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Integration of Smart Cities and Building Information Modeling (BIM) for a Sustainability Oriented Business Model to Address Sustainable Development Goals

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Abstract: The construction industry, business models, and smart cities are recognized as pivotal domains with profound implications for fostering sustainability, prompting extensive research endeavors. However, there remains a dearth of interdisciplinary integration within this sphere aimed at fostering sustainable development. Nevertheless, current studies suggest that research in this area could provide theoretical and practical guidance for the sustainable transformation of society and make a positive contribution to the realization of the Sustainable Development Goals (SDGs). Therefore, this paper aims to utilize an innovative mixed research approach combining macro-quantitative bibliometric analysis with subsequent micro-qualitative content examination based on the SDGs to explore the relationship between BIM and smart cities in promoting a sustainability-oriented business model, which provides a comprehensive understanding of the overall situation and development of research topics in the field and contributes to the improvement of the SDGs. The results show that, during the last 13 years (from the year 2011 to 2023), the period from the year 2011 to 2016 was the initial stage of the field, followed by a rapid growth after the year 2018, of which "BIM", "Smart City", "Business Model", "Building Life Cycle", "Urban Management", and "Business Model Innovation" are the keywords representing the current research hotspots. The circular economy model that has been developed since 2021 has contributed to life cycle stages, including "briefing stages" and "procurement stages". As such, the "whole life cycle", "strategic urban planning frameworks", and "sustainable business models" have become future research trends, whilst real-world applications such as "smart tourism", "e-government", and "green building" have emerged. Further, the key partnerships of "city managers", "corporate enterprises", and "public participation" for smart cities contribute to the achievement of SDGs 8 and 17 in terms of integrating urban information technology and urban infrastructure, policy regulation, knowledge-sharing, improving economic efficiency, and promoting sustainable economic growth.

Keywords: smart city; building information modeling (BIM); life cycle; sustainability; business model; innovation; urban management; sustainable development goals (SDGs)

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1. Introduction

Information technology and the natural environment require a broader perspective on sustainable development due to the challenges of population growth, accelerated urbanization, and resource shortages. The notion of sustainable development is undergoing rapid evolution to encompass the continuous interplay among social, economic, and environmental systems [1]. The Sustainable Development Goals (SDGs) mentioned in the

2030 Agenda for Sustainable Development created by the United Nations Department of Economic and Social Affairs are directly tied to the development of smart cities, which has now become a global phenomenon [2]. The smart city is an urban development model based on information and communications technology (ICT) that aims to enhance urban sustainability, effectiveness, and residents' quality of life [3], which enhances intelligence and sustainability through the integration of stakeholders optimizing the governance of interactions between services and infrastructure technologies [4]. The collaboration of numerous government organizations, companies, and communities is essential to the development of smart cities, which offer synergies to change how whole communities take advantage of smart city services for long-term sustainability [5].

The application of Building Information Modeling (BIM) technology has extended information modeling from the individual building level to the broader scale of cities [6]. Initially considered a frontier in the development of smart cities, BIM facilitates comprehensive data management and visualization, enabling more efficient urban planning and infrastructure development [7]. BIM constitutes a digital representation encompassing both the physical infrastructure and functional characteristics of a structure. It serves as a dependable cornerstone for information modeling, functioning as a communal knowledge repository for facility information across its entire life cycle [8]. The integration of BIM significantly improves the accuracy and efficiency of collaboration among urban stakeholders, facilitating the streamlining of construction project processes. Consequently, this advancement fosters the promotion of resource recycling and waste management initiatives within cities, thereby enhancing energy efficiency and mitigating environmental pollution [9]. From a business perspective, smart city stakeholders committed to resolving important social and environmental problems can keep promoting innovation [10]. Integration of sustainability into urban business models can enable research on sustainable value propositions that meet socio-economic and environmental needs [11]. At the same time, business model innovation can be a key driver in achieving the SDGs. Innovations in sustainable business models can promote the efficient use of resources and the development of the circular economy and green industries, which cover social enterprise, circular economy models, and sharing economy models [12]. The construction industry, business models, and smart cities are recognized as pivotal domains with profound implications for fostering sustainability, thus prompting extensive research endeavors. However, there remains a dearth of interdisciplinary integration within this sphere aimed at fostering sustainable development. Nevertheless, the findings of Zandee [13] and Zanni [14] collectively show that research in this area could provide theoretical and practical guidance for the sustainable transformation of society, which can make a positive contribution to the realization of the UN SDGs.

The limited existing research focuses more on city-wide digital transformation and innovation. For example, one noteworthy contribution comes from Espina-Romero and Guerrero-Alcedo [15], who delve into the realm of digital applications. They posit that BIM, business models, and sustainable development within the urban industrial sector stand as pivotal domains for digitalization efforts. Additionally, Gao et al. [16] use co-word analysis to visualize research in this field. At the same time, some scholars focus on city-specific facilities and services, such as urban heritage facility management [17] and carpooling platform projects [18]. These studies contribute to a deeper comprehension of smart cities and digital technologies, particularly BIM, in fostering sustainable innovation within the business sector. However, a general mapping of the fields and objective metrics for sustainability assessment is lacking. Additionally, an exclusive reliance on quantitative research methodologies proves insufficient in delving into the nuanced intricacies of this research domain. Therefore, this paper aims to utilize an innovative mixed research approach combining macro-quantitative bibliometric analysis with subsequent micro-qualitative content examination based on the SDGs to explore the relationship between BIM and smart cities in promoting a sustainability-oriented business model, which provides a more comprehensive understanding of the overall

situation and the development of research topics in this field, and also contributes to the improvement of the SDGs. The research rationale consists of following two research questions (RQs), as shown in Figure 1: (1) What is the development sequence and current research status of BIM–Business Model–Smart City-theme-related research? (2) What is the BIM–Business Model–Smart City theme's expected contribution and development trend to the SDGs?

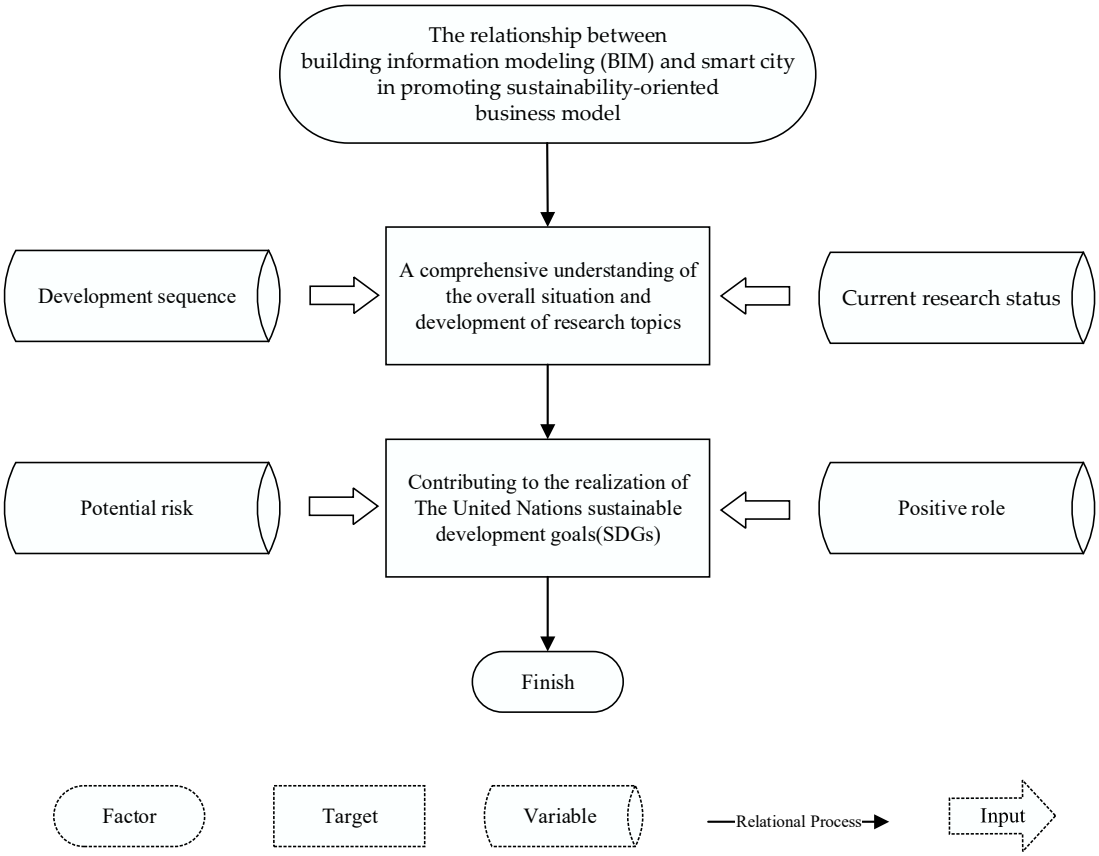

Figure 1. Research rationale (generated by the authors).

2. Materials and Methods

The research methodology flowchart depicting the data collection and analysis processes is delineated into six sequential steps, as illustrated in Figure 2.

2.1. Phase 1: Refinement of Research Objectives

This paper endeavors to address the research questions delineated in Section 1, for which two following objectives (Obj) need to be attended to:

Obj1: to explore the development sequence and current research status of BIM–Business Model–Smart City-related research.

Obj2: to identify contribution and development trend of the BIM–Business Model–Smart City theme to the SDGs.

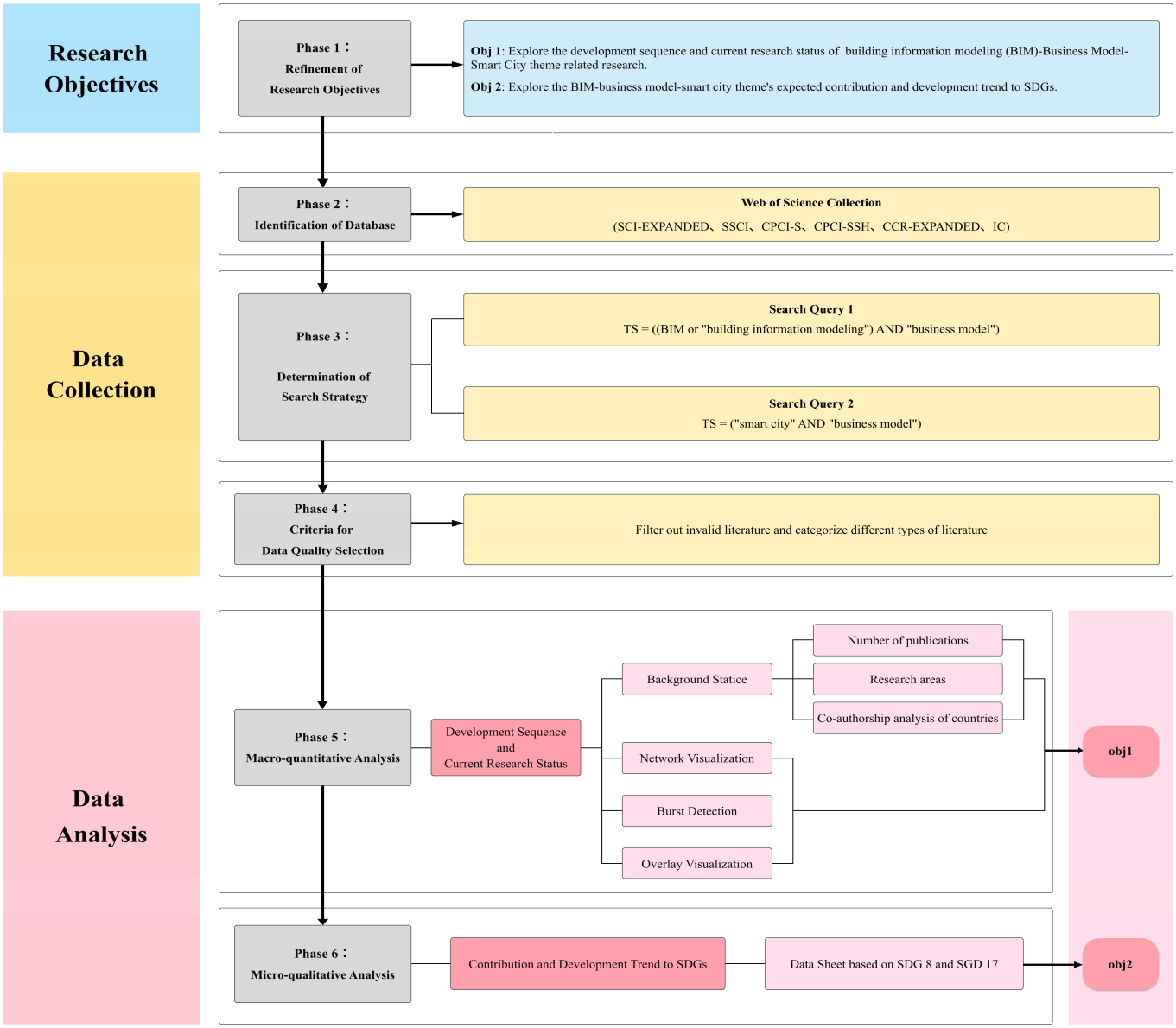

Figure 2. Research methodology flowchart (generated by the authors).

2.2. Phase 2: Identification of Database

Since the most significant data source for unbiased bibliometric analysis, where the literature spans the majority of scientific knowledge areas, is widely acknowledged to be the Web of Science (WOS) [19], the Web of Science Core Collection was used as the source for data collection.

2.3. Phase 3: Determination of Search Strategy

The obtaining of data incorporating the keywords “BIM” and “business model”, as well as “smart city” and “business model”, was conducted, respectively, on 9 March 2022, for which the search query was determined as “TS = ((BIM or “building information modeling”) AND “business model”)” and “TS = (“smart city” AND “business model”)”, resulting in a cumulative result of 76 papers, spanning from the year 2011 to 2022, for the subsequent stage analysis, as depicted in Table 1.

Table 1. Search query and literature quantity.

Search Query	Literature Quantity
TS = ((BIM or "building information modeling") AND "business model")	16
TS = ("smart city" AND "business model")	60

2.4. Phase 4: Criteria for Data Quality Selection

To maintain data integrity and to minimize bias, the following criteria were established for filtering out irrelevant data that may have been inadvertently included during the automated retrieval processes:

- Repeated literature;
- Retracted publications;
- Literature unrelated to business models;
- Literature that does not mention any type of application to BIM or smart cities;
- Literature not in English;
- Literature types other than "Article", "Review article", or "Proceeding Paper".

One paper was excluded after screening due to being an inappropriate literature type and a total of seventy-five papers were obtained for the subsequent quantitative macro-analysis. The obtained data were exported as a "plain text file" encompassing comprehensive data labeled as "Full Record", which includes details such as the publication year, language, source, title, authors, funding information, keywords, document type, abstract, and citations. In addition, before the micro-qualitative analysis, the obtained 75 papers were screened again based on the following principles for the SDGs, i.e., SDG 8 and 17, as shown in Table 2.

Table 2. Principles and literature quantity.

SDGs	Principles	Literature Quantity
SDG 8	Literature content unrelated to sustainability	70
SDG 17	Literature content unrelated to sustainability Literature that does not mention any type of city stakeholders	54

2.5. Phase 5: Macro-Quantitative Analysis

Scientific mapping is one of the mainstream methods of bibliometric analysis that can be used to explore the structure and evolution of a focal research area [20]. VOSviewer, version 1.6.18, facilitates the creation and visualization of bibliometric networks. These networks are built upon co-citations, bibliographic couplings, and collaborations among journals, scholars, and specific works [21]. CiteSpace (6.2.R4) serves as an information visualization software tool primarily employed for the measurement and analysis of scientific knowledge data [22]. In this paper, the raw data were imported into the VOSviewer (1.6.18) and CiteSpace (6.2.R4) software to visualize the structure of knowledge, including the research background statistics, network visualization, burst detection, and overlay visualization, to address research objective 1.

2.6. Phase 6: Micro-Qualitative Analysis

The micro-qualitative analysis aims to address research objective 2 by ascertaining the anticipated contribution and development trend of BIM, business models, and smart cities to SDG 8 and SDG 17, which are the most relevant to the theme, through the data sheet classification of specific goals.

3. Results

3.1. Results of Macro-Quantitative Analysis

3.1.1. Research Background Statistics

The quantity of publications serves as a significant indicator for gauging the trajectory of the research development. Figure 3 illustrates the progression of publications, which can be categorized into three distinct phases. During the initial phase of development (from the year 2011 to 2015), there was a consistent increase in the number of publications. Subsequently, following a sudden decline in the year 2016, the volume of publications stabilized for a period of time. However, post-2019, there was a notable resurgence in publication numbers within this research domain, indicating a sustained interest among researchers in recent years.

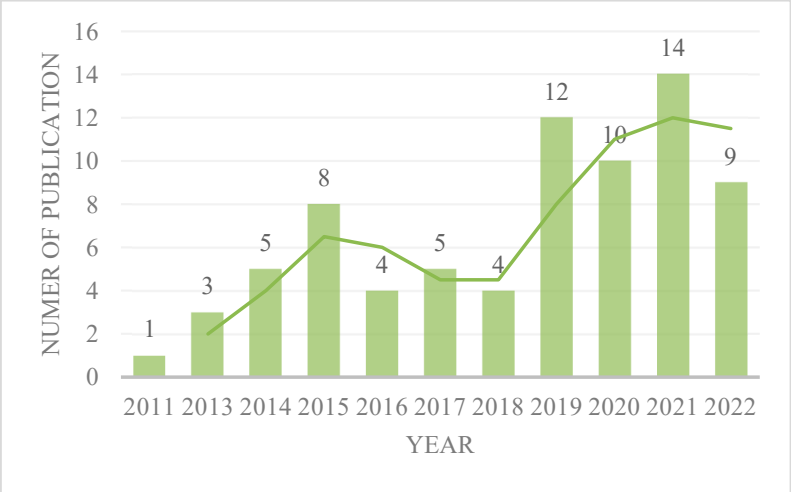

Figure 3. Number of publications on BIM–Business Model–Smart City-theme-related research (generated by the authors).

As shown in Figure 4, an examination of prevalent research domains on the BIM–Business Model–Smart City theme via the "Analyze Results" tool within the Web of Science Core Collection (WoSCC) database reveals the top ten trending areas of study. The findings indicate that "Computer Science" and "Engineering" emerge as the primary research areas, with a concentrated distribution of publications in this field, collectively constituting over 40% of the total output.

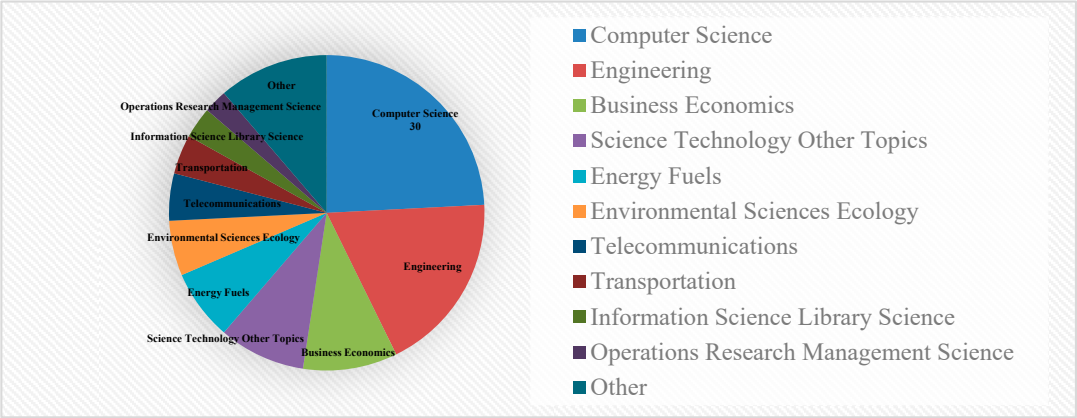

Figure 4. Number of publications in different research areas on BIM–Business Model–Smart City-theme-related research (generated by the authors).

Figure 5 shows the most influential countries and co-authorship analysis of countries on BIM–Business Model–Smart City-theme-related research. These findings are derived from research results generated using VOSviewer (1.6.18) and are further presented visually using Scimago Graphica (1.0.42) software, enhancing the clarity and intuitive understanding of the data. It is readily apparent that China, the United Kingdom, and Italy stand as the foremost influential countries within this research domain. Moreover, the collaborative knowledge exchange among researchers from Italy and counterparts in Canada, as well as the collaboration between United Kingdom and Finland has notably catalyzed further research endeavors in this field.

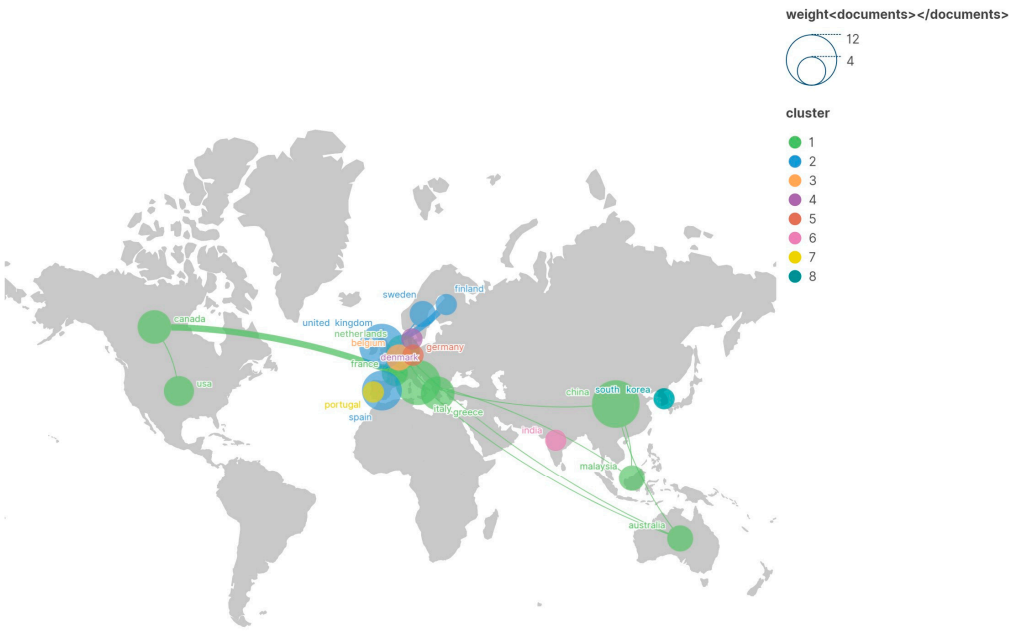

Figure 5. Co-authorship analysis of countries on BIM–Business Model–Smart City-theme-related research (generated by the authors).

3.1.2. Network Visualization

The data were imported into VOSviewer (1.6.18) software for the purpose of co-analyzing keywords and generating a cluster map utilizing the VOS clustering algorithm.

As shown in Figure 6, VOSviewer (1.6.18) divides the keywords of BIM- and business model-related research into four clusters, the red cluster, green cluster, blue cluster, and yellow cluster, via keyword network co-occurrence visualization. The blue cluster 1 keyword with the highest weight is "sustainability", focusing on the sustainability of smart cities and buildings through emerging technologies such as "virtual reality", "artificial-intelligence" and "machine learning", and sustainability management. Green cluster 2 focuses on the terms of the sustainability of the business model and strategic planning for smart cities during its life cycle. The yellow cluster (cluster 3) delves into how BIM is applied to sustainability. Lastly, red cluster 4 is associated with the implementation of circular economy principles within the construction sector. The "strategic planning", "design", and "procurement" stages of the life cycle in green cluster 2, the "construction" stage of the life cycle in red cluster 4, and the "maintenance" stage of the life cycle in blue cluster 1 together form the "briefing stages", "design stages", "procurement stages", "construction stages", and "post-construction stages" of the full life cycle. As such, the research and application areas of BIM and business models have a symbiotic relationship with sustainability.

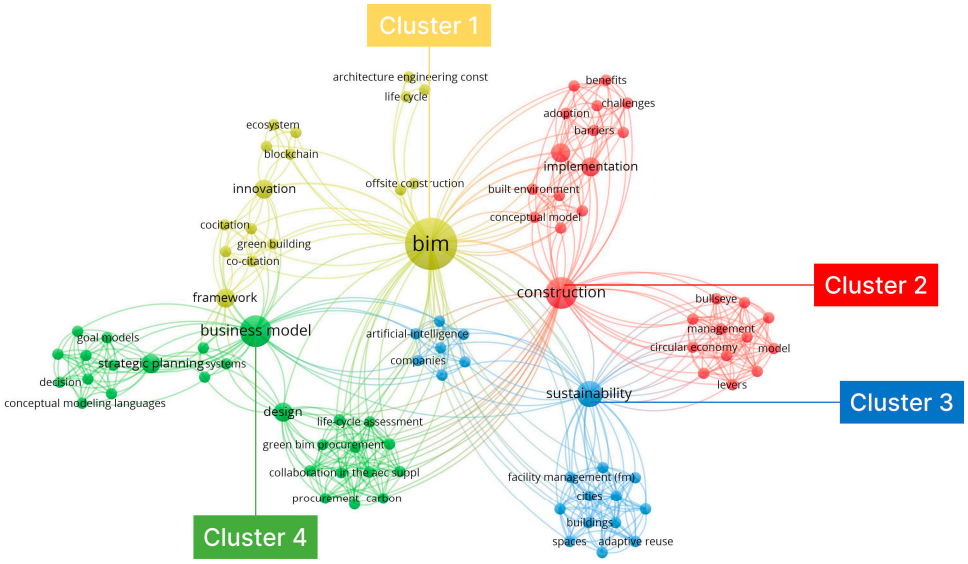

Figure 6. Keyword co-occurrence network visualization of BIM and business model-related research (generated by the authors).

In addition, as shown in Figure 7, the research on smart cities and business models is analyzed via the VOSviewer (1.6.18) software tool to form the following four different color clusters: blue, red, yellow, and green. The yellow cluster focuses on business models and the projects and services of the smart city. It is used to further categorize the keywords in the red, blue, and green clusters into two categories. The first category incorporates the connection between sustainability, life cycle, and innovation in the business model. The second category covers cutting-edge technology and systems facilitated by IoT, cloud computing, big data, smart mobility, and e-government for creating smart city projects and maintaining smart city services. As such, it illustrates the symbiotic relationship that exists between the smart city, business model, and sustainability.

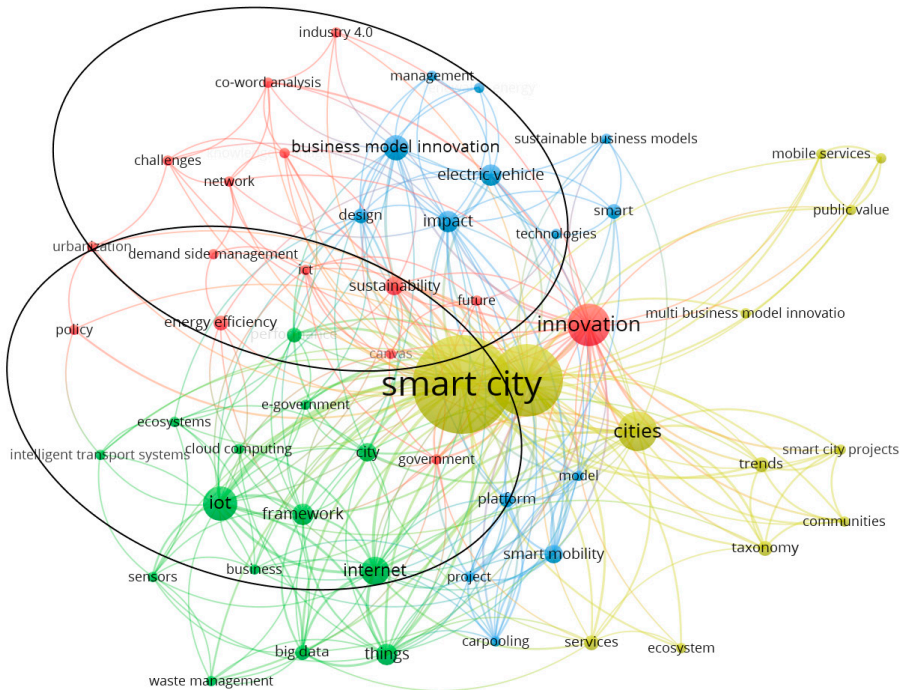

Figure 7. Keyword co-occurrence network visualization of smart city and business model-related research (generated by the authors).

There are two identified research themes. The first theme pertains to the utilization of digital technology, such as BIM, to enhance the service delivery and management of smart city projects. The second theme focuses on the smart city circular economy and building life cycle.

The first research topic shows the business value of virtual reality, artificial intelligence, and deep learning in the areas of urban facilities management and green buildings, of which the digitization of infrastructures and modules supported by BIM digital technologies provides a new way of creating, transmitting, and capturing value, resulting in driving innovation in business models, which is consistent with the findings of Karl Taeuscher et al. [23] on the platform business model. However, little attention has been paid to how alterations in the business models of the digital services that underpin the technology may affect people's perceptions in the current developing market of information systems for the residents of smart cities. Enhancing the perceived value of consumer business models for basic digital services in several dimensions based on new digital services assists in the realization and maintenance of the economic worth of smart cities in the context of the technologically homogenized market [24]. The distributed and varied characteristics of city manager-led innovation subjects, however, significantly lower the cost of information model searching and sharing, increasing the efficiency of information and resource sharing as well as cooperation among innovation subjects, and gradually forming a value co-creation system with a high synergistic utility [25].

The second area of research is the circular economy of smart cities and the building life cycle. The concept of the circular economy has emerged as a pivotal research domain, particularly due to the disruptive influence of novel digital technologies on established business paradigms. The circular economy has the potential to have significant positive effects on the economy and society by being implemented in service-oriented technology. Understanding the innovations in circular economy business models catalyzed by digital technologies is useful for city managers seeking to capture the promise of the circular economy while improving economic and environmental potential, which is consistent with the findings of Joan Manuel F. Mendoza [26] and Valtteri Ranta et al. [27] on digital technologies and circular economy business models. In addition, the implementation of circular economy principles in the smart city construction industry is closely related to the building life cycle.

3.1.3. Burst Detection

Utilizing the burst detection algorithm [20], the CiteSpace (6.2.R4) software tool identifies sudden spikes in node occurrences and extracts pertinent burst words to delineate research hotspots within specific timeframes. Should a burst period extend into the current period for a node, it persists, offering insight for forecasting research trends. Illustrated in Figure 8 are the top 19 keywords exhibiting the most robust citation bursts between 2011 and 2023, where "Year" signifies the keyword's initial appearance year, "Strength" denotes the magnitude of the burst, and "Begin" and "End" indicate the commencement and conclusion years of the burst, respectively. The red line depicts the duration of the keyword burst, while the blue line illustrates the study's duration.

In 2013, there was a surge in interest in public engagement, followed by a notable shift towards environmental and energy efficiency topics within two years. The period between 2016 and 2018 witnessed a significant rise in research attention towards emerging digital technologies like cloud computing and the Internet-of-Things. By 2021, artificial intelligence and BIM emerged as prominent areas with heightened research activity. This trend underscores the growing importance of integrating the circular economy concept with novel digital technologies, which persists as a prominent research trajectory to date, characterized by sustained momentum.

Top 19 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2011 - 2023
strategic planning	2013	1.14	**2013**	2014	
mobile service	2013	1.03	**2013**	2015	
public value	2013	1.03	**2013**	2015	
public governance	2013	1.03	**2013**	2015	
smart environment	2014	1.02	**2014**	2016	
energy efficiency	2016	1.56	**2016**	2018	
cloud computing	2016	1.03	**2016**	2018	
internet of thing	2016	1.03	**2016**	2018	
framework	2013	0.47	**2016**	2017	
design	2013	0.8	**2017**	2019	
innovation	2015	1.22	**2019**	2021	
conceptual model	2019	0.79	**2019**	2020	
city	2015	0.38	**2019**	2020	
impact	2020	1.29	**2020**	2021	
electric vehicle	2017	0.91	**2020**	2021	
challenge	2021	1.12	**2021**	2023	
artificial intelligence	2021	1.12	**2021**	2023	
bim	2019	0.79	**2021**	2023	
circular economy	2021	0.74	**2021**	2023	

Figure 8. Top 19 keywords with the strongest citation bursts on BIM–Business Model–Smart City-theme-related research (generated by the authors).

3.1.4. Overlay Visualization

Overlay visualization can reflect research hot topics by year and help reveal future research trends via VOSviewer (1.6.18). The colors range from purple to yellow, with different colors corresponding to the year of keyword appearances. The more the color leans toward purple, the more it indicates that the keyword appeared earlier, and the more the color leans toward yellow, the more indicates that the keyword appeared later.

As shown in Figure 9, before the year 2016, research on business models, BIM, and smart cities was in its infancy. The purple keywords "e-government" and "mobile services" reflect the informatization and digital transformation of urban construction and services. Most of the keywords in Figure 9 appear after the year 2018, indicating a period of rapid growth in the field. Business model innovation and sustainability have become hot topics for the widespread adoption of emerging technologies, such as IoT, big data, and smart mobility, since the emergence of the smart city concept, the digital transformation of the construction industry, and the ongoing development of economic models. After the year 2021, smart cities have been iterating their business models in a sustainable context and have been committed to running the circular economy development model that is in line with the concept of sustainable development, in which life cycle issues have also been given an unprecedented opportunity for growth.

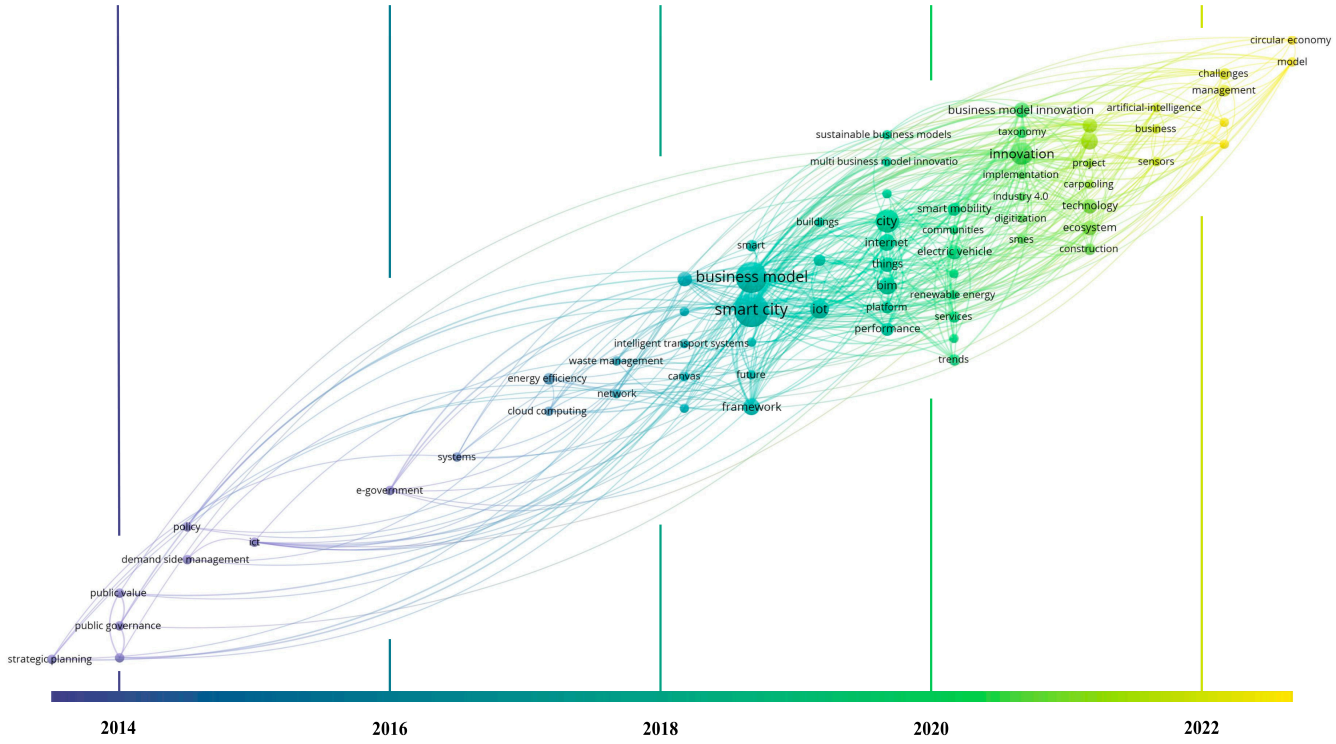

Figure 9. Keyword co-occurrence overlay visualization of BIM–Business Model–Smart City-theme-related research (generated by the authors).

3.2. Results of Micro-Qualitative Analysis

The above-mentioned macro-quantitative examination of keywords conducted through the utilization of the VOSviewer (version 1.6.18) software serves as the cornerstone for the subsequent micro-qualitative analysis. The macro-analysis reveals that the integration smart cities and information modeling for business models is driven by sustainability. Hence, the micro-qualitative analysis was conducted regarding the SDGs to analyze the smart city-, business model-, and BIM-related issues to fully exploit the role of BIM in the transfer of linear to circular economic growth [28], to comply with and continuously advance the development and realization of the SDGs, and to better promote the sustainable development of smart city construction and services through business model innovation.

In terms of economic benefits (business), the development of smart city projects and services, as well as the integration and application of BIM technologies, cannot be separated from the sustainable environment, which has a positive impact on sustainable development to achieve the SDGs. As such, the integration of smart cities and BIM to promote sustainability from the perspective of economic benefits (business) is closely related to SDGs 8 and 17.

3.2.1. Decent Work and Economic Growth (SDG 8)

A total of 70 publications closely related to SDG 8 have been screened for the follow-up in the micro-qualitative analysis, of which 12 publications (as stated in Table 3) are related to SDG 8.1; SDG 8.2 contains 28 articles (as stated in Table 4), covering corporate diversification, technical advancement, and innovation; as indicated in Table 5, SDG 8.3 has 9 publications, mainly focused on the support of business-related policies; SDG 8.4 (with 13 publications), as shown in Table 6, is associated with resource efficiency in global consumption and production.

- SDG 8.1—Sustainable Economic Growth

The studies on the application of business models in the field of integration of smart cities and BIM are closely related to SDG 8.1, as shown in Table 3. Relevant research

started in the year 2013, mainly adopting case studies [3,29–33], literature reviews [34–37], and taxonomies [35] as research methods, of which the research topics were associated with smart cities with the perspectives of different smart city participants [38], and were conducted within the dimensions of the business model framework [36], business model canvas [34], and theory of business model logic [33].

Table 3. Literature on the Smart City–Business Model–BIM theme for SDG 8.1 (generated by the authors).

SDGs	Year	Research Method	Topic
8.1	2013	Case Study	Business Model Framework [29]
8.1	2015		Smart City Business Model [30]
8.1	2015		"Urbanization" Business Model [31]
8.1	2019		Business Model Framework for Transportation Projects [32]
8.1	2020		Business Model Logic for Metropolitan Smart Processes [33]
8.1	2021		Business Model for Smart City Services [3]
8.1	2019		Smart City Business Model Canva [34]
8.1	2019	Literature Review	Smart City Business Model [35]
8.1	2021		Business Model Framework for Sustainable Smart City [36]
8.1	2022		Open Data Business Model [37]
8.1	2018	-	Sustainable Civic Engagement Business Model [38]
8.1	2020	A Taxonomy with Polythetic Classes	Smart City Business Model [39]

Due to the widespread adoption of cutting-edge technologies such as BIM, the services offered by cities have expanded as studies have continued to grow with respect to smart cities. Industries and markets associated with smart cities are expanding significantly, maximizing value in a variety of areas such as economic benefits, ecological benefits, and environmental advantages [3].

Furthermore, the smart urban environment emerges from investing in diverse resources, such as human, social, innovative, infrastructure, technological, and commercial assets. These resources facilitate sustainable economic development through efficient management and governance mechanisms [40]. The viability, profitability, and sustainability of the initiatives are undermined by lacking the further integration of business and governance models, even if smart city projects have gradually begun to push new collaborative business models [39]. Recent research has demonstrated that BIM is now a successful method for addressing the fragmentation of the industry in the context of urban intelligence, which creates and manages the whole process of asset information as a foundation for digital transformation in the construction and engineering industries. Based on intelligent models supported by a remote platform, structured and multi-domain data are integrated to generate digital representations of assets throughout their life cycles, providing an enabling environment for resource consolidation and efficient project completion [41]. In addition, numerous studies have looked at business models from the logic [33], framework [32,36], and canvas [34] perspectives to achieve wisdom-oriented value creation. Business model logic describes how building blocks for business models are created, arranged, and reconfigured to support the development of smart cities [33]. Additionally, by defining the financial and non-financial components of the company, the sustainable smart city business model framework can assist potential investors in addressing the ESG (environmental, social, and governance) aspects of the business model [36], whilst the smart city business model canvas provides a helpful framework for developing and communicating a comprehensive, integrated vision of smart city business models, fostering innovative thinking for sustainable value creation [34].

- SDG 8.2—Diversifying, innovating, and upgrading economic productivity

Table 4 displays studies on the use of the business model in the field of BIM and smart city integration, which are directly related to SDG 8.2. Starting in the year 2013, pertinent studies have used case studies [42–55], literature reviews [15,30,56–61], mixed studies [62,63], bibliometric analyses [16], and interviews [64] as their research approaches, concentrating on the topic of business model innovation in various contexts and fields.

Table 4. Literature on the Smart City–Business Model–BIM theme for SDG 8.2 (generated by the authors).

SDGs	Year	Research Method	Topic
8.2	2013	Case Study	Tactical Business Intelligence Model (TBIM) [42]
8.2	2014		Urban Logistics Business Model [43]
8.2	2014		Combined EPC and BIM Business Model [44]
8.2	2015		Multilateral Market-Based and Freemium Business Model [45]
8.2	2015		Alternative Business Model [46]
8.2	2016		Smart City Business Model [47]
8.2	2017		Public Service Business Model [48]
8.2	2020		Business Model Innovation [49]
8.2	2020		Business Model Innovation [50]
8.2	2020		Sustainable Business Model [51]
8.2	2020		SCP Classification Based on Business Model [52]
8.2	2020		Information Architecture and Business Model [53]
8.2	2021		Data Enablement Platform Business Model [54]
8.2	2021		Business Model Evaluation Smart City Mobility Program [55]
8.2	2019	Literature Review	Business Model Innovation [56]
8.2	2020		Business Model Innovation [57]
8.2	2021		Circular Economy [58]
8.2	2021		Post Smart City Business Model [59]
8.2	2022		Business Model Innovation [60]
8.2	2022		Digital Business Model [15]
8.2	2022		Green Building Business Model [61]
8.2	2014	Interview	Business Model Canva [64]
8.2	2015	Interview and Case Study	Mobile Services and Their Business Model [62]
8.2	2021	A Bibliometric Analysis And Systematic Literature Review	A Multilateral Platform Business Model [63]
8.2	2022	Bibliometric Analysis	Business Model Innovation [16]
8.2	2015	-	Cloud Platform Business Model [65]
8.2	2017		Smart Services Business Model [3]
8.2	2019		Multi-Business Model Innovation [66]

In general, innovations in the context of smart cities provide fresh insights to explain conventional business models and expose the factors that convert productivity from novel technology to elements of effective sources of economic benefits. When digital technologies, such as BIM, are associated with business models and public demand, there are new emerging prospects for urban development [53]. Additionally, shifting the focus to the area of business model innovation can lead to the achievement of higher levels of economic productivity [60].

In addition, between the years 2013 and 2022, the smart city business model achieved digital transformation and innovation from relying on information technology to relying on digital technologies such as BIM in multiple dimensions and aspects, including the reconfiguration and design of the business model innovation process [16]. Digital innovation develops business models or value propositions through digital devices. As a representative area of digital technology applications since the year 2018, BIM integrates multidisciplinary data to create digital representations and manages them through a cloud platform, ensuring face-to-face collaboration. Digital skills are associated with business models to deliver sustained profit growth to the market with the use of information modeling [15]. In addition, related studies have explored how to improve economic productivity levels through the circular economy for green process innovation and the integration of information architecture and business models [53,58,61].

Further, in the year 2016, next-generation information technologies in various sectors of smart cities have been proposed for future business models and architectures aimed at managing big data in smart cities [47]. In the year 2020, the concept of urbanization and digitization created a cutting-edge vision for sustainable infrastructure and steady economic growth in cities across the world [50]. Metropolitan environments can foster innovation from knowledge and creative human capital, thus making the business model canvas an effective tool for exploring urban smartness in more detail [56], while business models use BIM as a digital complementary tool to promote creative technologies, value network mapping, life cycle assessment, and product–service system innovations. This also enables managers to commercialize cutting-edge technology in the market. Additionally, business models can expand the scope of systemic innovation and act as a source of competitive advantage to foster long-term innovation [61]. Many studies have suggested that the digital transformation of socio-technical systems is vital for productivity innovation and upgrading, with the ultimate goal of creating value co-creation. Currently, business model innovation research focuses on integrating various groups to achieve the progressive transition from value generation to value co-creation [54]. Hence, digital technologies such as BIM in the urban metabolism enhances efficiency. They equip policymakers, city managers, and planners with valuable instruments for gathering, tracking, analyzing, and assessing the circularity of environmental, social, and economic resources. This aids in enhancing their efficacy and caliber. Ultimately, the integration of the circular economy with digital technologies provides benefits in streamlining cycles and improving materials, waste, by-products, emissions, energy, knowledge, data, and information [58].

- SDG 8.3—Job creation and enterprise development

Table 5 displays studies on the use of business models in the field of BIM and smart city integration, which are directly related to SDG 8.3. The pertinent research was initiated in the year 2011, using case studies [67–70], interviews [41,71], mixed research [13,48], and the DT process [72] as research methods. The research questions depict the business models of organizations' enterprises in various industries. The research on the use of business models in the field of integration of smart cities and BIM in relation to SDG 8.3 is analyzed and described in the following section.

Small- and medium-sized businesses (SMEs) are investigating obstacles, strategies, and best practices in business operations in the context of sustainable smart cities, and are continuously seeking out new procedures and technologies to boost productivity, market share, and competitiveness. In addition, by providing financial and policy support, the government can assist SMEs in their transition to digitalization. BIM utilizes information modeling to update and share data among project participants during the planning to commissioning phases of an enterprise project, enabling more effective exchange and updating of enterprise project data, improving communication and information management, and thus facilitating collaboration throughout the project life cycle [41].

Table 5. Literature on the Smart City–Business Model–BIM theme for SDG 8.3 (generated by the authors).

SDGs	Year	Research Method	Topic
8.3	2011	Case Study	Pharmaceutical Industry Business Model [67]
8.3	2014		Business Intelligence Model [68]
8.3	2015		Architectural Project Design Management Business Model [69]
8.3	2019		Developing and comparing four types of business model [70]
8.3	2022	Interview	SME Business Model [41]
8.3	2022		Innovative blockchain ecosystem business model [71]
8.3	2017	Interview and Case Study	Business Model Evaluation Tools [48]
8.3	2022		Circular Economy in Construction [13]
8.3	2019	DT Process	Business Models for the Adoption of BIM in the Built Environment [72]

In addition, in the year 2011, technology-driven businesses were the key to achieving smart cities, although their product-centered business models are no longer able to satisfy the shifting needs. Studies over the following decade have analyzed the fundamental inefficiencies of business models in the marketplace, attempting to transform and innovate the current business models and business processes of the corporations with the aid of business model assessment tools and business intelligence models, and finally use BIM to visualize and design for end-users [67,69,70]. The business model assessment tool serves as a straightforward, structured, adaptable, and transparent system that assists companies in defining, assessing, or planning the implementation of business models that shape corporate sustainability in the following three dimensions: economy, environment, and society [48]. Business intelligence models are designed to help business users organize and understand large amounts of data about the enterprise and its external environment, and analyze strategic goals, business models, business processes, markets, trends, and risks [68].

Further, recent studies have argued that SMEs use resources such as knowledge, complementary assets, and intellectual property outside their borders to commercialize innovations and thereby address skill shortages and financial liquidity. The government can stimulate commercialization, accelerate the digital revolution, and support emerging business change. The life cycle of sustainable design collaboration, as well as associated intellectual property difficulties and legal responsibilities, can be addressed with the use of existing digital delivery models involving BIM [71]. In addition, to improve communication between internal and external stakeholders, foster interdependence between government and business, and achieve a shared vision across the market environment, a certain level of openness and confidence in the marketplace is necessary [13].

- SDG 8.4—Improving resource efficiency in consumption and production

Table 6 displays studies for the use of business models in the field of BIM and smart city integration, which are directly related to SDG 8.4. Since the year 2013, pertinent studies have used case studies [73–77], literature reviews [17,78], interviews [79,80], mixed studies [14,63], action designs [81], and AHPs [82] as research methods. Additionally, the study topics focus on how effectively resources are used in consumption and production across a range of industries and areas.

Table 6. Literature on the Smart City–Business Model–BIM theme for SDG 8.4 (generated by the authors).

SDGs	Year	Research Method	Topic
8.4	2013	Case Study	Sustainable Business Model [73]
8.4	2017		Smart City Business Model [74]
8.4	2020		Business Model Innovation [75]
8.4	2020		Electric Vehicle Business Model [76]
8.4	2021		Business Model Innovation [77]
8.4	2019	Literature Review	Water Sector Research and Integrated Business Model [78]
8.4	2021		New Potential Business Model [17]
8.4	2019	Interview	Collaborative Business Models for Green BIM [79]
8.4	2017		Green Business Model [80]
8.4	2014	Action Design Research Methodology	Waste Management Business Model [81]
8.4	2019	Interview and Case Study	Full Life Cycle Cost Impact Business Model [14]
8.4	2021	AHP Method	Electric Vehicle Business Model [82]
8.4	2021	A Bibliometric Analysis And Systematic Literature Review	A Multilateral Platform Business Model [63]

The smart city paradigm, which incorporates new cross-cutting ideas and business models that can give consumers functionality while minimizing environmental effects, has emerged as one of the most crucial urban strategies to support green growth and enhance urban sustainability in the context of climate change. The combination of the smart city paradigm with BIM is currently regarded as a successful way to reduce emissions, go green, and cut costs, which has benefited the growth of the market and the industry [76].

With the increasing demand for the development of smart cities and smart energy systems, the cross-cutting concept of smart energy cities has emerged in recent years. Studies have analyzed the serious challenges of urbanization and resources, proposing the use of BIM to provide data for the early assessment of energy performance and sustainability, and to improve the quality and optimize energy efficiency across the life cycle through building energy modeling for project energy performance [79]. Additionally, it is thought that giving environmentally friendly alternatives to conventional production in smart city activities can result in cost savings and the formation of creative business models [77], which, in turn, can improve energy system efficiency, optimize the structure of the energy system, boost economic growth, and encourage sustainable urban development [75].

3.2.2. Partnerships for Achieving These Goals (SDG 17)

Stakeholders of the city, such as city managers, corporate businesses, people, universities, and research organizations, are the main targets of current research on the use of business models in the field of smart city and BIM integration.

A total of 54 papers closely related to SDG 17 were screened with a micro-qualitative analysis for which studies focused on stakeholder relations, city managers, company businesses, and civic/citizen participation. As such, this paper focuses on stakeholder interactions in the functioning of urban business models. As shown in Table 7, the use of business models in the field of BIM and smart city integration directly related to stakeholder relationships are listed, which began in the year 2013, mainly adopting the research methods of case studies [3,29,30,43,50,54,55,75], literature reviews [35–37,56], interviews [79,80], and action designs [81] for investigation.

Table 7. Literature on the Smart City–Business Model–BIM theme for SDG 17 (stakeholder relationships) (generated by the authors).

Partnership	Year	Research Method	Topic
Stakeholders	2013	Case Study	Collaborative Business Models for Green BIM [29]
Stakeholders	2014		Water Sector Research and Integrated Business Model [43]
Stakeholders	2015		New Potential Business Model [30]
Stakeholders	2020		Smart City Business Model [75]
Stakeholders	2020		Sustainable Business Model [50]
Stakeholders	2021		Business Model Innovation [3]
Stakeholders	2021		Business Model Innovation [54]
Stakeholders	2021		Electric Vehicle Business Model [55]
Stakeholders	2019	Literature Review	Full Life Cycle Cost Impact Business Model [35]
Stakeholders	2019		Waste Management Business Model [56]
Stakeholders	2021		Electric Vehicle Business Model [36]
Stakeholders	2022		Green Business Model [37]
Stakeholders	2017	Interview	Full Life Cycle Cost Impact Business Model [80]
Stakeholders	2019		A Multilateral Platform Business Model [79]
Stakeholders	2014	Action Design Research Methodology	Waste Management Business Model [81]
Stakeholders	2015	-	A Multilateral Platform Business Model [65]

According to the governance perspective, the development of smart cities depends on the relationships among urban stakeholders, which are valued more highly than other urban notions [56]. Over time, fresh working connections between iterations of BIM and smart city stakeholders have been developed [79]. Additionally, the business model has a macro-viewpoint and views on all socioeconomic actors as crucial contributors to value development [54].

In addition, in the year 2015, Nemetschek [65] developed a completely new cloud-based platform called BIM+ to support collaboration between different participants in construction projects. In the year 2019, it was posited that stakeholders' common vision and goals for urban development should be compatible with the city's character and human, environmental, and economic resources [56]. Numerous studies have since examined the collaboration of BIM and business models from technological, organizational, and social aspects with smart city stakeholders. Vilas-Boas et al. [79] argue that BIM can have a significant impact on business by incorporating ICTs and frameworks that support stakeholder collaboration throughout the project life cycle. Additionally, a study conducted in the year 2020 suggested that stakeholders must cooperate to strengthen project planning, policy research, and related investments to explore workable business models and innovations in project business models that are suitable for each region [75], for which searching for collective stakeholder bargaining to establish transparency in policies, communication, mutual collaborations, and business models is one of the main obstacles [50]. Further, recent research proposes open data business models aimed at creating new BIM-based digital services in an open innovation process that promotes stakeholder collaboration, which continuously generates value and new business models in the collaboration of different products or services [37].

4. Discussion

4.1. Hot Research Areas, Existing Challenges, and Future Trends of the BIM–Business Model–Smart City Theme

The results of Section 3.1.2, Figures 6 and 7, delineate two pivotal research themes pertinent to the field. These illustrations encapsulate the primary focus areas under scrutiny by researchers, of which smart tourism is the main area of practical application and challenge for BIM and business models in the sustainable development of smart cities. As the foundational technology for the growth of smart tourism in tourist places, BIM digital technology has become a crucial component of the business models to tourism organizations, which gives smartphone users assistance and services through a variety of applications. The application of BIM technologies in the field of smart tourism provide inspiration for city management, such as public institutions and local governments. For example, the integration of BIM and GIS for the 3D modeling of cities provides an efficient way to share information and knowledge about architectural heritage to city managers involved in decision-making processes and territorial management [17]. In addition, business models in the context of tourism services usually refer to modern technologies that create value through the use of digital technologies, such as augmented reality (AR), to access big data and to measure and analyze it on a large scale, sometimes even in real-time [83]. This enables city managers and stakeholders to track environmental impacts, support decision making, and accelerate the introduction of new policies [84]. Further, although the majority of recent research studies have emphasized the benefits of smart tourism, concerns should also be taken into account, which include information security issues arising from digital footprints left by unsuspecting users, and damage and misuse issues arising from heavy reliance on smart technology. Hence, local governments, service providers, application designers, and other stakeholders in smart tourism destinations should consider these challenges and take necessary action to prevent problem amplification and exacerbation [83].

Additionally, the results of Section 3.1.2 demonstrate that "business model innovation", closely tied to the life cycle, is a crucial component of smart cities' economic responses to resource consumption and management, which also plays a crucial role in the well-being and sustainable growth of the cities. While information technology mainly increases productivity at the management level, digitalization changes the business model from the dimensions of business, R&D, service, and decision making. Digital technology-driven business model innovation is what is meant by "digital transformation", as opposed to just applying and deploying digital technologies. Productivity is changed from aspects that are cutting-edge sources of economic gains to components that are transformed through a comprehensive shift in organization, processes, people, and business models.

Furthermore, the results of Sections 3.1.3 and 3.1.4 collectively indicate that the concept of the circular economy has garnered significant attention in recent years and continues to exhibit a sustained developmental trajectory. Digital technology, as a key enabler of circular business models, improves the ability of the circular business models to retain value by sharing data and identifying and tracking materials. By enhancing the monitoring, analysis, and control of industry data, extending the project life cycle, and facilitating supply chain recovery, BIM enables the circular economy with its possibility to use real-time information data models for decision making to support production and maintenance optimization [27]. Techniques for collecting data can only slightly increase the effectiveness of resource use, value creation, and capture, while the application of data integration and analytics technology can permit more fundamental advancements in both areas [85]. Recent developments in BIM are often closely linked to emerging circular business model innovations, which share business models in the construction sector, help reduce transaction costs, and enhance communication along the supply chain. Future research is needed to further strengthen the vertical and horizontal integration of sustainable business model design approaches associated with well-known self-relevant environmental, social, and economic tools, such as stakeholder social responsibility and life cycle assessment [86].

4.2. BIM–Business Model–Smart City Theme's Expected Contribution and Development Trend to SDGs

The results in Section 3.2 demonstrate that the positive effects and potential risks of BIM, business models, and smart cities for the SDGs are focused on SDG 8 (Decent Work and Economic Growth) and SDG 17 (Partnerships for the Goals).

BIM and business models are important for fostering sustainable economic growth in smart cities (SDG 8.1—Sustainable Economic Growth). With the development of smart cities, the provided services also become more diversified with the wide application of advanced technologies such as BIM, from which the smart city-related industries and markets grow significantly, maximizing the value of the city in terms of economic benefits, ecological benefits, and environmental benefits [3]. The smart city business model canvas offers a useful framework to support, develop, and communicate a more comprehensive and integrated vision of smart city business models, and to enable more sustainable value creation through innovation [34]. In addition, the integration of business models and public demand with digital technologies such as BIM [53] and the shift of focus to business model innovation can help to achieve higher levels of economic productivity, which, in turn, assists in the achievement of SDG 8.2 (Diversification, Innovation, and Upgrading of Economic Productivity) and "Civic Engagement" in SDG 17. Future research could focus on the deep integration of smart city service businesses and urban governance models to provide a favorable environment for resource integration and effective project completion to ensure the viability and continued profitability of smart city projects [39].

Moreover, SDG 8.3 stresses a strong emphasis on job creation and business development. In the context of smart cities, business and city managers act as a key partnership (SDG 17), utilizing BIM to explore strategic practices for running smart city projects with a business model, which is in line with the ideas presented by Mahmoud when exploring the barriers, strategies, and best practices of research on BIM adoption in SMEs who constantly look for new processes and technologies to increase productivity, market share, and competitiveness by analyzing business models [41]. Governments can also aid SMEs in their transitions to digitization by providing financial and policy supports, for which BIM has been adopted to assist in updating enterprise projects through information models from the planning to commissioning stages for sharing among enterprise project participants, which enables more effective exchange and the updating of enterprise project data, enhances communication, and information management, and thus facilitates collaboration throughout the project life cycle. In the future, transparency and trust are needed for the market to develop new standards and policies, enhance internal and external stakeholder communication, build interdependence between government and business, and achieve a common vision across the market environment [13].

Currently, the integration of the smart city paradigm and BIM is seen as an effective solution for reducing emissions, environmental protection, and cutting costs, which has a positive impact on the market and industry [76]. The smart city paradigm has emerged as one of the most important urban strategies for promoting green growth and improving urban sustainability in the context of climate change. New crossover concepts and business models provide consumers with new functions and reduce environmental impacts, in line with SDG 8.4, which advocates increased resource efficiency in consumption and production. In addition, future studies should continue to concentrate on improving energy system efficiency, optimizing the energy system structure, supporting economic growth, and promoting sustainable urban development [75].

Furthermore, citizens, city managers, and corporations are seen as important stakeholders for value creation in the sustainable development of smart cities. According to the governance perspective, urban stakeholder relationships in smart cities are considered more important than other urban concepts and their value is decisive for the success of smart cities. Additionally, multi-stakeholder partnerships are acknowledged in SDG 17 as an important tool for mobilizing and sharing knowledge, expertise, technology, and financial resources to support all countries, particularly developing countries, in achieving

sustainable development goals, for which BIM can, in turn, have a significant impact on businesses by incorporating information communication technology (ICT) frameworks that drive stakeholder collaboration across the project life cycle [79]. In addition, the Digital Product Passport (DPP) serves as a tool among stakeholders and participants for collecting and sharing product data throughout the life cycle to release profit, case, and value. Further, the open data business model proposed by the latest research aims to facilitate the development of new BIM-based digital services in an open innovation process of stakeholder collaboration, which continuously generates value and new business models in the collaboration of different products or services [37], is an important development approach for future research.

5. Conclusions

This paper adopts a mixed research methodology to assess the relationship between BIM and smart cities in promoting a sustainability-oriented business model from macro-quantitative and micro-qualitative perspectives to build a sustainable society contributing to the SDGs. This paper provided an exploration of the two research objectives, including the review of the development sequence and current research status on the subject, as well as expected contributions and development trends to the SDGs. The main contributions of this paper are as follows: (1) In terms of the research content, this paper is one of a few attempts to examine the connection between BIM, business models, and smart cities in encouraging sustainable development. The predicted contribution of the multidisciplinary domains of BIM, business models, and smart cities to the realization of SDG 8 and SDG 17 is highlighted, which will help to achieve the United Nations Sustainable Development Goals (SDGs). (2) In terms of the research technique, this paper used the VOSviewer (1.6.18) and CiteSpace (6.2.R4) bibliometric visualization tools to conduct keyword co-occurrence and clustering analyses to identify important regions, authors, knowledge bases, hotspots, and evolutions of research on the topic. The results added to the body of knowledge on the subject, while the analytical process and the tool can also be used in other disciplines. (3) In terms of the research value, evaluating the relationship between BIM, business models, and smart cities for sustainability requires an integrated approach that takes into account factors from multiple fields, including architecture, business, and urban development. This multifaceted and integrated perspective, which is based on the SDGs, can offer both theoretical and practical advice for achieving sustainable development. It is also highly helpful for city administrators who monitor, evaluate, and assess urban sustainability and identify opportunities for changes in the economy, society, and environment. In addition, the results of this paper offer new perspectives to help urban investors build more socially sustainable cities, which make business models structured and simple, and which will help to produce more value in the implementations of business models.

Based on the current relevant research between the years 2011 and 2023, this paper reveals a panorama of this subject, and further demonstrates the objectives and means of the research theme in contributing to the achievement of the SDGs, encompassing SDG 8 and SDG 17. During the last 13 years (from the year 2011 to 2023), the period from the year 2011 to 2016 was the initial stage of the field, followed by a rapid growth after year 2018, of which "BIM", "Smart City", "Business Model", "Building Life Cycle", "Urban Management", and "Business Model Innovation" are the keywords representing the current research hotspots. The circular economy model that has been developed since 2021 has contributed to the life cycle stages, including the "briefing stages" and "procurement stages". As such, the "whole life cycle", "strategic urban planning frameworks", and "sustainable business models" have become the future research trends, whilst real-world applications such as "smart tourism", "e-government", and "green building" have emerged. Further, the key partnerships of "city managers", "corporate enterprises" and "public participation" for smart cities contribute to the achievement of SDGs 8 and 17 in terms of integrating urban information technology and urban infrastructure, policy regulation, knowledge-sharing, improving economic efficiency, and promoting sustainable economic growth.

However, this paper has some limitations. First, the Web of Science Core Collection is the only source for the bibliometric analysis, in which the database includes topics such as the natural sciences and engineering technology. Such disciplinary bias may lead to inadequate understanding and analysis of complex issues related to sustainability and urban development. In addition, the results of the bibliometric analyses (visualized graphs and networks) by VOSviewer (1.6.18) software require interpretation by the researcher, which may lead to individual preferences, subjective biases, or misinterpreted results. Although bibliometric analyses provide valuable information in assessing the relationship between BIM, business models, and smart cities in terms of sustainability, they still suffer from shortcomings such as selection bias, limitations in timeliness, neglect of non-documentary factors, and challenges of diversity and complexity. Therefore, future studies might take into account various research techniques and technology aids to improve the feasibility of the sample by collecting different sources and types of data, such as combining industrial databases with in-depth case studies to further explore the research. In addition, future research could explore new business models based on the concept of BIM and smart cities to promote sustainable development. This may include exploring the application of business models such as the sharing economy, circular economy, and digital platforms to promote resource sharing, energy efficiency, and environmental sustainability.

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