Integrating BIM into Built Asset Management: A Pathway to Achieve Social Sustainability

INTEGRATING BIM INTO BUILT ASSET MANAGEMENT: A PATHWAY TO ACHIEVE SOCIAL SUSTAINABILITY

Yujie Dong[1], Saeed Reza Mohandes, Richard Kirkham and Amir Rahbarimanesh

Department of Civil Engineering and Management, School of Engineering, Nancy Rothwell Building, The University of Manchester, Oxford Road, M13 9PL, Manchester, UK

Building Information Modelling (BIM) has emerged as a critical tool in the construction management industry's shift toward sustainability, enhancing sustainable practices in building asset management by focusing on environmental, economic, and social aspects. Despite BIM-based asset management makes a significant contribution to environmental and economic aspects of sustainability, BIM's role in promoting social sustainability which focuses on community well-being and equitable development in building asset management, remains underexplored. This study aims to investigate the application of BIM principles and methods in the context of social value and sustainability, conducting a systematic literature review of 253 papers from 2005 to 2024 to assess BIM's impact on the construction asset management sector. The findings highlight BIM's limited but growing contribution to social sustainability, identifying four key dimensions: health, safety and well-being; resilience and inclusivity; equity, accessibility, and user comfort; community needs and affordability. The bibliometric analysis and systematic review underscore the need for further research, mapping out existing gaps and suggesting future directions for BIM's potential to enhance social sustainability in asset management.

Keywords: asset management; Building Information Modelling; digital construction; sustainable development goal; social sustainability

INTRODUCTION

Building Information Modelling (BIM) is increasingly acknowledged as pivotal to the evolution of building projects, offering a data-rich platform that supports comprehensive sustainability solutions. BIM involves creating and managing digital representations of physical and functional characteristics of building assets, simplifying decision-making throughout the lifecycle and streamlining asset management (ISO19650, 2018). Effective building asset management aims to realise value from assets efficiently and effectively, a goal often hindered by traditional process inefficiencies (RIBA, 2020). Particularly, information and data on the sustainability of building assets are often underutilised (Santos *et al.,* 2019).

In contrast, BIM offers a pathway to enhance sustainable practices in asset management, particularly by enabling rapid data extraction and information, aligning

[1] yujie.dong@postgrad.manchester.ac.uk

Dong, Y, Mohandes, S R, Kirkham, R and Rahbarimanesh, A (2024) Integrating BIM into Built Asset Management: A Pathway to Achieve Social Sustainability *In:* Thomson, C and Neilson, C J (Eds) *Proceedings of the 40th Annual ARCOM Conference,* 2-4 September 2024, London, UK, Association of Researchers in Construction Management, 81-90.

with ISO **55000(**2014) asset management standards. This digital transformation emphasizes efficiency and effectiveness from development to disposal (Lin *et al.,* 2022). Integrating BIM into sustainable asset management represents a crucial step towards holistic sustainability in the construction industry. Although BIM has enhanced operational and maintenance efficiency (Almujibah, 2023) and promoted environmental sustainability through 'green BIM' practices (Wu *et al.,* 2023), its role in fostering social sustainability remains underdeveloped.

Social sustainability is defined as the ability of a society to develop processes and structures that not only meet the needs of the current population but also support future generations' ability to maintain a healthy community. This includes considerations of inclusivity, accessibility, affordability, community engagement, and overall well-being (Mohamed and Paleologos, 2021). While Dong *et al.,* (2024) presented a framework using BIM to integrate environmental, economic, and social factors, the focus remains on the environmental and economic dimensions. This oversight highlights the need for broader research into BIM's social sustainability applications. The potential of BIM to capture and utilise social data to enhance asset management has not been fully explored (Biancardo *et al.,* 2023), calling for increased research into stakeholder engagement and community needs within the BIM process (Salzano *et al.,* 2023; Olofsson Hallén *et al.,* 2023). By incorporating comprehensive asset information and data (Lin *et al.,* 2022), BIM could significantly contribute to achieving socially inclusive sustainable outcomes. This study aims to explore the underrepresented social dimension of BIM-based asset management, identifying gaps and proposing future research directions to enable a more inclusive and comprehensive approach to sustainability.

This paper conducted a systematic literature review of 253 journal papers from 2005 to 2024, utilising PRISMA and bibliometric analysis. This review discusses current research gaps and future research trends in four key areas of social sustainability in built assets: health, safety, and well-being; resilience, emergency management, and inclusivity; equity, accessibility, and user comfort; and community needs and affordability. The findings provide insights into how BIM can effectively support asset management for social sustainability.

The research questions of this review along with the corresponding objectives are elaborated on in the following lines:

1. What is the status of BIM in sustainable building asset management from a social standpoint? To respond to this question, this paper examines the use of BIM in sustainable building asset management from four social perspectives, by capturing publication trends, authorship statistics, and keyword co-occurrences using bibliometric analysis.
2. What is the state of BIM research across four social dimensions? To respond to this question, a content analysis was used.
3. What are the gaps existing in socially sustainable BIM-based asset management and the corresponding future works to be undertaken? To respond to this question, this study meticulously reviews all the identified papers, extracting research gaps and emerging trends for future exploration.

This comprehensive review employs a systematic literature review combined with bibliometric analysis to clarify how BIM supports asset management for social sustainability. This unique approach maps the current research landscape, identifies

key trends, and highlights significant gaps. It lays the groundwork for future research that adopts a more inclusive perspective on social sustainability in the built environment, making a distinctive contribution to understanding BIM's role in advancing social sustainable development.

METHOD

This study employed a systematic literature review (SLR) approach, complying with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring methodological rigor to synthesize information and address specific research queries (Murad, 2020). The research process involved collecting 253 pieces of literature through detailed search strategies and filtering processes as illustrated in the review framework shown in Figure 1, which includes literature collection, systematic review, bibliometric analysis, and in-depth discussion.

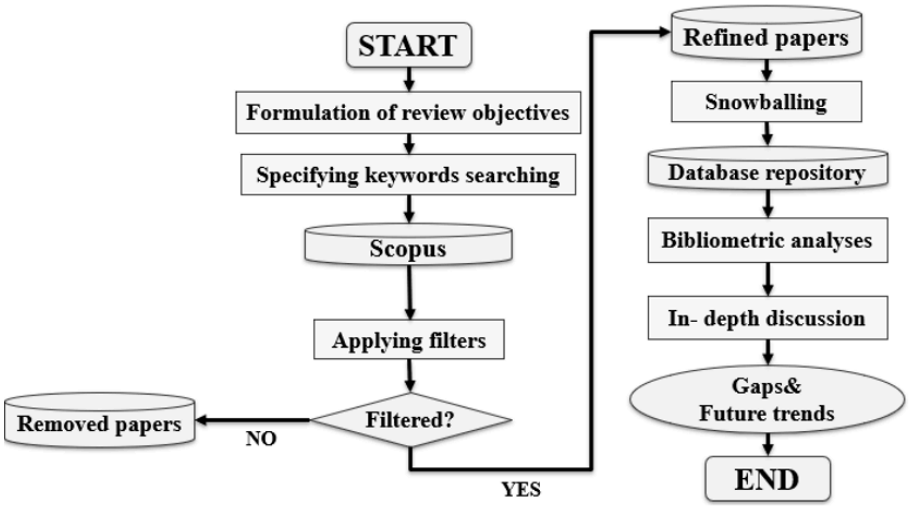

Figure 1: The review framework

Data collection for the literature

The Scopus database was selected for its extensive coverage and diverse range of literature (Falagas *et al.,* 2007). Three search strings were used (Table 1), with keywords informed by previous review papers and expert consultations. The review period spanned from 2005 to 2024 to capture the rapid developments in the field.

Table 1: The search string and keywords

"BIM" OR "building information modelling" OR "building information modelling"
AND
"social sustainability" OR "social sustainable" OR "sustainability" OR "sustainable"
AND
"asset management" OR "facility management" OR "asset" OR "facility"

The study also used snowballing to find relevant literature, checking references, related works in Scopus, and citations for relevance (Murad, 2020). Filters excluded non-English, non-journal, and off-topic papers, resulting in 253 relevant papers (Figure 2).

Bibliometric Analysis

After collecting the literature, a bibliometric analysis was performed. While social sustainability and BIM-based asset management have seen progress, research on their

intersection remains seldom, with a need for a clearer research trend. Bibliometric analysis helps to identify key authors, leading journals and emerging trends (Durán Sánchez *et al.,* 2016). For its ability to create intelligible visual representations, VOSviewer was the chosen software for this analysis.

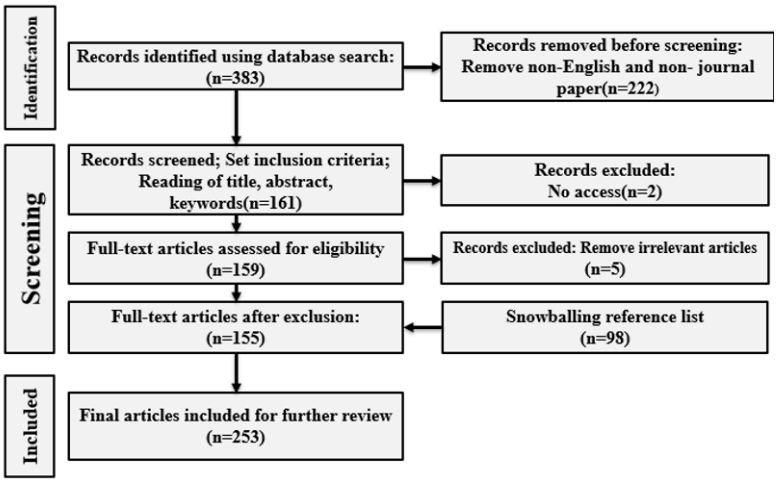

Figure 2: Full PRISMA process flow chart

FINDINGS AND DISCUSSION

This paper examines publication trends, journal contributions, co-authorship patterns, and keyword co-occurrences. Each of these is discussed in detail below.

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 3 shows the trend of publications in this field. The literature shows a growing trend in BIM-based asset management research over 20 years, with 253 papers analysed, indicating that research interest and outputs in this field are thriving. Initial research from 2008 to 2013 was sparse, focusing primarily on digitalising asset management rather than sustainability. Between 2013 and 2021, publications soared, reflecting advancements in technology and a push for sustainability, though still skewed towards environmental and economic factors. From 2021 to 2024, publication numbers levelled off as research began to probe deeper societal and community roles beyond technical aspects.

Author Statistics

Research trends in a field are often shaped by a few key experts, and analysing their publication patterns can reveal the current direction of study (Ellegaard and Wallin, 2015). The co-authorship network depicted in Figure 4 reveals a decentralised pattern of research collaboration, suggesting the need for greater joint effort to advance the field. As research matures, increased inter-organisational exchange and resource sharing will be vital for fostering integration and progress.

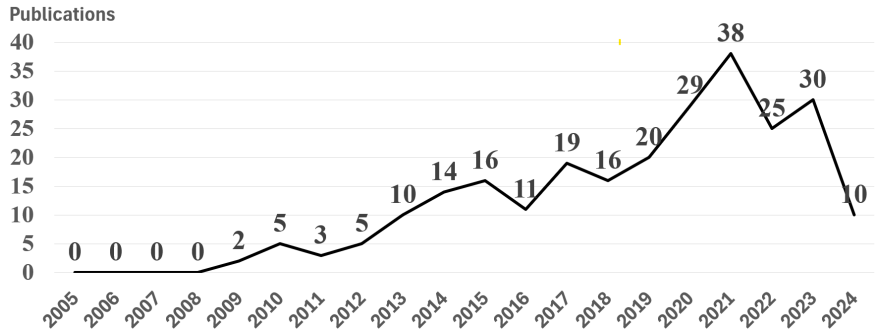

Figure 3: Distribution of published papers (2005−2024)

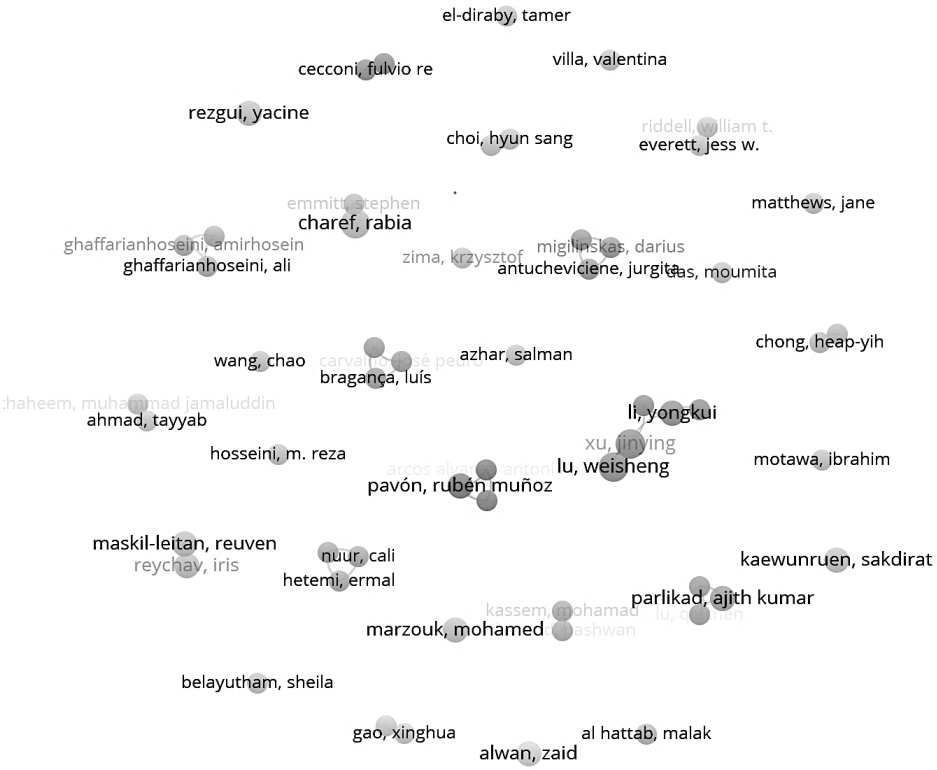

Figure 4: Collaborative relationship map of selected authors

Journal Statistics

Table 2 displays the leading journals in this review, with significant AEC industry impact, characterised by an average impact factor of 5.16 and an h-index of 83.50. "Automation in Construction" stands out for its high publication and citation numbers, signifying its central role in the field. Despite this, the overall publication quality and impact are uneven, suggesting the field's early development stage and the AEC industry's limited focus on social sustainability. Furthermore, the low citation rate for most papers points to a low influence of the current research.

Co-Occurrence Analysis of Keywords

Keywords reveal a research field's core interests (Moran, 2021). Using VOSviewer with a co-occurrence analysis of all keywords, from 773 keywords, 90 surpassed the minimum occurrence threshold of four. Figure 5 shows a network where keywords like 'building information modelling', 'asset management', 'facilities management', and 'sustainability' are most common, with 'sustainable buildings', 'social sustainability', 'circular economy', 'digital twin' and 'carbon neutral' also prominent.

Table 2: Breakdown of the leading journals

Source publication	Host country	Count	Percentage (%)	Impact factor	h-index
Automation in construction	Netherlands	30	11.9	10.3	157
Sustainability	Switzerland	27	10.7	3.9	136
Buildings	Switzerland	11	4.3	4.26	45
Journal of Building Engineering	Netherlands	10	4.0	7.25	72
Facilities	US	8	3.2	2.59	63
Built Environment Project and Asset Management	UK	6	2.4	2.63	28

The cluster in the upper right corner is centred around the social sustainability perspective, but it is not very dense, and related terms like 'stakeholder' and 'social collaboration' aren't strongly linked to it, indicating the research is in the early stages and ripe for growth.

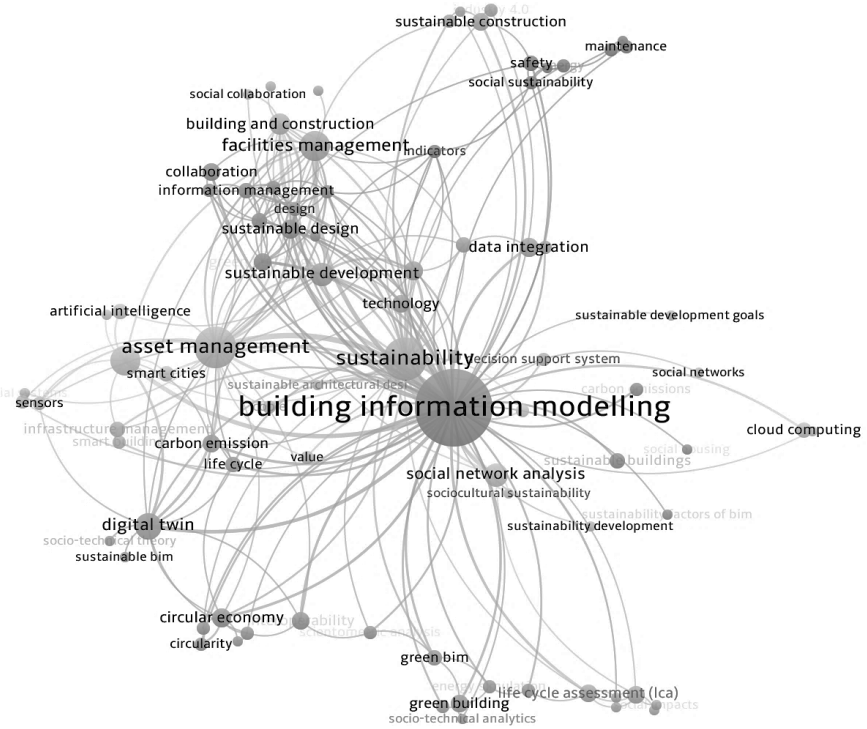

Figure 5: Keywords co-occurrence mapping

In addressing the research question, this paper extends beyond bibliometric analysis, performing a content analysis on the selected 253 papers. This section will outline the state of BIM research across four social dimensions—health, safety, and well-being; resilience, emergency management, and inclusivity; equity, accessibility, and user comfort; community needs and affordability—and will synthesize current gaps and future directions based on findings from the systematic review.

Health, Safety, and Well-being

Health, safety, and well-being are frequently studied topics within social sustainability. Figure 5's keyword co-occurrence highlights safety as a key element.

Early research focused on the use of BIM 4D modelling for safety analysis (Zhang and Hu, 2011). More recent research has evolved into the use of powerful BIM datasets and predictive capabilities for accident prevention, improving space allocation, predicting site risks, etc. (Trask and Linderoth, 2023; Sadhu *et al.,* 2023). However, BIM's role in overall well-being, including mental health, social well-being, and ergonomic design, requires further exploration. Integrating these metrics into BIM can create holistic environments that support both physical and mental health, promoting spaces that encourage social interaction and enhance community well-being, which are currently underrepresented.

Resilience, Emergency Management and Inclusivity

Research on asset resilience and emergency management has been catalyzed by global challenges, notably pandemics (Rockstrom *et al.,* 2023). Schönfelder *et al.,* (2024) have advanced emergency response capabilities within BIM frameworks by mapping fire safety equipment in building models. Ma and Wu (2020) have integrated user behaviour analytics into BIM to enhance dynamic emergency decision-making. Despite these technological strides, the unpredictability of emergencies and heavy reliance on sensor networks present ongoing challenges. Moreover, the inclusivity of emergency management remains insufficient, as current strategies frequently fail to fully consider the specific needs of vulnerable and marginalised groups, highlighting a critical area for further research and development.

Equity, Accessibility, and User Comfort

Keywords related to users and stakeholders appear frequently in Figure 5, but no distinct clusters. Despite frequent mentions of user-centric keywords, traditional BIM research has primarily focused on the needs of designers, clients, and contractors, often neglecting end-users (Santos *et al.,* 2019; Silva *et al.,* 2022). Recent initiatives, like the integration of Post Occupancy Evaluation (POE) by Gurevich *et al.,* (2017) and user interaction models by Olofsson Hallén *et al.,* (2023), demonstrate growing attention to user satisfaction and accessibility. These efforts are supplemented by incorporating universal design principles that address diverse needs, enhancing thermal, acoustic, and visual comfort to create more inclusive environments. This shift underscores the essential role of BIM in fostering spaces that are comfortable and accessible to all, including marginalised groups.

Community Needs and Affordability

Community needs and affordability remain pivotal yet underexplored in BIM research. Historical Building Information Modelling (HBIM) has progressed with initiatives like Cotella's (2023) use of laser scanning for non-intrusive management of historic buildings, enhancing preservation and community engagement. Vesho *et al.,* (2023) and Liu *et al.,* (2023) further illustrate BIM's role in virtual restoration, fostering community ties and resilience. But true participatory design remains limited. BIM must evolve to encompass broader community involvement and ensure affordability across housing and essential services, thus access to technology and fostering inclusive urban development. Enhancing BIM practices to meet these goals is crucial for achieving sustainable community's accessible goals.

Research Gaps and Future Trends

Research gaps and future trends identified from the bibliometric analysis and systematic review suggest several areas for development, as summarised in Table 3.

Table 3: Existing gaps and future trends

Dimension	Existing gaps	Future research to be undertaken
Health, Safety, and Well-being	Lack of comprehensive well-being integration in BIM systems.	Integrate broader well-being metrics into BIM.
	Inadequate protection of worker privacy.	Develop privacy-enhanced BIM applications.
Resilience, Emergency Management, and Inclusivity	Overlooking needs of vulnerable groups in emergency preparedness.	Integrate inclusive emergency management data. Improve reliability of historical data in BIM for emergencies.
Equity, Accessibility, and User Comfort	Gap between theoretical inclusivity and practical application.	Enhance user-centric design integration in BIM with direct feedback incorporation.
Community Needs and Affordability	Prohibitive costs of comprehensive modelling. Limited community engagement in BIM processes.	Explore cost-effective modelling strategies. Promote participatory design processes to enhance community involvement and affordability.

CONCLUSION

This study examined BIM in social sustainability, identifying significant gaps and future directions through systematic content analysis. Key findings include:

1. Emergence and Focus: Research on social sustainability within BIM is emerging, especially in developed regions, highlighting the need for global application and awareness.
2. Critical Dimensions: Four dimensions—health, safety and well-being; resilience and emergency management; equity and accessibility; and community needs and affordability—emphasize BIM's role in fostering inclusive and equitable environments.
3. Future Directions: Identified gaps include the need for better integration of comprehensive well-being metrics, inclusive emergency management strategies, user-centric design practices, and community-driven approaches. Addressing these gaps is essential for enhancing BIM's contribution to broader social sustainability goals.
4. BIM's Role in Sustainable Development: BIM not merely as a technological innovation but as an essential tool for sustainable development. By improving social sustainability aspects of asset management, BIM can contribute significantly to building environments that are not only efficient but also inclusive and supportive of community well-being.

This study illustrates that while BIM has made significant roles in environmental and economic domains, its potential in enhancing social sustainability warrants further exploration and adoption. Addressing the identified research gaps will be crucial in utilise BIM to meet global sustainability goals effectively.

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