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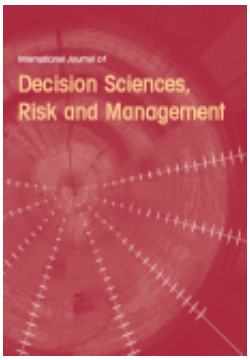

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Does integrated building information modelling support construction supply chains? A systematic review of theories, methods and actors

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Does integrated building information modelling support construction supply chains? A systematic review of theories, methods and actors

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Abstract: Building information modelling (BIM) and supply chain management (SCM) both aim to integrate data to enhance construction efficiency. While BIM holds transformative potential, current research mainly focuses on individual supply chain actors. This study aims to evaluate BIM/SCM literature, categorise research methods and theoretical lenses, identify insights for diverse supply chain actors, and propose future research directions. Through a systematic literature review (SLR), 56 relevant published studies were identified and analysed. Findings reveal that 17 studies explicitly used theoretical lenses. Most studies employed case studies and mixed methods, with a focus on individual actors. This suggests that BIM-supply chain research is still evolving, emphasising the need for further research to understand BIM adoption across the whole supply chain as one system. The study's originality lies in systematically analysing BIM-supply chain interfaces, providing a unique perspective on research methods, theoretical frameworks, and supply chain actors, which can guide future research.

Keywords: building information modelling; BIM; supply chain management; SCM; integration; systematic literature review; SLR.

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This paper is a revised and expanded version of a paper entitled 'Integrating building information modelling across the supply chain: a review of the literature and a research agenda' presented at the 2021 ISL Conference, online, 12–13 July 2021.

1 Introduction

Construction projects are typically complex, fragmented, risky, and challenging to manage (Fevranoglou and Diakaki, 2019). The supply chains for delivering construction projects come in various forms, involving a diverse range of actors (Loosemore, 2014). Multiple stakeholders often need to exchange a significant volume of information to meet client needs and maintain productivity and customer service standards (Wang et al., 2019; Ayinla and Adamu, 2018).

Sharing information within a construction project's diverse supply chain, however, presents various challenges. These challenges stem from both the quality of information

produced and its dissemination across various project stakeholders (Sepasgozar et al., 2016). Stakeholders are often reluctant to share information considered sensitive (Wang et al., 2017), prompting organisations to explore new approaches to address these issues (Saka and Chan, 2020). Scholars and experts propose information and communication technology (ICT) as a solution to enhance communication and boost productivity (Le et al., 2019).

One of the greatest advantages of implementing ICT into construction supply chains is that it allows different project participants to connect fragmented activities, share and manage information effectively, achieving integrated practices. Building information modelling (BIM) has inspired interest in this field and is acknowledged as an emerging collaborative technology. It facilitates and supports involved stakeholders to store vital information in one platform, which then can be easily accessed and shared among project actors. BIM can be defined as "a set of interacting policies, processes, and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life cycle" (Succar, 2009).

Acknowledging the benefits mentioned earlier of utilising BIM, governmental bodies worldwide are initiating efforts to implement strategic policies mandating the adoption of BIM in public construction projects. For example, since 2016, the UK Government has mandated BIM in all publicly procured projects, with the goal of enhancing the competitiveness of the construction industry. However, despite the best efforts by the UK Government and major engineering contractors to meet this objective, achieving full integration of the entire supply chain with BIM has proven challenging (Wang et al., 2017).

There has been a plethora of academic studies in disciplines such as engineering and architecture that examine BIM functionalities, applications, and associated technical, organisational, and legal issues (Volk et al., 2014; Azhar, 2011). However, much of this research focuses on BIM implementation by a single actor (Papadonikolaki et al., 2017; Wang et al., 2019). A significant research gap exists in understanding the supply chain implications on BIM in the construction sector, especially when considering the perspectives of different supply chain actors. Currently, there is no comprehensive literature review synthesising the existing body of knowledge on BIM implementation across the supply chain (Papadonikolaki et al., 2017). Hence, this study aims to conduct a SLR addressing the following research questions:

RQ1 What are the underlying theoretical lenses that underpin existing research addressing the role of BIM integration across the supply chain?

RQ2 What are the emergent methodological approaches exploited in such research?

RQ3 How could future research avoid myopic single-actor BIM implementation in the supply chain?

Theoretical lenses serve as valuable analytical tools to navigate the complexity inherent in BIM adoption within the construction supply chain (Egbunike et al., 2018; Seuring et al., 2021). These lenses offer distinct perspectives to explore the factors influencing BIM adoption, identify obstacles, and reveal opportunities for improvement. By investigating the theoretical frameworks used in previous studies, we can gain a more nuanced understanding of how BIM implementation plays out across different supply chain actors. This understanding will allow us to compare different research approaches,

identify potential gaps in the existing knowledge base, and inform future research directions that work towards successful BIM and supply chain integration.

To answer the research questions, we firstly categorise the journal-publication distribution and highlight the adopted research methods and theoretical lenses. Secondly, we identify insights, themes, and patterns from the literature for different construction supply chain actors. Finally, we propose directions for future research avenues to develop the integration of BIM across the supply chain.

The rest of this paper is structured as follows: Section 2 offers a literature background on SCM and BIM. Section 3 outlines the research methodology, including the keywords used, the article search procedure, and the inclusion/exclusion criteria for selecting reviewed articles. Section 4 analyses the findings, covering both descriptive and content aspects. Section 5 discusses the analysis and provides future research recommendations. Finally, Section 6 concludes the paper.

2 Background

SCM, a concept rooted in manufacturing innovations like just-in-time (JIT) and total quality management (TQM), emphasises strategic process integration across organisational boundaries for enhanced efficiency and competitiveness (Cooper et al., 1997; Christopher, 2016). Within the construction sector, these SCM principles have been adapted as construction supply chain management (CSCM). This field focuses on fostering collaborative relationships among diverse stakeholders (clients, designers, contractors, subcontractors, suppliers) to overcome the industry's inherent logistical and coordination complexities and achieve superior project outcomes (Vrijhoef and Koskela, 2000; Xue et al., 2007).

Furthermore, construction projects are plagued by fragmented supply chains where numerous actors with diverse capabilities contribute to the delivery process (Dubois and Gadde, 2002). This fragmentation, often worsened by extensive subcontracting practices, can significantly impede coordination and overall project success (Broft et al., 2016; Fellows and Liu, 2012).

Digital technologies address the challenges of fragmented communication and coordination within construction projects. Digital collaboration and communication tools streamline information sharing and task coordination (Ahuja et al., 2009). Another transformative technology is BIM, which promotes integrated practice through a centralised digital model (Jung and Joo, 2011). BIM's ability to facilitate real-time information exchange and establish a single source of accurate data is key to enhancing integrated practices. This integration extends across the supply chain network (Succar, 2009).

SCM aims to integrate processes across organisations to boost productivity (Flynn et al., 2010). This requires supply chain actors to collaborate and adopt a collective mindset (Awad and Nassar, 2010). Integration, a cornerstone of SCM, enhances process efficiency and effectiveness (Mentzer et al., 2001; Lambert et al., 1998). Flynn et al. (2010) emphasise the importance of both internal and external integration for collaboration and overall value creation.

The construction industry's fragmented nature hinders productivity, with various actors operating independently (Cagliano et al., 2006; Broft et al., 2016). Poor project

performance often stems from a lack of integration and inefficient communication channels among supply chain actors (Harsha et al., 2013). To tackle these challenges, modern digital technologies, notably BIM, play a crucial role in managing project data and fostering integrated supply chains (Wang et al., 2019). BIM centralises project data, streamlining information flow among stakeholders and enhancing project processes (Khosrowshahi and Arayici, 2012). Its digital data exchange capabilities improve information flow and bridge real-time information gaps in supply chains (Succar, 2009; Redmond et al., 2012).

SCM and BIM both emphasise integration and information sharing to enhance project performance (Papadonikolaki and Wamelink, 2017). SCM integrates project processes internally and externally, leveraging practices like inventory management based on BIM models and coordinated procurement schedules using BIM data (Le et al., 2022). Therefore, BIM acts as a facilitator for SCM principles by providing consistent information to various actors at the right time. However, successful integration of BIM with the supply chain requires effective communication and collaboration among project members (Wang et al., 2017).

The integration of BIM with SCM has vital importance. However, previous review studies have often concentrated on how construction organisations adopt BIM for different uses. For instance, Volk et al. (2014) explored key adoption factors for existing buildings, while Ahmed and Kassem (2018) examined factors influencing BIM adoption decisions. Studies by Abbasnejad et al. (2021) and Shehzad et al. (2022) focused on enablers and various factors associated with BIM adoption. A significant gap exists in understanding the adoption of BIM across supply chain actors as an integrated system. Therefore, this SLR aims to fill this gap, laying the groundwork for future research in the realm of BIM adoption across the supply chain.

3 Research method

This research applies a SLR, which is performed by following the approach proposed by Kitchenham et al., (2009). As discussed above, the goal of this study is to review the current available literature in relation to BIM adoption within the construction supply chain. SLR stands as one of the robust approaches that aim toward gaining in-depth knowledge about a particular topic and minimising bias through a transparent and systematic literature search (Jesson et al., 2011; Briner and Denyer, 2012). SLR is a well-defined approach for conducting a literature review and serves as an appropriate methodological technique to identify new research gaps, insights, and propose agendas for future research (Tranfield et al., 2003; Gough et al., 2017; Nelson and Campbell, 2017).

3.1 Database selection

In line with the studies of (Ahmed and Kassem, 2018; Abbasnejad et al., 2021; Shehzad et al., 2022) Scopus, EBSCO, ProQuest and Google Scholar research engines were used to search for relevant literature. Although these databases overlap somewhat, they are also complementary. These research databases are renowned as easily accessible and wide-ranging. The quality and quantity of the literature they contain is recognised to be sufficient and effective for the systematic review in the area of supply chain (Ali et al.,

2017), and are acknowledged by construction academicians and professionals (Lu et al., 2015).

These databases were chosen because they cover a wide range of business management and architecture, engineering, and construction (AEC) journals (Chen et al., 2022). This diverse collection ensures there are enough high-quality papers for a systematic review (Yevu and Yu, 2019). Additionally, they include a large number of abstracts and citations from well-known publishers such as Elsevier, John Wiley, Springer, Taylor & Francis, and Emerald Insight (Falagas et al., 2008; Aghaei-Chadegani et al., 2013).

3.2 Database search

Keyword searches were made through the selected databases to retrieve existing literature related to BIM adoption and supply chain integration. This includes the level 1 keywords: 'building information model*' OR 'BIM' AND 'supply chain' AND 'construction'.

Then, titles, keywords and abstracts of the relevant articles were screened and read to check their suitability for this research.

To comprehensively review the existing literature that focuses on 'supply chain actors' and related terms to 'supply chain integration' (as per Stevens, 1989), this study utilises level 2 keywords in conjunction with level 1 keywords to refine and narrow down the search criteria, facilitating the effective categorisation of relevant papers. They were applied to the level 1 keywords with the AND operator and consisted of sets:

1 keywords related to the main supply chain actors and project processes: 'project' OR 'client' OR 'contract*' OR 'subcontract*' OR 'procure*' OR 'design*'

2 keywords related to supply chain integration: 'integrati*' OR 'collaborat*' OR 'coordinat*' OR 'information sharing' OR 'relationship'.

It is important to note that, for the thoroughness of our BIM and SCM research dataset, we used the asterisk (*) symbol to capture various word combinations and drew reference from existing studies like Xue et al. (2007), Papadonikolaki et al. (2017), Wang et al. (2019), Dowsett and Harty (2019) and Oraee et al. (2022) to determine the selection of level 1 and 2 keywords.

3.3 Inclusion and exclusion criteria

To enhance transparency in the selection and collection process, we employed explicit criteria to assess relevant articles. Drawing from Gosling and Naim (2009), Nakamba et al. (2017), Yevu and Yu (2019) and Danese et al. (2020), the following criteria were considered and applied to refine the search:

- Only peer-reviewed scholarly journal articles were included: this criterion ensures that the selected studies have undergone rigorous scrutiny by experts in the field, guaranteeing a significant level of quality, reliability, and validity. The peer-review process helps filter out flawed research and promotes the dissemination of well-conducted, credible findings.
- Full-text articles published in scholarly journals were considered: by focusing on full-text articles, we gain access to the complete research narrative, including

detailed methodologies, results, and discussions. This allows for a thorough and nuanced understanding of the research conducted.

- Access to the full research articles was required: direct access to the complete text of each article is crucial for critical appraisal and in-depth analysis of the research methods, data, and conclusions.
- There was no restriction on the timeframe: by avoiding temporal constraints, we foster a comprehensive historical perspective and an understanding of how the research field has evolved. This enables the identification of key trends, shifts in focus, and potential gaps in existing knowledge.
- Books and conference papers were excluded from consideration: while valuable resources, books and conference papers may not always undergo the same level of rigorous peer-review as journal articles. Focusing on peer-reviewed articles maintains a consistent and verifiable standard of evidence for the review.
- Only articles written in English were included in the review: this aligns with the language proficiency of the research team and intended audience, ensuring accurate comprehension and analysis of the findings.

By adhering to these explicit criteria, we prioritise methodological rigour and transparency. This approach strengthens the credibility of our systematic review and contributes to building a robust foundation for subsequent research.

3.4 Study selection

The first stage of article selection involved extracting papers (identified using keywords across different databases) into an Excel spreadsheet. Details like title, year, journal, authors, objectives, theory, methodology, results, and conclusions were captured. Next, we implemented a multi-stage screening process with specific criteria to select pertinent articles and exclude those failing to meet our standards. The process of inclusion and exclusion (Figure 1) is as follows:

- Identification stage:

  Database search: selected databases were searched with level 1 keywords (‘building information model*’ OR ‘BIM’ AND ‘supply chain’ AND ‘construction’).

  Refinement with level 2 keywords: level 2 keywords focused on supply chain actors and integration were used in conjunction with level 1 keywords to narrow the search.

- Screening stage:

  Title screening: titles, keywords, and abstracts were evaluated for relevance. Titles clearly related to BIM adoption and supply chain integration were considered; unrelated topics and duplicates were excluded.

  Abstract screening: abstracts of articles passing title screening were examined for alignment with research objectives. Those discussing supply chain actors, project processes, and integration were retained; others were excluded.

  Full paper screening: the following inclusion criteria were applied to full papers: peer-reviewed scholarly journal articles, published in English, and providing full-text

access. Papers not meeting these criteria (e.g., conference papers, books) were excluded.

- Eligibility stage:

  Included: peer-reviewed scholarly journal articles published in English with full-text access.

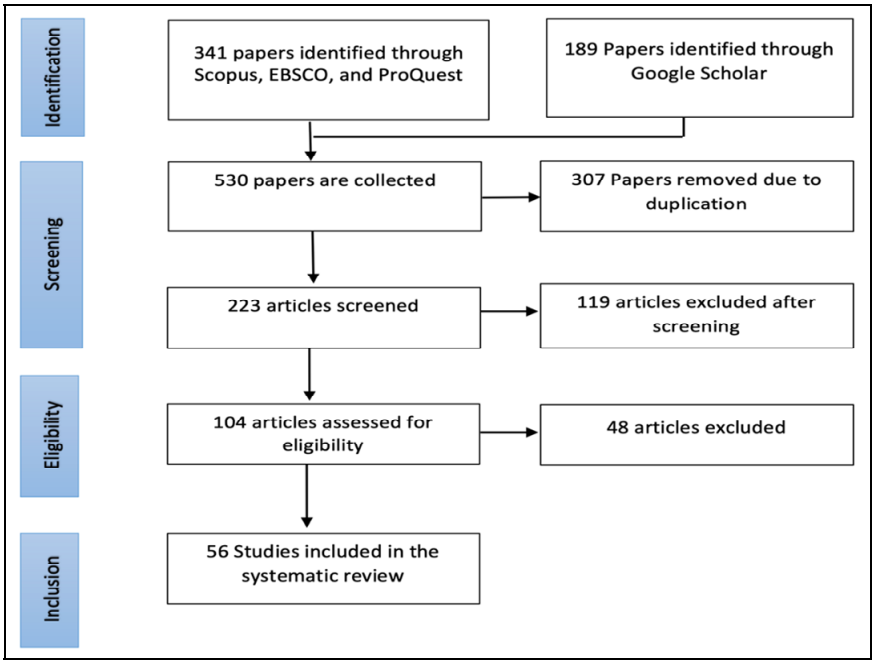
  Excluded: books and conference papers, articles not in English and no restrictions were placed on the timeframe to allow for a comprehensive perspective.

- Inclusion stage:

  Final selection: eligible articles were further evaluated (based on titles, abstracts, introductions, conclusions, and potentially full texts); to ensure direct relevance to the research objectives.

  This rigorous process, with well-defined exclusion criteria at each stage, ensured the selection of high-quality and highly relevant articles. This approach maintains transparency and enhances the credibility of the systematic review. This process ultimately identified 56 articles suitable for analysis.

Figure 1 Systematic review process (see online version for colours)



3.5 Analysis and synthesis

The findings for each selected article were analysed using both descriptive and content analysis. For descriptive analysis, information characterising each paper was captured

and recorded in an Excel spreadsheet, including bibliographic details, publication distribution across journals, and employed research methods and theoretical perspectives.

For content analysis, due to the extensive existing literature (Seuring and Gold, 2012; Badi and Murtagh, 2019), a priori coding system was defined to leverage existing knowledge as a foundation for testing or developing new models (Crabtree and Miller, 1999). The initial literature search served as a valuable knowledge base, facilitating the identification of potential taxonomies for BIM adoption across the supply chain.

Qualitative content analysis followed the approach of Chen et al. (2020), utilising a thematic coding system to identify emerging insights and themes for each supply chain actor in isolation. Emerging theme frequencies were then aggregated. The full text of all 56 identified papers was examined. Abstracts were tabulated to include study aims/objectives, methods, theoretical lenses, results, and conclusions.

To address myopic individual-actor BIM implementation (Papadonikolaki et al., 2017; Wang et al., 2019) and consider all supply chain actors, keywords were used for categorisation based on actor roles (client, main contractor, subcontractor, designer, project, IT provider, whole system).

4 Findings

4.1 Descriptive analysis

4.1.1 Journal distribution

The 56 research articles identified at the intersection of SCM and BIM were published in a variety of journals. The main publishers of these research streams are more technically oriented, focusing on issues related to construction management and SCM from an engineering perspective, rather than managerial considerations. The articles identified and selected relate to 17 journals, as illustrated in Table 1. The journals are classified and ranked according to the quantity of published articles, from most to least popular. It is worth noting that more articles are published in construction and engineering journals, whereas only a few are published in operations and SCM journals.

4.1.2 Distribution of theoretical lenses and research methods

Following the approach employed by Egbunike et al. (2018) for classifying and evaluating research focus and methods, an analysis of the theoretical perspectives and research methods adopted in the 56 selected papers is presented in Table 2. The analysis reveals that out of the 56 papers, only 17 explicitly make reference to a theoretical perspective. Consequently, the majority of the selected studies at the intersection of BIM and SCM appear to be a-theoretical. This observation may be attributed to the fact that the theoretical foundation in this research domain is still evolving and has not yet reached a level of maturity, and most of the research is intended to identify and solve practical issues that are associated with the implementation and diffusion of BIM and SCM.

The prevalence of a-theoretical approaches might not be surprising given that the area of study falls within the discipline of logistics and SCM, where practical challenges often take precedence. Furthermore, the analysis in Table 2 indicates that only five papers explicitly used the diffusion of innovation theory. This suggests a nascent trend in adopting innovation theory to comprehend the dynamics of BIM adoption in the SCM

context. While this marks a notable step towards introducing established theories into the BIM and SCM discourse, it also underscores the need for a more comprehensive theoretical foundation.

Table 1 Publication distribution amongst journals

Journal	*Number*
Engineering, Construction and Architectural Management	16
Architectural Engineering and Design Management	6
Construction Innovation	6
Construction Management and Economics	6
International Journal of Construction Management	6
Automation in Construction	3
Journal of Civil Engineering and Management	2
Journal of Construction Engineering and Management	2
Frontier in Engineering and Built Environment	1
Production Planning & Control	1
Smart and Sustainable Built Environment	1
Construction Economics and Building	1
Structural Survey	1
Building Research & Information	1
Renewable and Sustainable Energy Reviews	1
International Journal of Project Management	1
Leadership and Management in Engineering	1
Total	56

Among the various research methods employed, the case study approach emerges prominently, as evidenced by its utilisation in 17 papers. This prevalence can be attributed to its suitability for investigating the complex and multifaceted nature of construction projects, characterised by fragmentation and the involvement of diverse supply chain actors.

The inherent flexibility and depth of the case study method facilitate inductive exploration, allowing researchers to delve deeply into specific instances and extract rich insights. This approach is essential for understanding the nuanced role of public clients in driving industry change through BIM implementation, as demonstrated by Lindblad (2019). However, it is crucial to recognise that while the case study method enables rich contextual understanding, its reliance on individual cases may limit generalisability and theoretical grounding (Barratt et al., 2011).

In light of the prevailing trend within the field, where research often adopts an a-theoretical stance, prioritising empirical observations over theoretical frameworks, mixed methods research emerges as another prevalent methodology, featured in 16 papers. Mixed methods research combines quantitative and qualitative techniques, offering a multifaceted approach to data collection and analysis. This integration allows researchers to not only quantify trends and patterns but also to explore the underlying reasons and contexts behind them (Abowitz and Toole, 2010).

For example, Khosrowshahi and Arayici (2012) successfully employed mixed methods to identify challenges and offer strategies for BIM adoption in the UK construction industry. Their study integrated qualitative interviews to gather in-depth insights from industry practitioners with quantitative surveys to collect broader data on adoption rates and key issues. By triangulating data from multiple sources, they were able to construct a comprehensive picture of the challenges faced and strategies required for successful BIM implementation.

Table 2 Utilised research methods and adopted theoretical lenses

Theory \ *Method*	*Case study*	*Mixed method*	*Survey*	*Conceptual*	*Grounded theory*	*Semi-structured interview*	*Total*
A-theoretical	10	12	9	7		1	39
Diffusion of innovation	2		2		1		5
Social network theory		1					1
Institutional theory	1						1
Graph theory	1						1
Push model and grow model	1						1
Technology acceptance model			1				1
Absorptive capacity theory		1					1
DeLone and McLean model (information system theory)	1						1
Socio-technical theory		1					1
Technology adoption model			1				1
Unified theory of acceptance and use of technology		1					1
Actor-network theory	1						1
Entropy theory, set pair analysis and Markov chains			1				1
Total	17	16	14	7	1	1	56

Furthermore, surveys represent a commonly employed tool in the selected papers, featured in 14 studies. Surveys offer a structured means of collecting data from a large sample size, facilitating quantitative analysis and statistical inference. This focus on quantifiable trends is evident in the work of Liao and Teo (2017), who leveraged surveys to identify critical success factors for enhancing BIM implementation in building projects and investigate their interrelationships. However, while surveys provide breadth in data collection, they may lack the depth and context afforded by qualitative methods such as case studies (Kotzab, 2005). Researchers could enhance their understanding by carefully

balancing the use of surveys with other qualitative approaches, offering both a broad overview of factors and the detailed nuances of implementation (Kotzab, 2005).

Interestingly, the table also highlights that grounded theory and semi-structured interviews are the least adopted methods to obtain data. This presents an opportunity to explore and develop research utilising diverse methodological approaches.

4.2 Content analysis

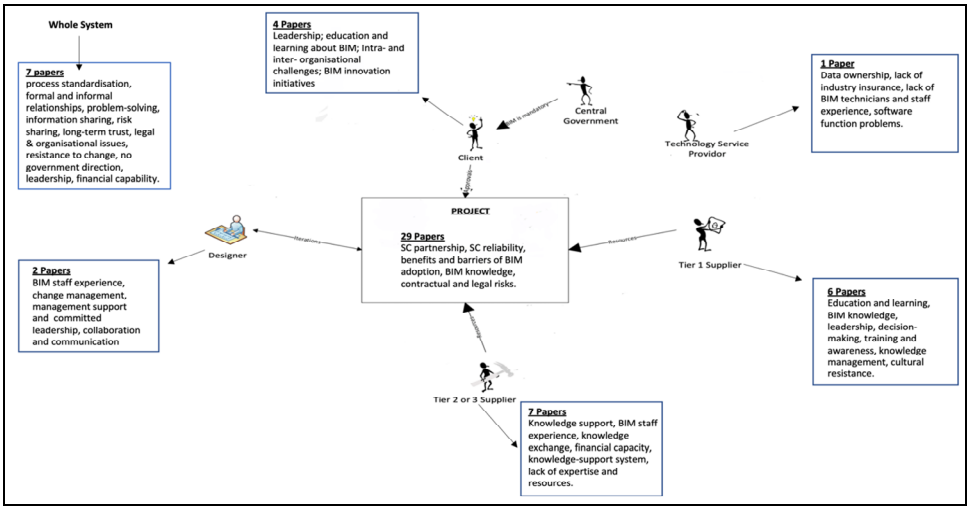
4.2.1 Insights from BIM literature across supply chain actors

The analysis shows that research on BIM applications has focused on individual actors within the construction supply chain, rather than examining it as an integrated system. Figure 2 illustrates the BIM literature, its application, and implementation across various supply chain participants. This prevailing approach overlooks the crucial holistic perspective of the entire supply chain as an interconnected system.

Consequently, the majority of BIM and SCM-related studies delve into the benefits, challenges, and factors enabling BIM implementation within construction projects. A significant portion, 29 papers, addresses these aspects. However, only a handful of studies consider the perspectives of other critical supply chain players. Notably, client, contractor, and subcontractor viewpoints are explored in just four, six, and seven papers, respectively.

While the current literature sheds light on factors influencing BIM adoption in construction projects, it lacks a substantial focus on strategic approaches. These approaches are crucial for determining each supply chain actor's capability to adopt BIM at a higher level and ensure the sustainability of such adoption. Addressing this gap in knowledge is essential for advancing BIM adoption and implementation to realising its full potential within the construction industry.

Figure 2 BIM/SCM literature across different actors (see online version for colours)



4.2.2 Emerging themes from the BIM/SCM literature

4.2.2.1 Knowledge sharing and management

Effective communication and sharing of knowledge play a significant role in lowering resistance to change behaviour and decreasing the risk and uncertainty related to adoption of novel systems, technologies and processes (Abbasnejad et al., 2021). Furthermore, knowledge sharing necessitates developing mechanisms for storage and retrieval of data to allow straightforward access to information that is used for problem solving and modifying strategic directions (Shi et al., 2022). The advancement of a BIM knowledge management programme enables the codification of employees learning experience, organise internal routines, circulating knowledge and building upon existing knowledge, manage multifaceted change activities and ultimately enhance dynamic capability of the organisation. In the absence of a knowledge management system, firms are limited in their ability to correctly capture and make use of acquired knowledge and experience (Ahmadian et al., 2017).

4.2.2.2 Organisational culture

BIM introduction can result in changes that may lead to resistance. This resistance can be avoided by effective communication which enables individuals to feel more engaged and confident with the implementation process and informed about critical aspects related to organisational practices, goals, and expectations (Khosrowshahi and Arayici, 2012). Ultimately, an organisational culture that encourages its members to be creative, promote transparency, and be open to change, while working on a foundation of shared goals and values, is most likely to overcome the barriers to BIM implementation (Hochscheid and Halin, 2019).

4.2.2.3 Management support and leadership

Top management's willingness and commitment to offer the required resources and their contribution in the process are vital. Top management is aimed to set goals, develop organisational structures, new roles and responsibilities alongside working in collaboration with BIM leaders to set up and supervise the successful application of BIM concepts and tools (Wang and Chong, 2015). Even though committed and supportive managers may use their authority to tackle a number of concerns and issues during the course of BIM implementation, the leading role in this process is not exclusive to top managers (Georgiadou, 2019).

4.2.2.4 Expertise and financial resources

BIM is fairly a novel concept in construction, and so one of the main significant obstacles that has been recognised to slow and hinder its implementation is lack of additional resources (Zhang et al., 2020). Likewise, the high level of expertise and BIM modelling skills required to work on BIM projects, adds on an additional cost for team's preparation and training. This has an impact on individual practitioners as well as the whole organisation. However, this also highlights the importance of raising awareness and the need for training and upskilling within the sector (Mahamadu et al., 2019).

Several researchers in this field contend that the increased cost and the need for additional financial resources for implementing BIM are major barriers in the construction industry. Nonetheless, Eadie et al. (2013) argue that BIM adoption nowadays depends on having the right expertise or training and responding to client demand. Additionally, the extra cost associated with training can be significantly reduced once a learning curve is well established within an organisation through experience in implementing BIM (Ahankoob et al., 2022; Demian and Walters, 2014).

5 Discussion and future research agenda

In the discussion section, Figure 3 visually summarises the core themes identified in the literature review. The figure clarifies the emphasis of existing BIM/SCM research and highlights potential research gaps, offering directions for future investigation. Additionally, a detailed discussion should provide a more rigorous and critical analysis of the main findings:

An analysis of journal publications reveals a prevailing focus on the technical aspects of BIM and supply chain topics across 56 articles in 17 journals. While this emphasis is understandable, it underscores a significant gap in our understanding of the under-researched human and behavioural factors that influence BIM implementation throughout the supply chain. For instance, areas such as change management strategies, actors' roles, and fostering collaborative mindsets within a BIM environment remain underexplored (Oraee et al., 2022). While technical aspects are undoubtedly crucial, comprehending and addressing these human and behavioural elements are equally essential for seamless BIM adoption and integration across the supply chain. Xu et al. (2022) argue that BIM adoption requires a human, organisational, and technological consideration that takes a holistic perspective, emphasising the interconnectedness of technical proficiency and human factors in successful implementation.

One notable exception is the work of Ibrahim et al. (2019), whose mixed-methods approach (questionnaires and interviews) delves into the often-neglected behavioural factors influencing information sharing within BIM projects. This study sheds light on the pivotal role of human interactions and underscores the potential for further exploration of the human dimension in facilitating successful BIM adoption. By examining how individual attitudes, communication dynamics, and trust impact information flows and project outcomes, their research paves the way for future endeavours dedicated to bridging the gap between technical proficiency and human factors.

The dominance of published research in architecture and engineering-oriented journals underscores a continued emphasis on technical features. This focus, while understandable, risks overlooking the crucial operational and supply chain management dimensions of successful BIM implementation (Shojaei and Burgess, 2022). Consistent with empirical evidence from the literature on ICT and CSCM (Tokar, 2010; Kakhki and Gargeya, 2019), a more comprehensive perspective requires broadening the scope of research. This presents a unique opportunity for journals to take a leadership role and set a new direction for BIM research. As the supply chain ecosystem in construction and its effects on BIM gain increasing popularity in practice, journals have the potential to drive advancements in our understanding. By actively encouraging and publishing research that

addresses supply chain implications within the context of BIM implementation, these journals can become pioneers for the field.

Another critical gap in BIM-supply chain research is the overreliance on a-theoretical approaches. While case studies remain valuable for in-depth exploration, this dominance hinders our ability to develop and test theory. Without a strong theoretical grounding, it becomes difficult to understand the complex interplay of factors influencing BIM/SCM integration and limits the generalisability of findings, reducing their applicability to broader contexts (Tsang, 2014).

To address these limitations and refine knowledge in this evolving field, future research needs to actively embrace diverse theoretical lenses from established disciplines such as supply chain management and information systems. Aligning research methods with established theoretical frameworks is crucial. For instance, leveraging diffusion of innovation (DOI) theory could offer valuable insights into the factors influencing BIM adoption across various actors within the supply chain. By analysing BIM adoption through the lens of DOI, researchers can identify the roles and behaviours of different actors during the adoption process, leading to a more nuanced understanding of diffusion across the supply chain system. This approach aligns with empirical findings that highlight DOI's focus on organisational-level innovation adoption and its consideration of contextual influences such as decision making and implementation phases (Hochscheid and Halin, 2019). Although research recognises the importance of identifying the factors that influence the adoption process (Matthews et al., 2018; Ahankoob et al., 2022), a lack of in-depth analysis remains regarding the roles and specific actions that actors could play.

Diverse methods, including mixed approaches grounded in flexible epistemologies, hold promise for capturing the multifaceted nature of BIM implementation. By integrating theory with methodology, researchers can unlock a more comprehensive understanding of cause-and-effect relationships, enhance generalisability (Abowitz and Toole, 2010), and ultimately contribute to a more robust body of knowledge in BIM-supply chain research. In the context of BIM, existing studies explore a full range of adoption levels – from individual and project levels to organisational, industry, and market levels (Kassem and Ahmed, 2022) – highlighting the importance of understanding BIM adoption dynamics at inter-organisational or supply chain level to develop effective implementation and integration strategies across the supply chain network.

Similarly, socio-technical theory (STT) could illuminate the crucial interplay between the social and technical aspects of BIM/SCM integration. STT emphasises the need to consider not just the technology itself (BIM), but also the organisational structures, workflows, and human behaviours that interact with it. This aligns with empirical evidence (Eadie et al., 2014; Rizzuto and Reeves, 2007), which highlights social barriers within the BIM socio-technical system as significant obstacles to widespread adoption. Research and practice should prioritise addressing social barriers over technical ones.

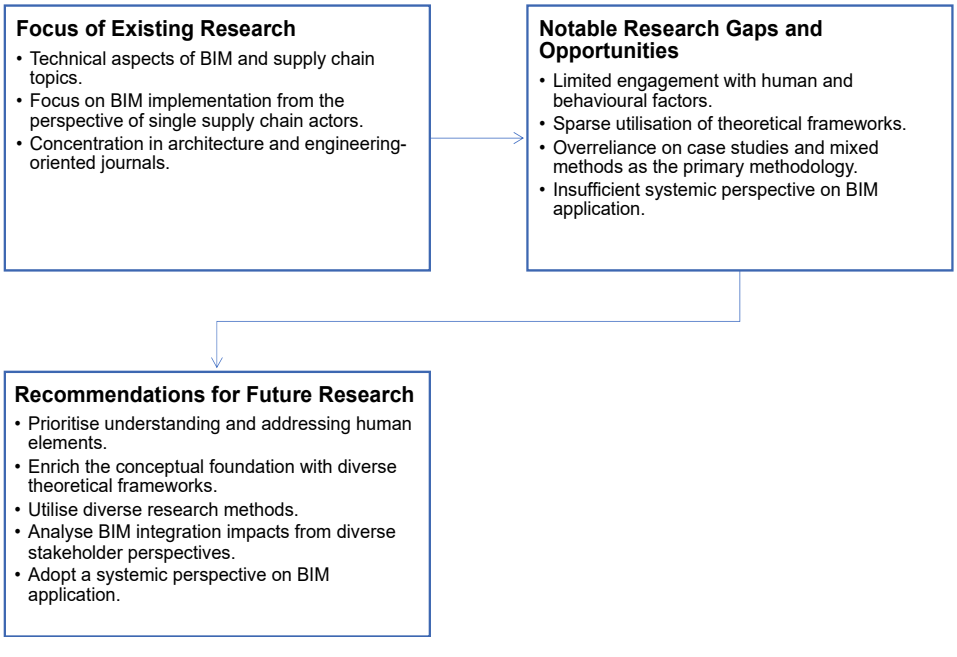
Additionally, the analysis of existing literature reveals a significant gap in our understanding of how BIM impacts stakeholders across the entire construction supply chain system. While the technical aspects of BIM implementation are often emphasised, there is a critical need to investigate the diverse effects and implications for various supply chain actors. Examining these impacts from multiple perspectives will shed light on unique challenges and opportunities faced by each stakeholder group, and crucially, how they can work collaboratively to overcome them (Wang et al., 2017; Shojaei and Burgess, 2022).

A systemic perspective on BIM application across the whole supply chain is needed to unveil critical interconnections and potential challenges. This holistic view fosters collaborative approaches, supporting a comprehensive understanding of BIM's impact on adoption processes and driving increased uptake. To ensure successful BIM implementation, collaboration on education, training, knowledge transfer, financial capabilities, and expertise is essential.

For example, while clients may benefit from improved project coordination and reduced costs, they play a vital role in driving BIM adoption by setting clear expectations and requirements from the outset (Lindblad, 2019). Additionally, clients can support the entire supply chain by providing access to training resources and mandating BIM use in contracts (Lindblad, 2019). This creates the motivation for contractors to adapt workflows and invest in necessary software upgrades (Ahankoob et al., 2018). Similarly, subcontractors might have trouble with sharing data and making software work together due to a lack of expertise and resources. In these situations, contractors and clients can help by making sure the software they use works well together, setting up ways to share information easily, and providing relevant training on data handling (Lindblad, 2019).

Understanding actor-specific challenges and opportunities is crucial for maximising the benefits of BIM/SCM integration and mitigating potential risks. Research and practice should collaborate to develop targeted strategies that address the diverse needs and capabilities of different supply chain actors. These strategies might include tailored training and education programmes designed for the specific roles and varying levels of BIM knowledge across the supply chain.

Figure 3 Summary of reviewed papers on BIM/SCM integration (see online version for colours)



Current research highlights the need for BIM-related training (Ahankoob et al., 2022; Demian and Walters, 2014). However, there is a gap in understanding how to effectively

train employees, particularly when considering actors with varied capabilities across the supply chain. This lack of practical guidance extends to other crucial aspects of BIM adoption, such as fostering collaborative processes and stakeholder coordination (Oraee et al., 2022). While studies acknowledge the importance of collaboration and strong relationships (Matthews et al., 2018; Ahankoob et al., 2022), they often lack in-depth analysis of how to develop these skills across the diverse network of supply chain actors.

By addressing these knowledge gaps, targeted initiatives can enhance BIM adoption throughout the supply chain. These strategies can foster a collaborative environment built on mutual support and a shared understanding of BIM's benefits and challenges.

6 Conclusions

Given the need and the strategic significance of integrating BIM across the construction supply chain, this study aimed at exploring the relevant body of knowledge that addresses the integration of BIM with supply chain and identifying the themes that emerge from the relevant literature. To achieve the aim of the study, a systematic literature review was conducted to synthesise the current literature, and was guided by three research questions, namely:

RQ1 What are the underlying theoretical lenses that underpin existing research that address the role of BIM integration across the supply chain?

RQ2 What are the emergent methodological approaches exploited in such research?

RQ3 How could future research avoid myopic single-actor BIM implementation in the supply chain?

In response to RQ1, the analysis reveals a notable absence of theory in most reviewed studies. This can be linked to two closely connected factors: the early stages of both BIM and SCM research, resulting in a focus on addressing practical challenges rather than establishing theoretical frameworks, and the emphasis on applied research prioritising real-world implementation over purely theoretical exploration. As for RQ2, the findings indicate the prevalent use of case study and mixed methods in existing SCM and BIM research. This choice may stem from the case study method's ability to facilitate in-depth, multifaceted explorations of complex issues in real-life settings and the flexible approach offered by mixed methods based on epistemological positions such as pragmatism. In answering RQ3, it is clear that most attention is on individual actors, neglecting the broader view of the supply chain as an interlinked system. This highlights the need for further research that explores the application of BIM from a supply chain perspective.

Potential avenues for future studies may include:

1 employing diverse research methods, this could involve a combination of quantitative, qualitative, and mixed methods approaches to capture various aspects of the impact of BIM on the supply chain

2 drawing on various theoretical frameworks, this can be achieved by integrating relevant theories from both information systems and SCM may possibly offer deeper insights and a more comprehensive understanding

3 targeting logistics/SCM journals for publication to ensure findings reach a wider audience within the relevant field.

Embracing these strategies can help future research move beyond the narrow focus on single-actor BIM implementation and delve into its potential within the integrated, systemic context of the supply chain.

This study makes a significant contribution by presenting the first systematic review at the interface of BIM/SCM, and this can guide future research in the area. The findings offer valuable insights for practitioners, urging them to adopt a more holistic view of BIM. By recognising its potential to optimise and integrate workflows across the whole supply chain, practitioners can move beyond individual-actor perspectives and unlock the full potential of BIM.

This study presents valuable insights; however, limitations exist. Notably, the early stage of BIM and SCM research, prioritising practical applications, has led to a lack of theoretical frameworks in most studies. Additionally, the predominant use of case studies and mixed methods limits generalisability. Furthermore, the singular focus on individual actors overlooks the broader supply chain system. Future research could utilise diverse methods, incorporate various theories, and target logistics/SCM journals to broaden its impact. Addressing these limitations will deepen our understanding of BIM's implications for the supply chain, providing a stronger foundation for future research.

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