoT) and the applications of technology in the fields of healthcare and urbanism, including telemedicine and online healthcare. This focus underscores the growing interest of researchers in the opportunities offered by digital technologies in creating smarter cities and more efficient healthcare systems through the application of digital health [34]–[35].

Digital health application, also known as digital health or e-health, refers to the use of information and communication technologies (ICT) in the healthcare domain to enhance healthcare delivery, disease management, and health promotion [36]–[43]. This approach encompasses a wide range of technologies such as mobile applications, wearable devices, online platforms, electronic health records, data analytics tools, and telemedicine. One of the main contributions of digital health application is its ability to improve accessibility and efficiency of healthcare. Health tracking mobile applications enable individuals to monitor their health status, track their progress in areas such as fitness, nutrition, and stress management, and even receive personalized advice based on collected data [44]–[47]. This provides patients with a convenient and immediate way to manage their well-being, while giving healthcare professionals a more comprehensive insight into their patients' health outside of the clinical setting. Additionally, e-health facilitates the management of chronic diseases by enabling patients to monitor their health status at home and easily share data with their healthcare providers. For instance, wearable devices can continuously monitor vital parameters such as blood pressure, blood glucose, and heart activity, allowing patients with chronic conditions such as diabetes or hypertension to quickly detect changes and adjust their treatment accordingly [48]–[50]. Furthermore, e-health can help overcome geographical barriers by enabling remote healthcare delivery, notably through telemedicine. Virtual medical consultations allow patients to access quality healthcare even in remote areas where access to traditional medical services is limited. This can also reduce waiting times for consultations, thereby improving the efficiency of healthcare services. However, despite its many benefits, digital health application is not without challenges. Issues such as privacy protection of health data, quality and reliability of information provided by applications, and disparities in access to digital technologies may pose obstacles to widespread adoption and maximum impact of e-health. Therefore, it is essential for public health policies and regulatory standards to be developed and implemented in a way that ensures digital health application is secure, effective, and equitable for all users.

Telemedicine and online healthcare emerge as essential pillars of research in urban health and smart cities. Their inclusion in the analyzed publications underscores their central role in transforming urban healthcare services by enabling remote access to healthcare, home medical monitoring, online consultation, and other related services. This innovative approach addresses the challenges of rapid urbanization and urban densification by providing solutions to improve accessibility, efficiency, and quality of healthcare in urban environments.

Furthermore, keyword analysis highlights the importance of concepts such as “smart city” and “healthcare”, which have emerged as central themes in the studied literature, with significant implications for the deployment and integration of telemedicine and online healthcare in smart cities. These terms reflect the growing recognition of the interconnectedness between smart urban infrastructures and initiatives aimed at improving healthcare delivery, with telemedicine and online healthcare serving as catalysts for this convergence.

VI. CONCLUSION

The results underscore the urgency and relevance of integrating these digital technologies into urban planning and management to enhance accessibility, efficiency, and quality of healthcare services for urban populations. Telemedicine and online healthcare offer innovative solutions to address the challenges posed by rapid urbanization and demographic growth, enabling more flexible, personalized, and efficient healthcare delivery. Moving forward, it is crucial to continue research in this field to better understand the implications and opportunities presented by telemedicine and online healthcare in smart cities.

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