THE APPLICATION OF BIM FOR CONSTRUCTION CIRCULAR ECONOMY: A SYSTEMATIC LITERATURE REVIEW

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The application of Building Information Modelling (BIM) within the Construction Circular Economy (CCE) represents a transformative approach to enhancing sustainability and resource efficiency in the built environment. Although many studies have explored the feasibility of BIM in meeting the goals of CCE, such as improving energy efficiency and promoting waste recycling, a holistic review of BIM's applications in CCE remains lacking. This study aims to fulfil the knowledge gap through systematically reviewing the relevant literature published from 2009 to 2024 by PRISMA structure and science mapping approach. Keyword co-occurrence and burst detection reveal evolving research from early lifecycle focus to recent themes such as digitalisation and demolition. Four key themes are identified. Despite growing interest, limitations remain in areas such as data interoperability and accurate waste source identification. Future research is included to integrate BIM with IoT to improve material tracking. This review provides practical implications for researchers, practitioners, and policymakers seeking to advance BIM-enabled CCE.

Keywords: building information modelling; digital technology; construction circular economy; systematic literature review; science mapping

INTRODUCTION

In recent years, the integration of Building Information Modelling into Construction Circular Economy (BIM-CCE) has been increasingly prominent, as BIM technology can enhance design optimisation, precision in construction, intelligent operation and maintenance, and sustainable demolition, thereby improving resource efficiency, reducing waste, and promoting zero-waste, low-carbon, and intelligent management in the construction industry (Tomczak *et al.,* 2024).

The circular economy (CE), as an emerging economic paradigm, has gained increasing attention over the past few decades (Benachio, *et al.,* 2020). Unlike the traditional linear economy model—characterised by a one-way flow of "take, make, dispose"—the circular economy emphasizes the continual reuse and recycling of materials within a closed-loop system to achieve a sustainable built environment (Yamoah, 2017). Existing research mostly focuses on specific subfields of this paradigm, such as waste management, material reuse, or life cycle assessment, and introduces the adoption of BIM to improve its efficiency. For instance, in the

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management of construction waste and material resources, BIM has significantly improved the efficiency of tracking, predicting, and classifying building materials (Akanbi *et al.,* 2019; Akinade and Oyedele, 2019; Handayani *et al.,* 2022). Secondly, BIM can simulate component connection methods and disassembly paths during the design phase in material recycling and building lifecycle management, enhancing the reversibility and reusability of the system (AlJaber *et al.,* 2023). At the economic level, BIM not only optimises cost control but also promotes the transformation of circular building business models. Finally, BIM has reduced losses and carbon footprints, improved resource efficiency, and created development space for the local recycled building materials market and green employment in enhancing building sustainability, optimising logistics chains, and fulfilling social responsibilities (Tomczak *et al.,* 2024).

Although research on BIM in the construction circular economy (CCE) has grown, it remains fragmented and limited to specific topics such as waste management or material reuse. Prior reviews, such as Celoza and Alvarez de Neyra (2023), provided a general overview but lacked methodological rigour and thematic structure. To address this gap, this study conducts a systematic literature review of 25 journal papers published between 2009 and 2024, using the PRISMA protocol and science mapping techniques. For further analysis, it also builds a thematic framework (Munaro, Tavares and Bragança, 2020), to identifies four core categories of BIM-CCE research: (1) waste, resources, and materials; (2) reuse, closed-loop systems, and lifecycle; (3) economic feasibility and business models; and (4) sustainability, logistics, and social responsibility.

It aims to systematically review the application of BIM in the circular construction economy and identify key research themes, gaps, and future directions. And fulfill the following four Research Objectives:

RO1: To review and synthesize existing BIM-CCE literature using structured methods.

RO2: To categorise the literature into coherent thematic areas

RO3: To identify gaps in the current research field and provide future direction.

As a result, this research contributes to a clearer understanding of the current state of knowledge. The findings offer valuable insights for both academics and industry practitioners seeking to implement BIM-driven circular strategies and lay a theoretical foundation for advancing sustainable practices in the built environment.

METHOD

This study adopts a systematic literature review (SLR) approach to examine the integration of Building Information Modelling (BIM) within the circular construction economy (CCE). The SLR methodology is a holistic and rigorous method in built environment research, aiming at scrutinising the existing knowledge, identifying gaps, and providing a structured analysis of pertinent research articles (Zhong, *et al.,* 2025). To ensure transparency and replicability, the PRISMA protocol was followed, to guide the screening process, including identification, filtering, and selection of relevant literature (Sarkis-Onofre, *et al.,* 2021). Following a structured search and evaluation process, 25 relevant articles were identified for final analysis, as illustrated in the review framework. Subsequently, a bibliometric analysis based on science mapping was conducted to explore research trends and thematic structures (Pilelienė, Alsharif and Alharbi, 2022). The details of PRISMA are as Figure 1.

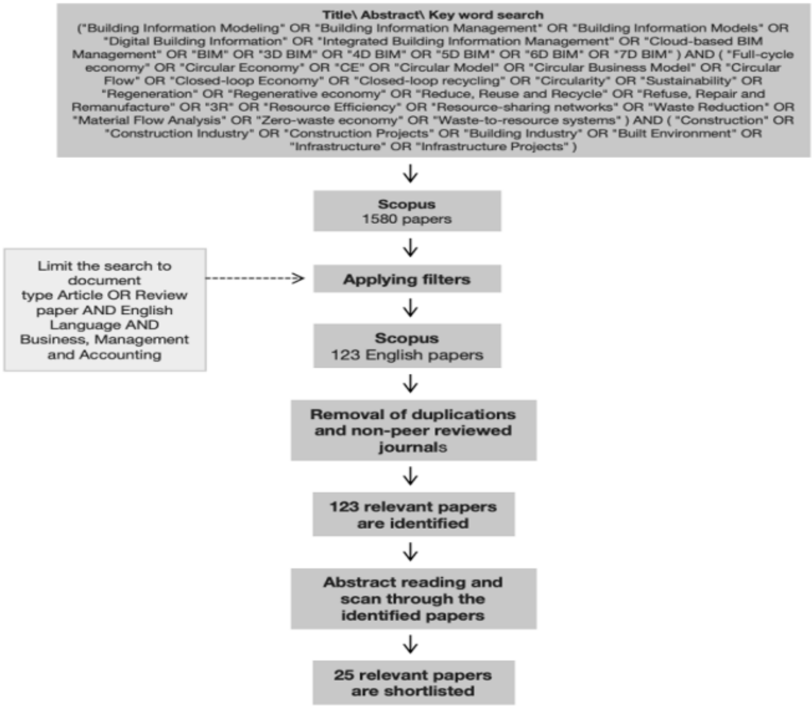

Figure 1: Full PRISMA process flow chart

FINDINGS AND DISCUSSION

This paper explores publication trends, the timeline co-citation map, keyword co-occurrence, strongest citation bursts, and its four key dimensions. The publication trends analysis tracks the growth of research output and emerging focus areas, while the timeline co-citation map reveals the development of influential studies and their interconnections over time. Keyword co-occurrence analysis identifies dominant research themes and their relationships, providing insight into the field' s structure. The strongest citation bursts highlight rapidly gaining research topics, indicating shifts in scholarly attention. Additionally, there is a content analysis, examined through four dimensions: waste reduction, resource efficiency, economic feasibility, and sustainability. Together, these analyses provide a comprehensive understanding of the current research landscape, its key contributions, and future research directions.

Publication Trend

The number of publications in the literature is an indicator of the pace, scope and outcomes of a field and helps researchers identify trends and progress in the field (Ellegaard and Wallin, 2015). Figure 2 shows the trends and progress in the field. The literature shows a growing trend in the applications of BIM in CCE research over 15 years, with 25 papers analysed, indicating that research interest and outputs in this field are sprouting. Initial research from 2009 to 2015, was sparse, focusing primarily on building green rather than construction circular economy (Tulacz, 2009). Between 2016 and 2019, publications increased, reflecting advancements in technology and a push for construction circular economy (Akinade and Oyedele, 2019). Although there is a decrease in 2020, publications recovered from 2021 to 2024, revealing there are more specific strategies to be explored (Tomczak *et al.,* 2024).

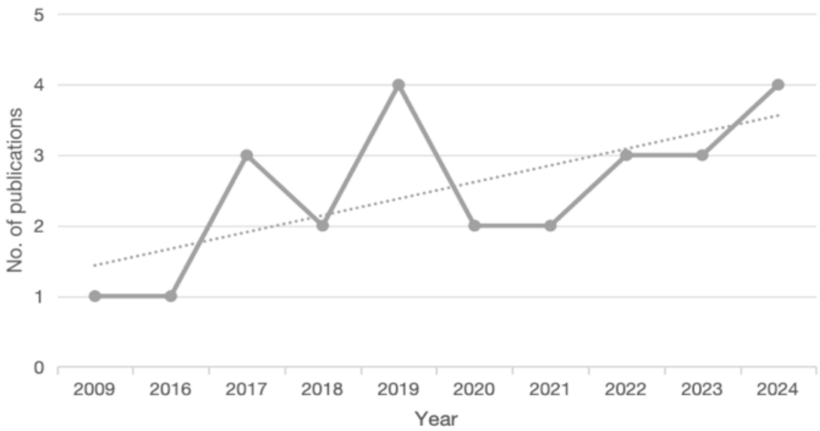

Figure 2: Distribution of published papers (2009-2024)

Co-occurrence Analysis of Keywords

Figure 3 represents a keyword co-occurrence network, visually mapping the relationships between key terms in BIM and Circular Economy (CCE) research. In this network, nodes (circles) represent keywords, where larger nodes indicate higher frequency of occurrence in the dataset, meaning they are core research topics.

Figure 3: Keyword co-occurrence network

The edges (lines) between nodes signify co-occurrence relationships, with thicker lines showing stronger associations between keywords in published studies.

Findings from Figure 3 indicate that "Building Information Modelling (BIM)," "Circular Economy," and "Sustainable Development" are dominant themes, forming the foundation of research in this field. The presence of emerging keywords like "decision making," "construction supply chain," and "energy efficiency" suggests a growing interest in optimising resource use and integrating BIM in sustainable construction practices. Additionally, the isolated cluster of "end of lives" suggests that BIM's application in managing the end-of-life phase of buildings remains an underexplored research area.

The timeline co-occurrence map (Figure 4) illustrates the evolving trajectory of BIM-related CCE research across three distinct phases. From 2009 to 2015, early studies predominantly focused on lifecycle management and BIM adoption, particularly in supporting the design of net-zero energy buildings (Tulacz, 2009). Between 2015 and 2020, the research emphasis shifted to addressing implementation barriers, strategic planning, and material supply decision-making through BIM (Alireza *et al.,* 2017; Saieg *et al.,* 2018; Vardan and Prasad, 2019). Nonetheless, limitations in BIM user capacity and digital skill gaps persisted as key obstacles (GhaffarianHoseini *et al.,* 2017). Since 2020, the research has increasingly concentrated on demolition planning and material recovery using digital technologies such as IoT and material banks (Balasubramanian *et al.,* 2024). However, challenges remain regarding the accuracy of material data collection and the integration of real-time tracking systems (Manganelli and Tataranna, 2020; Chen, Feng and Garcia de Soto, 2022). Overall, the evolution of BIM-CCE research reflects a gradual shift from lifecycle design to data-driven material recovery.

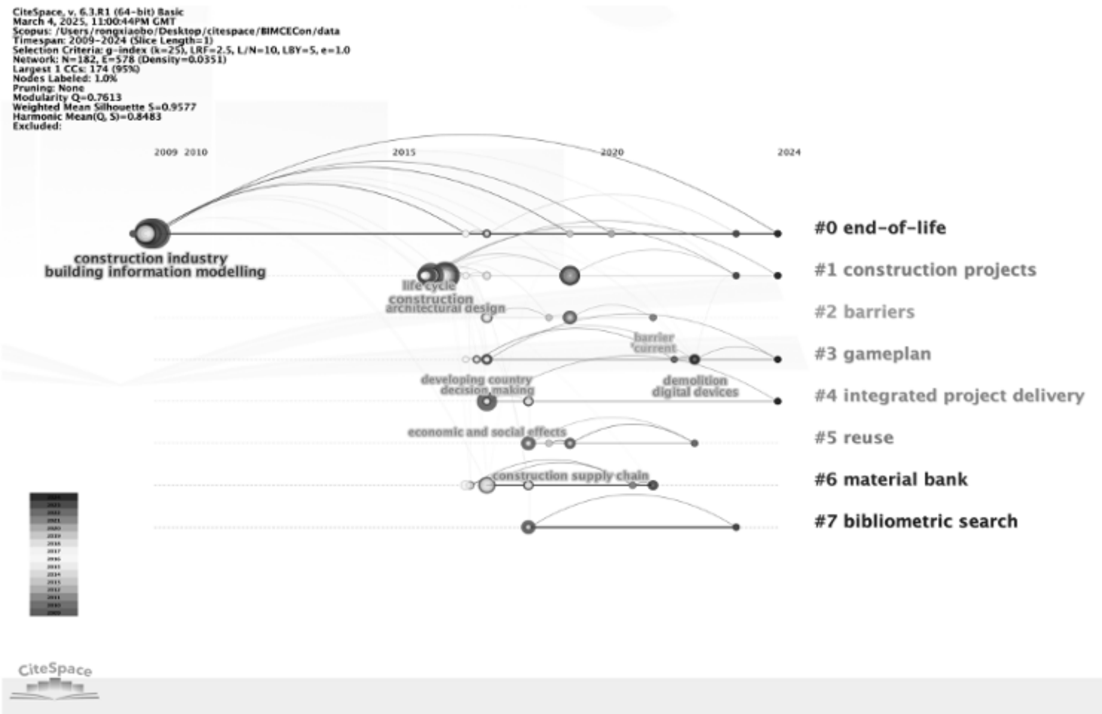

Figure 4: Timeline co-occurrence map of keywords

Keyword Citation Bursts Analysis

The role of burst detection is to identify research frontiers and emerging trends, reveal important topics, and predict future research directions (Zhang *et al.,* 2023). The keywords with the most robust citation bursts, summarised in Figure 5, represent the research trends in BIM in CCE. From 2016 to 2019, studies focused on sustainable building materials, decision-making processes, and the economic and social impacts of construction. Between 2019 and 2021, the emphasis shifted towards end-of-life strategies and circular economy models, highlighting material reuse and recycling within BIM-supported frameworks. More recently, from 2022 to 2024, research has increasingly centred on digital tools, smart technologies, and automated demolition, aiming to optimise resource recovery and enhance sustainability through BIM integration. This progression reflects a growing synergy between BIM, digitalisation, and circular economy principles in the construction industry.

Figure 5: Top 10 keywords with the strongest citation bursts during the research history of The application of BIM in CCE

Keywords	Year	Strength	Begin	End
building materials	2016	1.01	**2016**	2017
construction	2016	0.83	**2016**	2019
sustainable development	2009	0.79	**2016**	2018
information theory	2017	1.49	**2017**	2019
economic and social effects	2017	0.63	**2017**	2018
decision making	2017	0.63	**2017**	2018
end of lives	2019	0.87	**2019**	2021
circular economy	2019	1.03	**2021**	2022
demolition	2022	0.94	**2022**	2024
digital devices	2022	0.67	**2022**	2024

Content Analysis

Waste, Resources and Materials
This category centres on the application of BIM in managing construction waste and material flows, which is fundamental to circular construction. Although terms such as building materials are not visually prominent in Figure 4, they are critical in this field. Recent studies have increasingly integrated BIM with IoT to estimate waste generation and develop intelligent systems, such as ANFIS-based analytics, for material classification (Akanbi *et al.,* 2019; Akinade and Oyedele, 2019). Other works focus on identifying recyclable components using BIM-enabled databases (Handayani *et al.,* 2022). Despite these advances, BIM's role in supporting comprehensive waste and resource optimisation remains limited. Future directions include integrating BIM with real-time IoT sensors for material tracking and combining BIM with quantitative tools to improve the estimation of recoverable materials (Akanbi *et al.,* 2019; Akinade and Oyedele, 2019).

Reuse, Closed Loop, and Lifecycle
This category addresses how BIM facilitates material reuse and supports closed-loop systems across the building lifecycle. Studies have explored the integration of BIM and IoT to enable real-time tracking and promote reuse in construction and demolition phases (Heidari, Peyvastehgar and Amanzadegan, 2023) contributing building materials to be recovered, reused, or remanufactured at the end-of-life phase and reintegrated into the supply chain, thus forming a closed-loop system (Feng *et al.,* 2022). Besides, lifecycle assessment (LCA) remains a long-standing research focus (Alireza *et al.,* 2017; Atik, Aparisi and Raslan, 2024), buy a fully integrated framework that bridges BIM, LCA and circular economy principles is still lacking (Akinade and Oyedele, 2019). This highlights the need for systematic approaches to lifecycle-based circular construction.

Diversity, Economic Feasibility and Business Models
This category explores the economic and organisational feasibility of implementing BIM for circular construction. BIM has been applied to create material libraries for

reuse and recycling (Behún and Behúnová, 2022), and to model circular business strategies (Chen, Feng and Garcia de Soto, 2022). However, small- and medium-sized enterprises (SMEs) often face challenges in BIM adoption due to resource constraints (Geoghegan *et al.,* 2023), and the lack of economic incentives remains a barrier to its widespread use (Balasubramanian *et al.,* 2024). These challenges call for new business models and supportive policy frameworks to enhance BIM-driven circular practices.

Sustainability, Logistics Network and Social Responsibility

This category captures how BIM contributes to broader sustainability goals, including environmental performance, logistics coordination, and social impact. BIM integrated with circular economy strategies has been shown to reduce waste and improve recycling rates (Mandičák, Spišáková and Mésároš, 2024). Nevertheless, barriers persist regarding user competency and digital skills, which limit the depth of BIM application (GhaffarianHoseini *et al.,* 2017). In addition, logistics systems for industrial symbiosis and reverse logistics remain underdeveloped (Feng *et al.,* 2022). Further research is needed to enhance BIM-supported coordination across supply networks and stakeholder roles.

Research Gaps and Future Trends

Table 1: Existing Limitations and Future direction

Dimension	Existing gaps	Future direction
Waste, resources and materials	Lack of precise analysis of different sources of waste.	BIM combined with IoT sensors for real-time data tracking.
Reuse, closed loop and lifecycle	Overly theoretical predictions of recyclable materials.	Add quantitative methods to BIM to estimate the quantity of recyclable materials.
Diversity, economic feasibility and business models	Data exchange limitations in BIM through lifecycle.	Improve data interoperability and optimise data sharing mechanisms.
Sustainability, logistics network and social responsibility	Lack of a structured workflow for integrating BIM with LCA and CE principles.	Develop a structured BIM protocol.

This study identifies several existing research gaps across the key dimensions of BIM integration in the circular construction economy, with future directions. These findings serve as a basis for subsequent empirical investigation. Further studies are expected to design and validate a BIM-based framework for circular construction, with a particular focus on material tracking, lifecycle assessment, and cross-platform data integration, thereby making both theoretical contributions and practical impacts in advancing digital circular construction.

CONCLUSIONS

This study systematically evaluates the application of BIM in the CCE, highlighting its role across four key dimensions: waste and material management, reuse and lifecycle, economic feasibility and business models, and sustainability and logistics networks. It also identifies several research gaps, including the lack of IoT integration, quantitative methods for recyclable materials, optimised data-sharing mechanisms, limited BIM adoption, and weak integration with construction supply chains. Key findings include:

There has been a steady increase in the volume of scholarly publications concerning the CCE domain.

The CCE field has formed a knowledge framework centred on "BIM," "sustainable development," and "circular economy", and has expanded in recent years towards "decision making," "construction supply chain," and "energy efficiency" and other directions. At the same time, it also suggests that issues such as "end of lives" still belong to research blind spots and are worth exploring in depth.

The development path of BIM and CCE research from lifecycle management to intelligent deconstruction and recycling indicates that future research will rely more on digital tools to achieve data-driven sustainable transformation of buildings.

The development path of BIM in circular building research, from common concepts in the construction industry to intelligent deconstruction, reflects the gradual concretisation and digitisation trend of BIM in realising circular economy and achieving sustainability.

This study offers meaningful implications for various stakeholders. For academic researchers, the research trends and thematic framework provide a systematic roadmap for future exploration. For practitioners in the construction industry, the identified trends—such as material tracking, deconstruction planning, and resource reuse—can inform the implementation of BIM-based sustainable practices. For policymakers, the highlighted gaps (e.g., end-of-life building management, BIM-IoT integration) can serve as strategic directions for digital transformation and green construction policies. Therefore, this study contributes not only to the theoretical understanding of BIM-CCE integration but also to actionable insights for promoting sustainable and circular practices in the built environment.

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