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A Bibliometric Analysis of Circular Economies through Sustainable Smart Cities

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Abstract: The rapid pace of urbanization has presented cities worldwide with a range of complex issues pertaining to the management of resources, reduction of waste, and promotion of sustainable practices. The concepts of circular economies and sustainable smart cities have arisen as viable solutions, converging to establish a revolutionary framework for the future of urban living. This study conducts a bibliometric analysis using literature focusing on the past ten years (2013–2022) of research on the circular economy and smart cities using VOSviewer. The most frequently used Scopus database was used to extract bibliometric data. 163 articles were considered for the analysis. This study utilizes co-authorship, co-occurrence, citation analysis and bibliographic coupling of author keywords while grap0hically mapping the bibliographic material using VOS viewer software Version 1.6.19. The bibliographic analysis reveals that the significant themes published in journals revolve around "circular economy", "Sustainable development", "sustainability", "smart city", "waste management", "recycling", "Sustainability", "climate change", "smart technologies", "municipal solid waste", "renewable energy", and "planning". The results would provide a robust base for more research in this area. The research work paves the way for future research in the related areas and issues of the domain, as it is an emerging issue in research, and many problems are untapped.

Keywords: bibliometric analysis; circular economy; smart cities; urbanization; smart technologies; VOSviewer

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1. Introduction

Recently, the issues of smart cities, climate change, and the circular economy have attracted extensive scientific research on a global scale. According to predictions from the United Nations, 68% of the world's population will reside in cities by the year 2050, up from around 55%. More than 70% of the world's CO_2 emissions are produced by industrial and motorized transportation systems, which use fossil fuels and are dependent on distant infrastructure made of carbon-intensive materials. Cities and metropolitan areas account for approximately 70% of the world's Gross Domestic Product [1–4]. This urbanization process creates Environmental, Social, and Governance (ESG) issues, stressing the significance of developing environmentally sound methods to reduce resource consumption, such as urban mining. Smart cities use technology and data to optimize resource allocation and reduce waste and energy consumption. For example, smart cities can use sensors and analytics to monitor and manage energy consumption in buildings, optimize traffic flow to

reduce fuel consumption and emissions, and use data to identify areas where waste can be reduced and recycled. The concept of the "circular city" is a recent addition to a series of urban sustainability concepts that advocate for fundamental alterations in urban planning, construction, and city development. Nevertheless, this aspect frequently receives criticism due to its inherent ambiguity. Experimentation is a commonly employed approach to urban government to achieve revolutionary goals amid significant uncertainty and ambiguity. However, it is important to note that experimentation is susceptible to manipulation by many stakeholders with different and sometimes self-interested agendas [5]. On the other hand, the goal of a circular economy is to move away from the traditional "take-make-dispose" linear paradigm and towards a more sustainable one where resources are used for as long as feasible while waste and pollution are reduced. This involves designing products for reusability, recyclability, and repair ability and creating closed-loop systems where waste from one process becomes a resource for another. The adoption of sustainable practices has emerged as a strategic approach to gain a competitive edge in the marketplace. The effect of this phenomenon has resulted in significant changes to organizations' behavior in the market, internal organizational structures, interactions with suppliers and customers, as well as the innovation of their product and service offerings [6]. Considering the ongoing process of global urbanization, it becomes imperative to discern and use novel urban development paradigms and tactics to effectively address the complexities associated with sustainable development. The increasing complexity of urban environments necessitates the development of a comprehensive framework for assessing the circular economy in cities, as they grapple with ongoing obstacles in achieving full circularity [7,8].

The Sustainable Development Goals (SDGs) serve as a collective agenda for nations and serve as a focal point for progressive policy discussions. The analysis and monitoring of the Sustainable Development Goals (SDGs) are crucial measures in assessing potential remedial actions [9]. The primary goal of the Sustainable Development Goals (SDGs) is to foster the attainment of a society that is characterized by inclusivity, resilience, safety, and sustainability. Policy makers, entrepreneurs, and residents are tasked together with a significant endeavor to maximize the efficiency of land utilization. The pursuit of sustainability in urban development poses a multifaceted challenge due to its intricate nature, characterized by a network of interdependent linkages. Determining the best equilibrium point within this system presents practical obstacles [10].

The concepts of "Smart Cities and Circular Economies" can be complementary by facilitating more effective resource use, lowering waste and emissions, and enhancing the tracking and management of resources across the metropolitan system. Smart city technology can also assist in the transition towards circular economy practices. For example, smart city technologies can help track and trace materials throughout the supply chain and create more effective waste management systems that reduce the amount of waste sent to landfills. Similarly, circular economy principles can help guide the development of smart city technologies by emphasizing the need for sustainable, long-lasting, and resource-efficient solutions. A "Smart City" is a well-developed urban area that uses cutting-edge, integrated infrastructure, sensors, electronics, and networks interfaced with computerized systems made up of databases, tracking, and decision-making algorithms to be efficient, safe, and environmentally friendly. All structures are developed, constructed, and maintained, whether they are used for power, water, transportation, energy efficiency, etc. Smart city policies encourage innovative ways of planning, organizing, and administering cities and their flows on the one hand while also imposing a new moral order on the city by establishing technical criteria to discriminate between "good" and "bad" cities. The implementation of sustainable urban logistics is crucial to achieve urban sustainability objectives. Within the European context, the European Union (EU) established a notably ambitious objective in 2011, aiming to achieve urban logistics that are essentially devoid of carbon dioxide (CO_2) emissions by the year 2030. Nevertheless, the extent to which these European Union (EU) aims have influenced the development of policies at the national and metropolitan levels remains uncertain [11].

A smart city is one where information and communications technology (ICT) and traditional infrastructure are coordinated and integrated using new and innovative digital technologies [12]. The circular economy (C.E.) may benefit from new digital technologies such as Big Data, Machine Learning, Artificial Intelligence (A.I.), Internet of things (I.O.T.) and Blockchain. Several global issues are believed to have solutions in these digital technologies and sustainable business models, especially those related to the circular economy's transition [13]. A circular economy is a crucial sustainability strategy to fight against climate change. Several governments at various levels have been establishing a long-term circular economy vision. The growth of circular economy capabilities depends on digital progress. Artificial intelligence fueled by big data analytics has recently gained importance [14]. The adoption of a circular economy (CE) is becoming more widely acknowledged as a viable approach to address urgent sustainability issues at the urban level. Indicator-based frameworks, also known as integrated systems of indicators, are widely recognized as valuable instruments for monitoring the process of this shift. It is noteworthy that the majority of frameworks primarily comprise environmental indicators, with only three frameworks incorporating indicators that encompass the various dimensions of sustainable development, namely environmental, social, economic, and governance aspects [15]. The management of electronic waste, commonly referred to as e-waste, has emerged as a pressing concern in the contemporary era characterized by rapid technological advancements. Despite the identification and development of several methods aimed at enhancing e-waste recycling efficiency, the improper disposal of outdated items by end users remains a prevalent issue, as observed in different studies [16].

Cities can become less resilient due to flooding, water pollution, adverse health consequences, inadequate repair and maintenance of water and wastewater systems, rapid urbanization, climate change, poor solid waste management, and water scarcity and pollution [17]. A revolutionary idea called "smart cities" is quickly gaining acceptance since it offers solutions to severe urban problems such as traffic, pollution, energy use, and waste management. "Digital cities", "green cities", and "knowledge cities" are a few examples of older urban planning ideas that have been combined to create "smart city" ideas. Thus, a smart city is a progressive, long-term vision of an enhanced metropolitan area that seeks to reduce its implications on the environment and develop the quality of life for its citizens. It is critical to take the necessary steps to protect our world and modify our wasteful approach to natural resources since the world is continually being pushed to adapt to global climate change and new foreign and internal dangers. Many municipalities worldwide have already started moving in this direction, offering everything from smart parking places to smart benches for solar-powered charging of portable electronics.

The potential of smart cities to address environmental challenges and waste management represents a serious issue that necessitates more profound academic research and policy makers [18]. Modern cities aim to become smarter, yet one of the biggest obstacles is how to process trash effectively. Citizens must be encouraged to interact with modern technology and utilize it daily, especially in emerging economies. The growth of IoT technology has enhanced the need for designing and implementing waste management systems that engage and include the public in the waste management process [19]. The construction industry has a detrimental impact on the environment because of the resources it uses, the energy it consumes, and the waste it produces. The "Circular Economy" (C.E.) is a new paradigm that has the potential to dramatically improve the sustainability of this sector [20].

The amount of Green House Gases (GHGs) discharged by each organization or activity is measured by carbon footprints (CFs). A starting step towards adopting sustainable educational practices could be to report the number of CFs in CO_2 from educational campuses [21]. Smart technology can significantly solve today's major population problems and lay the groundwork for a sustainable future. Today's key challenges are ensuring balanced economic development of society and reducing the effects of global warming. Much research should be performed on topics such as efficient energy conversion tech-

nologies, integrating renewable energy systems, enabling the circular economy framework, integrating processes effectively, and other concerns crucial to the public [22]. Ref. [23] demonstrated a statistically significant association that was the contrary. According to their findings, the analysis sample's plastic recycling rate decreases as educational attainment rises. The authors attribute the result to higher opportunity costs for households with higher levels of education. The concept of smart cities has become a prominent subject of scholarly investigation, with a significant focus on technological aspects in the generated knowledge. In this context, the absence of social intelligence, cultural artefacts, and environmental qualities necessary for ICT-related urban innovation is highlighted by the research being advocated [24].

The delivery of public services and the transition from a "take-make-dispose" to a "circular economy" are two areas where current socio demographic expansion poses new challenges for Czech cities. We must introduce new policies to increase city residents' participation, awareness of the issue, and support for the reforms. It is fascinating that younger individuals make more plastic waste than older people do. Two possibilities are possible: either these groups consume differently, with younger consumers buying more plastic packaging products, or younger consumers are more eager to sort and recycle plastic garbage [25]. Since only 42% of post-consumer plastic packaging waste is recycled in Europe, European Regulation 2018/852 set the crucial target of a 55% plastic packaging waste recycling rate by 2030. Plastic Circle was developed as a project supported by the European Union's Horizon 2020 research and innovation as an initiative to promote packaging recycling, improve all stages of garbage pickup, and encourage responsible consumption [26]. Stakeholder Value Creation (SVC) is a fundamental theoretical concept under Stakeholder Theory, as stakeholder-oriented management is primarily concerned with fulfilling the needs of stakeholders [27,28]. The concept of Stakeholder Value Creation (SVC) has the potential to contribute to the promotion of urban sustainability. The Sustainable Development Goals (SDGs) serve as effective instruments for examining and evaluating sustainable development processes. The relationship between social value creation (SVC) and urban sustainability is evident, but the specific impact of SVC on the achievement of the Sustainable Development Goals (SDGs) remains unclear. Social value creation (SVC) plays a significant role in advancing several Sustainable Development Goals (SDGs) inside urban areas, particularly SDGs 11, 17, 9, and 8. The contribution of smart sustainable cities (SVC) to the Sustainable Development Goals (SDGs) is primarily centered around consensus building, as well as the establishment of innovative ecosystems. These key elements play a crucial role in advancing the objectives of the SDGs [29]. The integration of social, economic, and institutional dimensions within the framework of urban sustainability is comprehensive. However, there is a need for improved integration of the Environmental Dimension. Hence, the present dyadic phenomenon might be categorized as either unsustainable or characterized by weak sustainability [30].

The recycling of end-of-life vehicles (ELVs) and the associated methods for assessing their quality in Malaysia are subject to limitations and face numerous significant obstacles. The obstacles encompass the absence of suitable recycling procedures that fully optimize material recovery, as well as concerns regarding the quality and dependability of components utilized in the implementation of circular economy principles [31]. Promoting recycling and reuse methods at the household level can also significantly impact waste creation. Paper, plastic, glass, metal, textile, kitchen, and garden garbage are just a few of the nine material types of waste that have had waste practices related to generation, reuse, and recycling documented and examined [32]. The literature on a crucial area such as smart cities contributing to the circular economy is relatively limited. From the researcher's point of view, much work needs to be conducted in this area. There is a necessity for a study abroad that reviews the available literature and organizes the knowledge and conclusions from past studies. Thus, this research will provide significant awareness of the concept of smart cities and circular economies and cover how smart cities contribute to circular economies. It will also include other vital areas addressed in the literature and

suggest untouched areas for future research. Readers will gain an up-to-date perspective on the circular economy by reading this paper, which will also identify the most prominent authors, publications, and theme structure output relevant to the circular economy. The establishment of a robust collaboration between individuals with social and technological expertise poses a novel and significant undertaking for academics across various disciplines. The management of product end-of-life has garnered significant attention, with a focus on developing technologies that effectively handle this waste. This approach aims to assess the economic and environmental advantages via the lens of the circular economy idea [33].

The purpose of this bibliometric analysis is to comprehensively examine the scholarly terrain concerning the incorporation of circular economies in sustainable smart cities. This analysis aims to provide stakeholders with a structured overview of this intricate and dynamic field, facilitating their understanding and navigation within it. This study covers data of 10 years. The remaining part of this study addresses various sections. The following section addresses the research methodology, and the next section addresses the data analysis; the next section addresses discussions and findings leading to the scope for further research directions, implications of the study, and conclusions.

2. Materials and Methods

The current study uses bibliometric analysis to assess the literature's effectiveness and intellectual and social structure on sustainable cities and the circular economy. Bibliometric analysis is a scientific method for analyzing literature in which publication and citation data are analyzed using quantitative methods [34–36]. The current study explicitly follows [35] a four-step method for bibliometric analysis, which entails defining the objectives and scope of the study, selecting the appropriate analytical techniques, gathering the necessary data, conducting the research, and summarizing the results. The technique's ability to manage enormous amounts of bibliographic information is its vital benefit [37]. Similarly, it helps in analyzing a significant amount of data for decision-making that researchers may have ignored. It helps in the exploration and analysis of past data related to a research topic, with the help of which investigators can identify concealed patterns in their studies [38]. Appendix A shows Top Cited 15 Articles Included for Bibliometric Analysis.

The research performs a bibliometric analysis to analyze the dispersed work in the smart city area and its impact on creating a circular economy and assess the significant trends in its theoretical and intellectual association. The work attempts to answer the subsequent research questions, which translate the scope of the research work.

(RQ1) How has the research publication productivity in smart cities and circular economies evolved?

(RQ2) Which journals and researchers are the top performers in the field of smart cities and circular economies?

(RQ3) What are the collaborative networks in smart cities and circular economies?

(RQ4) What are the most searchable topics and themes on smart cities in becoming circular economies?

The dataset for the analysis was extracted using "Smart city" and "Circular Economy" as keywords. After fetching the results, the following filters were applied to refine the results: information related to these documents in the title, authors, abstracts, and keywords was extracted after using the above filters. After the extraction, the file was exported in plain text format, and then search result extraction was performed using VOSviewer. The file was imported in the same format for further processing.

A total of 163 articles were found in the Scopus database accessed on 21 December 2022. The search was limited to document type (research article and review), source type (journal), language (English), and year of publication (2013 to 2022). Full-text articles were considered for analysis. The data for the bibliometric analysis were collected from the Scopus database and exported in a ".csv" (Microsoft Excel) format for use [39]. Scopus was selected as the database for extracting the articles for this study because it is the largest

database of intellectual papers and is considered the most acceptable choice among the various multidisciplinary databases [35,40,41].

3. Bibliometric Analysis and Findings

According to the research questions, we conducted an in-depth analysis of the publication trend over ten years related to Circular Economy and Smart City with the help VOSviewer. In particular, results about influential articles, publication productivity, prominent themes and keywords, and promising application areas are related to the first, second, third, and fourth research questions.

The scientific output of this study is described in this section, with the results broken down into co-occurrence mapping, co-authorship mapping, bibliographic coupling, citation, and co-citation analysis. The findings from the bibliometric analysis are presented based on the research questions they address.

3.1. Publication Output

The bibliometric data frame, comprising the period from 2013 to 2022, as no time filter was used while fetching the database. This shows that this area lacked research work in the last ten years with only 163 articles during the above period, and improvement is required in the amount of collaboration among the authors.

The study of smart cities and circular economies has garnered considerable attention in recent times because of the worldwide focus on sustainability, the complexities of urbanization, and improvements in technology. To offer a comprehensive analysis of the progression of research publishing production in these respective domains, it is possible to categorize it both chronologically and thematically. The origins of smart cities and circular economies can be attributed to the discourse surrounding sustainability and urban development throughout the latter part of the 20th century.

Although the specific terminology of "smart cities" and "circular economies" may not have been widely used, scholarly investigations commenced to prioritize sustainable urban design, effective resource allocation, and the utilization of technology to augment urban living conditions. The concepts of "smart cities" and "circular economies" were formally introduced and distinguished in the academic literature throughout the early 2000s.

The proliferation of the Internet and digital technologies has had a significant impact on the development of cities that utilize technology to enhance governance, infrastructure, and services for their citizens. Simultaneously, there emerged apprehensions regarding the depletion of resources, management of waste, and damage of the environment, prompting the formulation of the circular economy framework. This framework places emphasis on the principles of recycling, reusing, and waste reduction. During the 2010s, there was a notable increase in scholarly investigations centered on smart city solutions and circular economy concepts, driven by the rapid growth of urban populations and the escalating effects of climate change. The fields under consideration experienced a significant surge in publication output during the latter half of the 2010s, which can be attributed to the heightened worldwide concern and fascination around these domains. Research has explored the potential of data analytics, the Internet of Things (IoT), and smart governance to facilitate circularity within urban contexts. The research productivity in this convergence field had significant growth, as evidenced by several publications that concentrated on case studies, best practices, and technology breakthroughs aimed at advancing smart and sustainable urban settings.

The emergence of technologies such as artificial intelligence (AI), blockchain, and 5G is expected to contribute to the ongoing expansion of research productivity, enabling the exploration of novel aspects pertaining to intelligent, sustainable, and circular urban environments.

Annual Scientific Production and Growth Trend:

The number of publications on Smart City contribution towards Circular Economy is shown in Figure 1. The annual scientific output in the research domain shows an upward trend from 2013–2022. We have seen a good number of publications in this domain between

2018 and 2021, reaching a level of 48 in 2021. It reflects a growing interest among researchers globally, and it's gradually emerging as an upcoming field of interest.

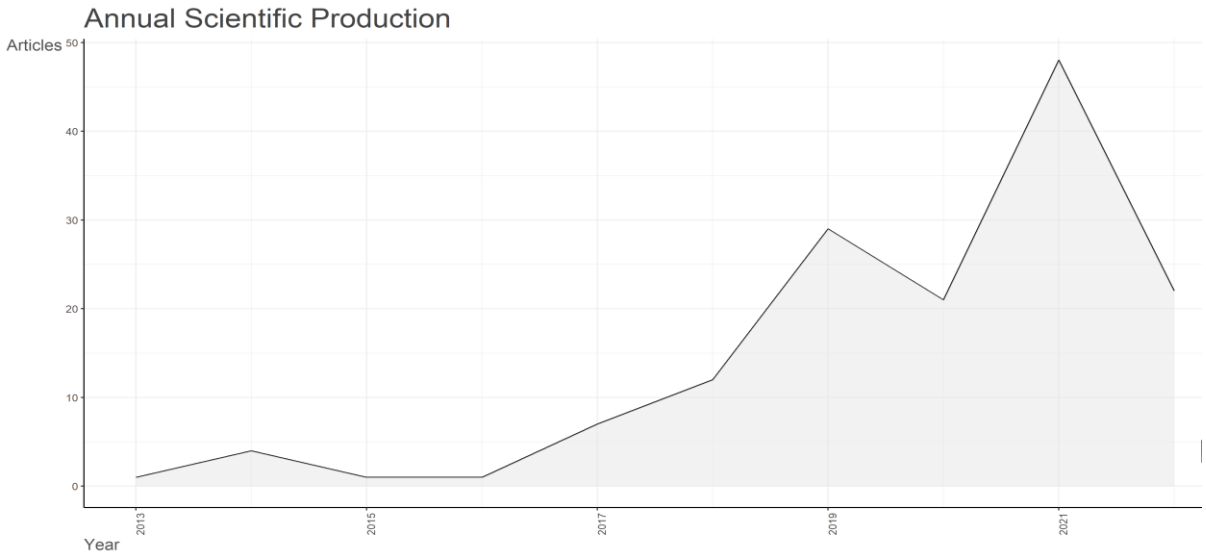


Figure 1. Scientific output.

3.2. Co-Occurrence Mapping

3.2.1. Analysis Based on All Keywords

With the help of the full counting method, all keywords were considered as the analysis unit in the co-occurrence mapping. This study also imposed some restrictions on the field of investigation. For instance, a limiting factor was established as a minimum of five (5) instances of a keyword. Therefore, only 47 keywords out of 1401 from 163 articles met the criterion. The links refer to the occurrence of two items together (for example, two keywords). The total number of cited references between any two items is represented by the overall link strength [42]. The occurrences represent the number of articles in which the keyword was found [4].

Figure 2 illustrates the keywords most frequently used by the authors and the most critical topics in this research area. The keywords that appeared most were "Circular Economy" (total link strength 343), which had the highest frequency of appearance, followed by "Sustainable Development (total link strength 253), "Smart cities" (total link strength 244), "Waste Management" (total link strength 132), "recycling" (total link strength 131) and "Sustainability" (total link strength 131) and "climate change" (total link strength 84) as shown in Table 1.

Network visualization was also used to show how often the terms occurred together [43]. Figure 2 illustrates how 1401 keywords were able to group into 5 clusters and 560 links: cluster 1 (red) had 14 items, cluster 2 (green) had 13, cluster 3 (blue) had 11, cluster 4 (yellow) had 7, and cluster 5 (purple) had 2. The size of the circles and texts in each cluster indicates how frequently they occur alongside other keywords. The lines and item distances simultaneously display the relatedness and connections between the keywords. Three distinct visualizations—network visualization, overlay visualization and density visualization—can be used by VOSviewer to depict bibliometric maps.

The overlay visualization in smart cities and circular economies is shown in Figure 3. The update for each phrase is displayed in the visualization overlay. The uniqueness of each phrase is indicated by its color. The area's level of impact increases with color brightness. Circular economies and smart cities are the current research hot topics. Consequently, this could be a crucial subject for future research to identify various themes associated with smart cities and the circular economy.

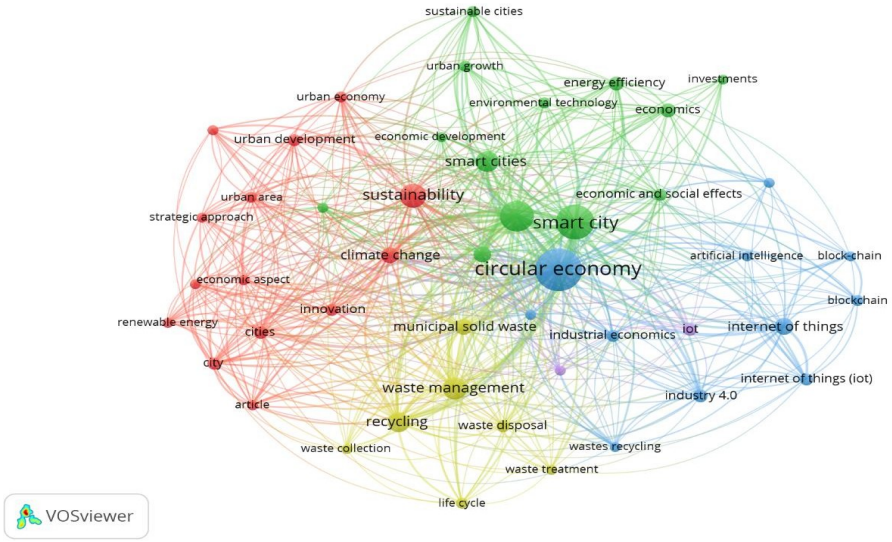


Figure 2. Network analysis with keywords (VOSviewer software).

Table 1. Top Keywords.

Item	Total Link Strength
Circular Economy	343
Sustainable Development	253
Smart City	244
Waste Management	132
Recycling	131
Sustainability	131
Climate Change	84
Municipal Solid Waste	69
Internet of Things	66
Industry 4.0	54

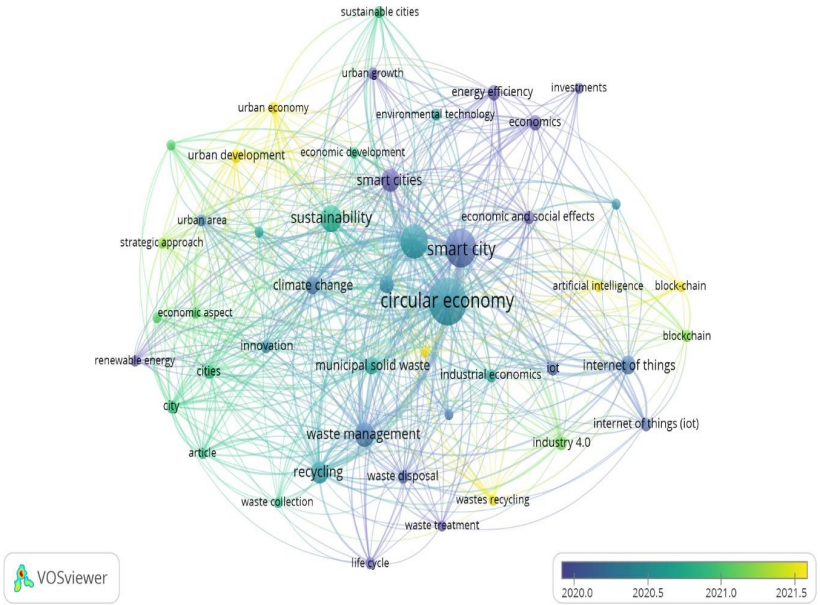


Figure 3. Overlay analysis with keywords (VOS viewer software).

According to the density visualization shown in Figure 4, the more frequently a term appears, the darker or brighter the yellow hue is, and the larger the diameter of the term's circle. This indicates that there are more studies being conducted on relevant topics. There will be fewer studies on a phrase as its color ages and becomes more similar to the background color. According to Figure 4, many studies have been conducted on smart cities, the circular economy, sustainability, waste management, recycling, climate change, artificial intelligence, blockchain, Internet of Things, and their economic and social implications. According to the results of the data mapping of the articles gathered, the keywords that most frequently appeared are the circular economy, smart city, recycling, waste management, Internet of Things, blockchain, and sustainability. We can use this information to search for smart cities and circular economy studies.

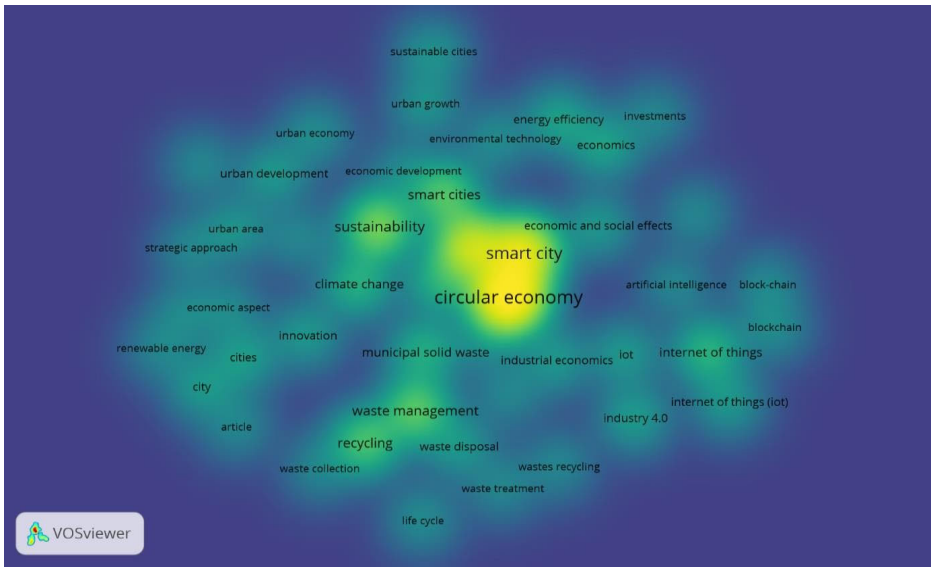


Figure 4. Density Visualization of Keywords.

3.2.2. Co-Occurrence Network of Most Frequently Used Author Keywords

A total of 550 keywords from 163 research publications were given a threshold of 2, resulting in 78 distinct keywords that were used more than twice as shown in Figure 5. The number of highly referenced articles overall is represented by the bubble size, while link strength and clustering are indicated by the line thickness and color, respectively.

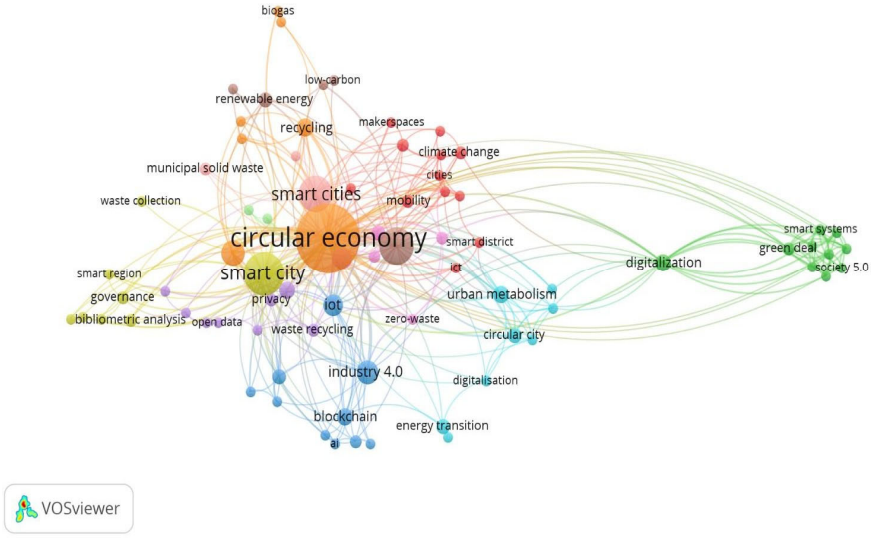


Figure 5. Co-occurrence network of most frequently used author keywords.

3.3. Co-Authorship Visualization Analysis

The authors, connected institutions, and countries that publish on circular economies and smart cities were examined using the function module of VOS viewer's coauthorship visualization. The threshold value for the minimum number of documents was set at two, and the minimum citation was left at one to make it simple to identify the well-known authors who had made contributions in the form of publications in this field. Some of the 551 authors, however, were not linked to the other writers in the network. Only 26 authors met the criteria as shown in Figure 6.

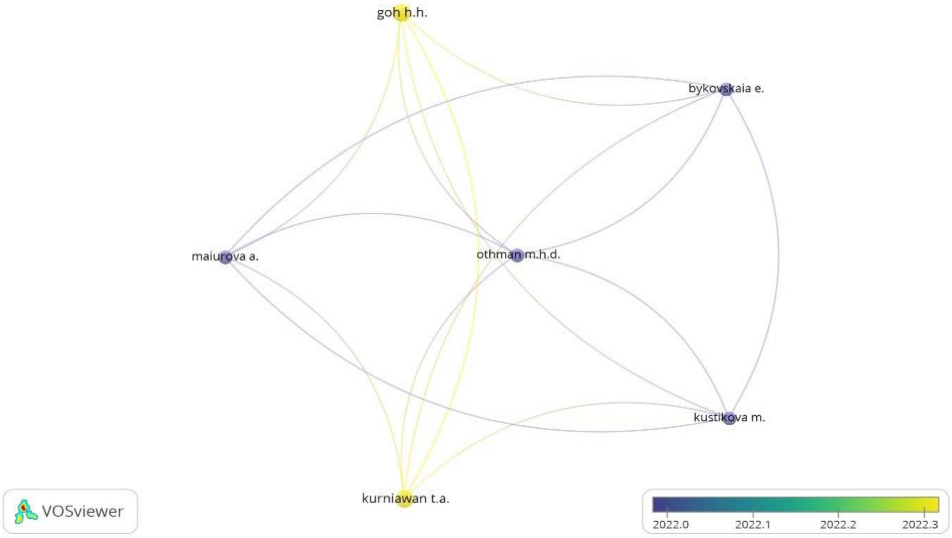


Figure 6. Co-Authorship Analysis of Collaboration of Author (Overlay Visualization).

Based on the bibliographic data collected from the Scopus database, a country co-authorship network visualization map was created (Figure 7) with VOSviewer. In the process of mapping Figure, the minimum document threshold of a nation was set at two, and the minimum number of citations of a country was set at one. Thirty-nine countries out of fifty-seven countries met the thresholds. Figure 7 shows seven clusters between countries involved in smart cities and circular economy research. Researchers from Italy, United Kingdom, China, Romania, and the US are prominently networking countries working in this area.

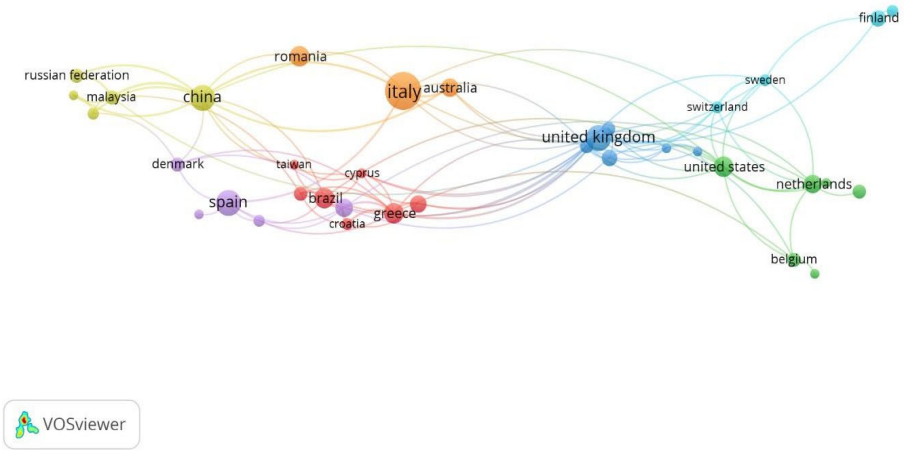


Figure 7. Coauthor network visualization analysis of countries/regions.

The northern regions of Italy exhibit superior performance, with the province of Trento ranking at the forefront. This is followed by the region of Valle d'Aosta and the province of Bolzano, so reaffirming the triumvirate that had already emerged in the preceding year.

An intriguing observation pertains to the expansion of central regions, which exhibit a tendency to approach a value similar to that of the northern regions. Notably, the regions of Toscana, Marche, and Lazio exhibit commendable performance. Furthermore, it has been verified that the southern areas consistently occupy the lowest positions in the ranking, with the sole exception of Abruzzo. Italy presents itself as a strategic focal point for the promotion and advancement of the Sustainable Development Goals (SDGs) to transform the Mediterranean region into a pivotal hub within the future global economy [9].

Regarding the obstacles impeding the implementation of Circular Economy (CE) practices, three distinct categories have been identified: financial, bureaucratic, and regulatory. Companies believe that besides enhancing their brand name and practices, this approach has resulted in advantageous outcomes, including decreasing carbon dioxide emissions and regenerating components within a perpetual cycle. The transition towards a long-term perspective and mindset involves considering not just the economic impact but also the overall performance of the organisation and the consequences of each action. It is important to acquire a circular mindset that can effectively guide the transition to a Circular Economy (CE) or the creation of a Circular Supply Chain (CSC) rather than solely focusing on individual circular initiatives [44].

Italy has been a key contributor to the advancement and advocacy of the circular economy, both domestically and within the European context. The ability of small and medium-sized enterprises (SMEs) to adopt a circular business model and achieve success is contingent upon the level of support provided by various factors. These include the establishment of a company culture that embraces environmental sustainability, with both staff and managers demonstrating a "green" mindset. Additionally, the presence of a local or regional network comprising other SMEs and supporting entities plays a crucial role in facilitating information sharing and raising awareness. Lastly, the advantages derived from cultivating a "green" image and being acknowledged as a supplier committed to sustainability by customers contribute significantly to the overall success of SMEs in transitioning to a circular business model [45]. The nation actively encourages innovation by providing financial resources and assistance to startups and businesses that prioritize circular economy ideas and solutions [46].

3.4. Citation Analysis

3.4.1. Most Cited Authors

Citation is the most frequent method for assessing the influence of an author, journal, and country since it allows for the quick identification of significant works in the chosen area. By taking 1 document and 1 citation as a minimum number of papers and citations of an author as a criterion for citation analysis, we have 444 authors meeting the thresholds out of 551 authors of 163 articles as shown in Table 2. A research paper written by [17] has 372 citations, followed by researchers such as [18,20,22,34,47–50].

Table 2. Most Cited Authors.

Name of Author/s	Documents	Citations
Koop et al.	1	372
Esmaelian et al.	1	232
Nizetic et al	1	234
Hens et al.	1	259
Pencarelli	1	171
Fatimah et al.	1	243
Chauhan et al.	1	146
Sodiq et al.	1	148
Norouzi et al.	1	118

3.4.2. Most Cited Countries

Figure 8 and Table 3 shows that Italy leads the number of publications and United States lead in the number of citations. United Kingdom leads the total link strength. Countries such as India, China, Romania, Colombia, Cuba, Chile, and Belgium are connected, as reflected in Cluster 1. Cluster 2 includes Australia, Iran, Italy, Jordan, Qatar, South Africa, and Spain. The third cluster comprises the Czech Republic, Denmark, France, Indonesia, Slovakia, and Ukraine. The fourth cluster includes Brazil, Germany, Malaysia, Singapore, and the United States. Canada, Croatia, Greece, Russia, and the UK are significant collaborators in Cluster Five. Researchers from India has 13 documents with 187 citations and Researchers from Spain has 11 documents with 171 citations.

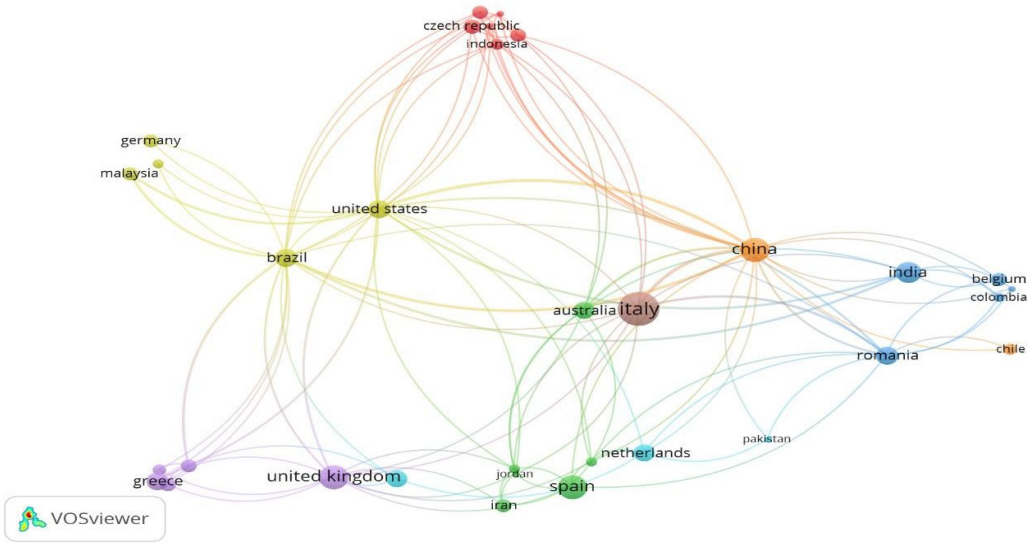


Figure 8. Citation Analysis of Most Cited Countries.

Table 3. Country-wise Production.

Country	Documents	Citations	Total Link Strength
United Kingdom	15	119	22
China	11	215	16
Brazil	10	504	13
Greece	7	249	13
Italy	23	241	13
Malaysia	5	110	11
United States	7	530	10
Cyprus	4	20	9
France	3	55	9
Netherlands	6	260	9

Taking 1 document and 1 citation as a minimum number of papers and citations of an author as a criterion for citation analysis, we have 77 journals meeting the threshold out of 117 journals. Figure 9 reflects the top cited journals. The Journal of Cleaner Production, Sustainability, Waste Management, Environment, Development and Sustainability tops the list of most cited sources as shown in Table 4.

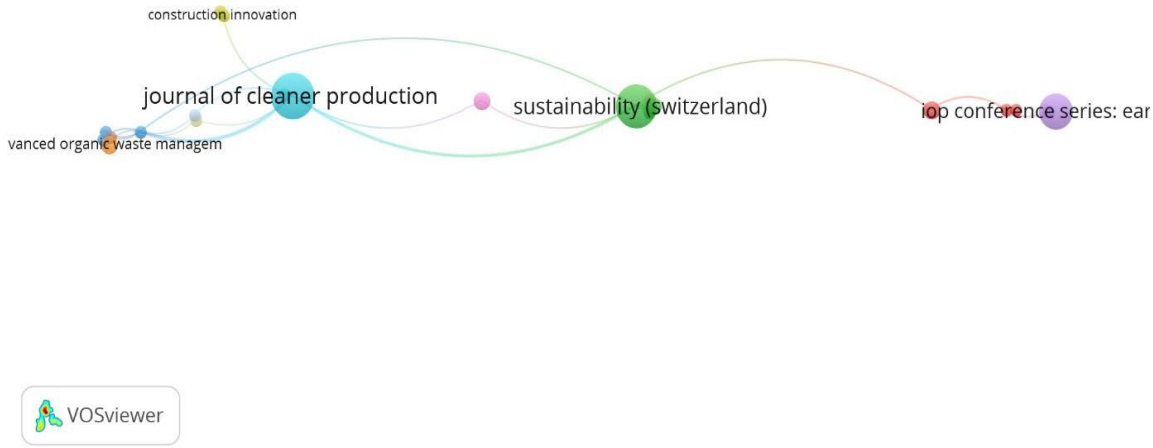


Figure 9. Analysis of Most Cited Sources/Journals.

Table 4. Most Cited Sources/Journals.

Source	Documents	Citations
Journal of Cleaner Production	13	851
Sustainability	9	137
IOP Conference Series: Earth and Environmental Science	7	9
Circular Economy and Sustainability	2	2
Environment, Development and Sustainability	2	372
Journal of Urban Regeneration and Renewal	2	17

3.5. Bibliometric Analysis of Bibliographic Coupling of Authors, Institutions and Countries

Bibliographic coupling is something that is observed when two authors make references to a shared collection of prior works, so suggesting a certain degree of thematic or topical affinity in their respective research endeavors. Bibliographic coupling pertaining to older works may suggest that the writers have established a distinct expertise within a specific field of research. This particular area of expertise, which is grounded in extensive historical or foundational knowledge, enables individuals to conduct more thorough investigations into subjects and generate more profound understandings. When two documents cite the same source, this is known as "bibliographic coupling" [51–53]. The bibliographic coupling map of authors is shown in Figure 10. Citations are used in bibliographic coupling to describe the similarities between two texts, authors, institutions, or nations. This method is grounded on the notion that two papers citing a third paper are highly connected and should be grouped in the visualization map's cluster solution. Using a criterion of a minimum of 1 citation of 163 documents, a total of 108 met the threshold. Eleven clusters were obtained from the analysis. Cluster 1 includes 13 items, and the research area is the circular economy (shown in red). The Red Cluster was anchored by [54], whose research focuses on how automated smartphone recycling could be supported by Artificial Intelligence (A.I.) and could also act as an enabler for Circular Smart Cities (C.S.C.). Research work conducted by researchers [55] from the same cluster considers the circular economy from the perspective of sustainable development, which is one of the main goals of contemporary societies. The main characteristic of a circular economy is the requirement to increase resource efficiency through waste reduction and recycling.

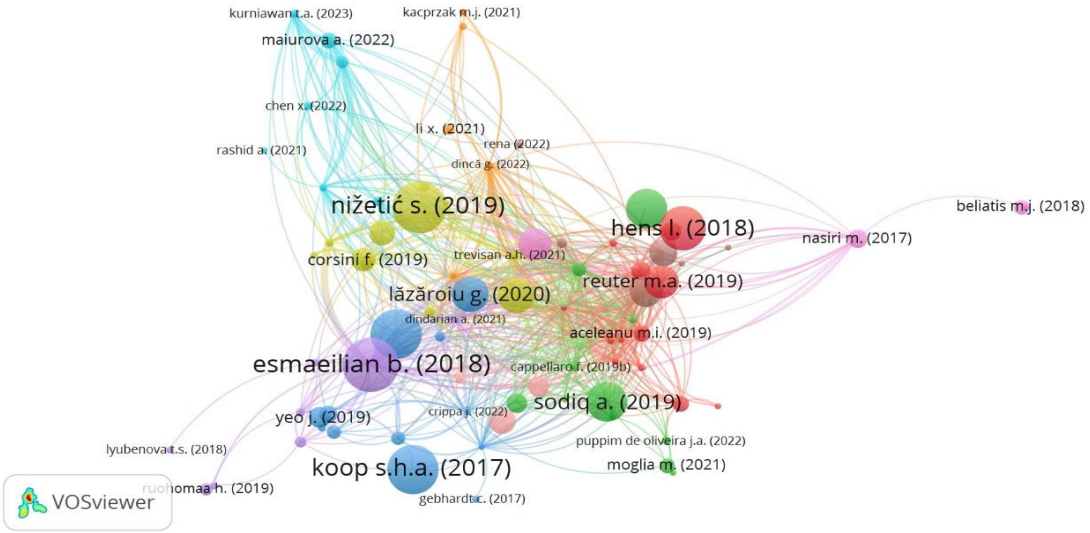


Figure 10. Bibliometric Coupling of Authors (Authors Own Work).

The other clusters are anchored by Arias (green) with 12 items, anchored by Benltoufa (blue) with 11 items, and anchored by Andrade (yellow) with 11 items. The green cluster mainly focuses on research work related to green infrastructure [56] and the environment, highlighting nature and biodiversity [57,58] circular strategies and urban regeneration [59] and the Internet of Things [60]. The blue cluster focuses on smart cities, waste management [48,61], the circular economy, urban branding [48,62], smart technology, and sustainable development [63]. The yellow cluster focuses on smart cities and the circular economy [64], sustainable consumption and the sharing economy [65], municipal solid waste and energy recovery [66], and sustainable business [67].

The analysis of bibliographic coupling among universities with respect to older publications demonstrates a common focus on fundamental knowledge and research approaches. The aforementioned concentration of efforts, together with the advantages derived from extensive immersion in well-established knowledge, can elucidate the exceptional performance of these establishments within their respective fields. Researchers can gain a more comprehensive perspective by actively engaging with non-recent scholarly works. The use of a holistic perspective enables researchers to establish linkages between historical and contemporary discoveries, so cultivating a more comprehensive comprehension of their own discipline. A comprehensive understanding of existing research and scholarship is essential to prevent institutions from duplicating efforts in areas that have already undergone extensive investigation. Alternatively, individuals have the capacity to expand upon preexisting knowledge, so challenging conventional limits while maintaining a foundation in established ideas. Bibliographic coupling of institutions occurs when publications from two institutions reference publications from a third common institution. Figure 11 shows the bibliographic coupling of the institutions with network visualization. The minimum number of publications for an organization was one, and the minimum number of citations was one. Of the 360 organizations, 280 met the thresholds. For each of the 280 organizations, the total strength of the bibliographic coupling links with other organizations was calculated. The organizations with the highest total link strength were selected. Key Laboratory of Poyang Lake Environment and Resource.

Utilization, Ministry of Education, China, was at the top of this list with two publications, 17 citations, and a network strength of 2289. We can observe some other institutions that are contributing to the field and dominate the coupling and anchor its most significant clusters: Academy of Romanian Scientist, Bucharest, Romania), University of Buffalo (New York, NY, USA), Western New England University (Springfield, MA, USA), Georgia Institute of Technology (Atlanta, GA, USA), Massachusetts Institute of Technology (Cambridge, MA, USA), and Pontifical Catholic University of Paraná, Curitiba, (Paraná, Brazil).

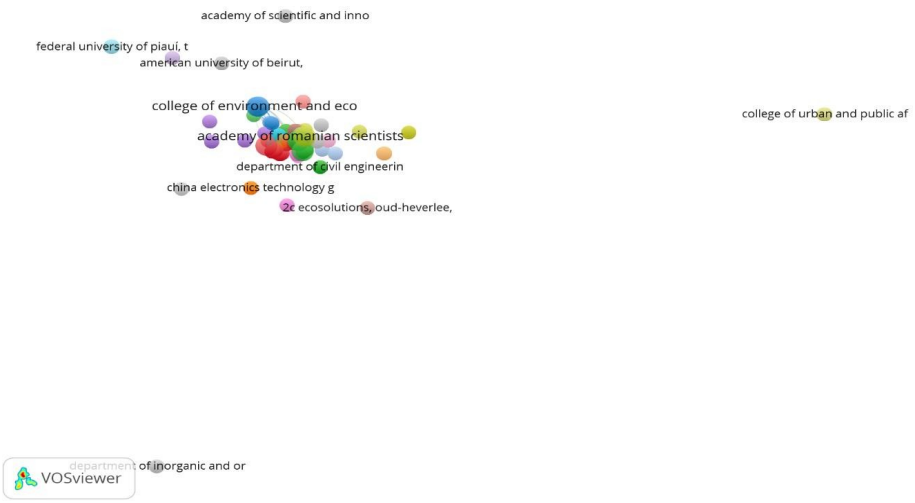


Figure 11. Bibliographic coupling of institutions (network visualization).

Figure 12 presents the bibliographic coupling of countries. Bibliographic coupling of countries occurs when publications from two countries reference publications from a third country. According to this graph, scholars from Brazil make a substantial contribution to this field of study, along with those from Canada, Croatia, Cyprus, Poland, and Greece. Figure 12 also shows how frequently coupling occurs among other nations, including Australia, Finland, Germany, India, Mexico, and Romania.

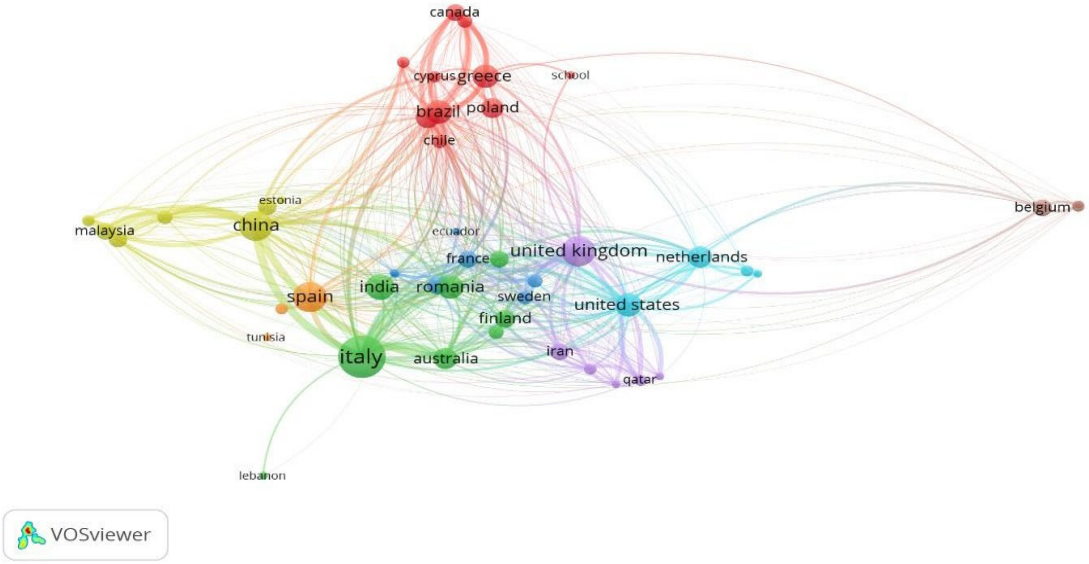


Figure 12. Bibliographic coupling of countries.

4. Conclusions

This study highlights the scope of smart cities and circular economy research using bibliometric analysis, collecting datasets from 2003 to 2022. It further portrays the research topic's theoretical, intellectual, and community structure. The present study tries to integrate the fragmented literature on the topic with the help of VOSviewer. The dataset for this study was extracted from the Scopus database due to its extensive coverage and quality. The dataset shows that the research domain shows an upward trend. Even though it is still in its initial stage, the circular economy is a crucial sustainability strategy that global and corporate leaders use in the battle against climate change. By incorporating relevant elements of the economy, technology, mobility, quality of life, and other areas that contribute to the well-being of its citizens, a smart city is highly developed, inventive, and

environmentally friendly [68]. Rapid environmental degradation, a growing number of cars on the road, and a shortage of resources are issues that circular cities and a circular economy can resolve. Our cities are developing into more livable and sustainable places. It is essential to emphasize the value of smart cities through pilot projects that will serve as the testing grounds for the later expansion of CE concepts on a broader, more global scale.

The phenomena of urbanization and climate change are compelling cities to navigate unexplored trajectories to achieve sustainable outcomes. Numerous urban areas are embracing the captivating notion of the 'Circular Economy' (CE) as a guiding principle for this shift. The concept of the Circular Economy (CE) proposes a novel approach to the management of resource flows within economies, aiming to create a closed-loop system [69]. The circular economy aims to shift away from a linear economy to one that is more circular and turns waste into resources. All interested parties, including the public sector, business sector, and public, must work together and be willing to do this. Many European Union member states currently lack the requisite waste-handling infrastructure. It is crucial to establish precise long-term policy goals to direct actions and expenditures, create systems and methods for waste treatment, and prohibit recyclable materials from being used at the bottom of the waste hierarchy [70]. A circular economy in cities will require unprecedented levels of cross-sector and public–private cooperation in the twenty-first century. The time has come to make the most of the numerous opportunities circular cities offer and establish a system that will benefit the environment, society, and economy over the long run. The circular economy has emerged as one of the most widely used theories to address environmental problems. However, research on the circularity subject is still developing, particularly at the firm level [71]. Cities and metropolitan areas can lead circular economies while supporting the use of renewable energy, energy efficiency, sustainable production and consumption, sustainable transportation, resource conservation, and sustainable waste management. Goal 11 of the Sustainable Development Goals 2030 Agenda was to "Make cities and human settlements inclusive, safe, resilient, and sustainable" to achieve these objectives. Research is required to determine how sustainable finance may improve the circular economy and investment opportunities. The circular economy exhibits considerable potential in facilitating the attainment of various Sustainable Development Goals (SDGs), encompassing SDG 7 pertaining to Affordable and Clean Energy, SDG 8 concerning decent work and economic growth, SDG 11 addressing sustainable cities and consumption, SDG 12 focusing on responsible consumption and production, SDG 13 targeting climate action, SDG 14 emphasizing life below water, and SDG 15 centering on life on land [6].

The term "smart city" was first introduced in the 1990s, but research started gaining momentum in the early 2010s. The circular economy as a concept has been around for decades, but research on the topic has increased in recent years, particularly since the publication of the [72] report "Towards the Circular Economy" in 2012. Technology is a crucial part of the global endeavor to reach net zero, but as we move from our current behaviors to a more climate-friendly society, its adoption necessitates practical sacrifices [73].

There are several journals and researchers that are top performers in the field of Smart Cities and Circular Economy. Journal of Cleaner Production, Waste Management, Sustainability, Environment, Development and Sustainability are the journals with the maximum contribution to smart cities and circular economies. Overall, these journals and researchers represent some of the top performers in the field of smart cities and circular economy and have contributed significantly to the knowledge and understanding of these topics. Research publication productivity in both smart cities and the circular economy has experienced significant growth in recent years, reflecting the increasing interest and importance of these fields in addressing environmental and social challenges. The study found that there is a growing body of research on smart and circular cities, with a steady increase in research publications and citations over the past decade. The study also found that research on smart cities and the circular economy is becoming increasingly interconnected, with more studies exploring the potential synergies between the two concepts. The United States, Brazil, China, and Italy have the most citations

and research publications. Countries such as India, China, Romania, Colombia, Cuba, Chile, and Belgium have a good collaboration network. Taking a circular approach can also tackle many other socio-economic problems afflicting cities, for example, providing access to affordable accommodation, expanding and diversifying the economic base, and building more engaged and collaborative communities in cities [74]. Cleaner Production (CP) entails the reduction of energy and materials consumption, as well as the replacement of environmentally and health-hazardous products with less damaging alternatives [47]. In order to gain a more comprehensive understanding of the dynamics, difficulties, and facilitators of sustainable consumer behaviour within the circular economy, it is imperative to conduct longitudinal studies [75].

The analysis revealed that the research on smart cities and the circular economy is multidisciplinary, involving researchers from various fields, including urban planning, engineering, economics, and environmental science. The most common research topics were "Circular Economy", "Sustainable Development", "Smart cities", "Waste Management", "recycling", "Sustainability" and "climate change". Refs. [18,22,34,48–50,76,77] were the top cited researchers. The study suggests that there is a growing recognition of the potential for smart cities and the circular economy to work together to create more sustainable and livable urban environments. The research in this area is becoming more integrated and sophisticated over time. The intersection of smart cities and the circular economy has generated interest and study in recent years, and several topics and themes have emerged as the most searchable. Here are some examples:

- Smart and circular infrastructure: This involves using smart technologies to optimize the use of infrastructure and resources in a circular economy context. Examples include the use of sensor networks and data analytics to improve energy efficiency, waste management, and mobility.
- Circular business models: This focuses on the development of business models that enable circularity in the city, such as product-as-a-service, sharing economy, and closed-loop systems. Smart technologies such as blockchain and IoT can facilitate implementing and scaling these models.
- Circular design and manufacturing: This involves the integration of circular principles into the design and manufacturing of products and materials, such as using recycled or renewable materials and designing for disassembly and repair. Smart technologies can support the implementation of circular design principles, such as digital fabrication and 3D printing.
- Circular supply chain management: This topic involves using smart technologies to optimize the circular supply chain, such as real-time tracking of materials and products and using data analytics to improve resource efficiency and reduce waste.
- Circular and smart governance: This topic focuses on the role of governance in enabling and supporting the transition to a circular and smart city. Examples include policies and regulations promoting circular business models and smart technologies and using open data and citizen engagement to support circular and smart city initiatives.

4.1. Potential Areas for Future Research

The bibliometric analysis shows that smart cities and circular economies are emerging areas for policymakers and researchers. In the last ten years, less research has been conducted, and keyword analysis shows that the research primarily focused on smart cities, circular economies, waste management, climate change, technology, and sustainability. The research study also depicts numerous studies on the adoption and diffusion of mobile banking. One should consider including alternative metrics, sometimes referred to as altmetrics, in addition to standard citation counts. Altmetrics encompass a broader range of indicators, such as online mentions, social media shares, and other forms of digital engagement.

The integration of bibliometric analysis with qualitative research methodologies allows for a more comprehensive exploration of the content within publications, enabling the examination of nuanced conversations, case studies, and contextual factors.

In light of potential geographical variations in the adoption of circular economies within smart cities, it is advisable to conduct distinct bibliometric analysis for different areas or nations. This approach can yield more context-specific insights.

To enhance the comprehensiveness of data sources, it is recommended to include gray literature, conference proceedings, and non-academic publications. By incorporating these sources, a broader spectrum of discussions can be captured.

4.2. Implications of the Study

The current study will help marketers' practitioners frame and implement various plans and policies related to smart cities and build a circular economy covering issues such as climate change, energy efficiency, climate change, and waste management. By identifying the most frequently cited authors, publications, and keywords, this analysis can help researchers to understand the research landscape and to identify gaps and opportunities for further research. This can help to identify potential collaborators and opportunities for joint research initiatives and highlight gaps in the collaboration that need to be addressed. By identifying the most highly cited publications and the most frequently used keywords, policymakers and practitioners can better understand the key concepts and approaches in this field and use this information to inform their work. Overall, a bibliometric analysis of smart cities and the circular economy can provide valuable insights for researchers, policymakers, and practitioners, helping to identify trends and gaps in research, highlighting opportunities for collaboration, and informing policy and practice in this critical and rapidly evolving field.

As urban areas embark on the process of enhancing their services to tackle urgent sustainability concerns, policymakers and urban planners encounter the task of comprehending intricate, multifaceted systems and assessing the potential impact of proposed investments or policies on these systems [78]. Digital technology has the potential to decrease the quantity of Municipal Solid Waste (MSW) that is not recycled, while also preserving natural resources and lowering both operational expenses and Green House Gas (GHG) emissions. The process of digitalization enhances the resilience of cities by reinforcing local waste management practices in order to effectively address the global COVID-19 pandemic [79]. According to the bibliometric analysis, policymakers and scholars are increasingly interested in circular economies and smart cities. Little research has been conducted in the last ten years. A keyword analysis reveals that this study mainly concentrated on smart cities, circular economies, waste management, climate change, technology, and sustainability. It is nevertheless easy to overlook significant articles despite efforts to mark at a base as complete as possible, particularly those that are not peer-reviewed or published in less accessible places, such as conference proceedings. Circular economies and smart cities are still relatively fresh and developing ideas. Because of this, there can be variations in how authors define and use these terms, which could cause problems with comparison and interpretation. This research paves the way for future research in the related areas and issues of the domain, as it is an emerging issue in research, and many problems are untapped. Additionally, it highlights the emerging themes of the field on which future research can be conducted. Pragmatic sustainability presents a practical and flexible strategy for attaining a sustainable future, whereas sustainable education equips individuals with the requisite knowledge and resources to actively contribute to this overarching goal. The simultaneous integration of these principles has the potential to guide society towards a state of enhanced equilibrium and a more mutually beneficial cohabitation with our planet.

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Appendix A

Table A1. Top Cited 15 Articles Included for Bibliometric Analysis.

S. No	Title	Journal	Citations	Reference No
1	The challenges of water, waste and climate change in cities	Environment, Development and Sustainability	372	2017, 19(2), 385–418
2	On the evolution of "Cleaner Production" as a concept and a practice	Journal of Cleaner Production	259	2018, Volume 172, 3323–3333
3	Industry 4.0-based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: A case study of Indonesia	Journal of Cleaner Production	364	2020, Volume 269, 122263
4	The future of waste management in smart and sustainable cities: A review and concept paper	Waste Management	232	2018, 81, 177–195
5	Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management	Journal of Cleaner Production	234	2019, Volume 231, 565–591
6	The digital revolution in the travel and tourism industry	Information Technology & Tourism	171	2020, 22(3), 455–476
7	The interplay of circular economy with industry 4.0 enabled smart city drivers of healthcare waste disposal	Journal of Cleaner Production	146	2021, Volume 279, 123854
8	Towards modern sustainable cities: Review of sustainability principles and trends	Journal of Cleaner Production	148	2019, Volume 227, 972–1001
9	Circular economy in the building and construction sector: A scientific evolution analysis	Journal of Building Engineering	118	2021, 44, 102704
10	Promoting digital transformation in waste collection service and waste recycling in Moscow (Russia): Applying a circular economy paradigm to mitigate climate change impacts on the environment	Journal of Cleaner Production	57	2022, Volume 354, 131604
11	The First Two Decades of Smart-City Research: A Bibliometric Analysis	Journal of Urban Technology	607	2017, 24(2), 3–27
12	Circular economy business models: The state of research and avenues ahead	Business Strategy and the Environment	195	2020, 29, 3006–3024.
13	Linking circular economy and digitalization technologies: A systematic literature review of past achievements and future promises	Technological Forecasting and Social Change	185	2022, 177, 121508
14	Circular cities	Urban Studies	134	2019, 56(13), 2746–2762
15	Smart cities of the future	The European Physical Journal Special Topics	2806	2012, 214, 481–518

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