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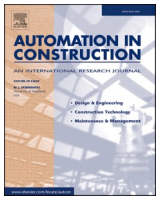

Review

Comprehensive analysis of BIM adoption: From narrow focus to holistic understanding

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ABSTRACT

Despite ongoing research in Architectural, Engineering, Construction and Operations (AECO), little is understood about BIM's interaction with its adoption process. This paper conducts a comprehensive scoping review that utilises secondary data to systematically map the existing literature on the adoption of BIM within AECO organisations. A literature review identified 146 papers on BIM in AECO organisations, categorising them into 46 on pre-adoption, 85 on post-adoption, and 15 on both phases. Findings reveal a tendency towards a 'tunnel vision', isolating a single organisational aspect or adoption phase. However, the study finds that BIM significantly interacts with various organisational elements, such as environment, power dynamics, social structure, and culture, necessitating comprehensive changes and strategies both before and after adoption. Advocating for a holistic approach, the study emphasises integrating change management, continuous learning, and ongoing improvement in BIM implementation. This perspective is a significant contribution to understanding BIM's multifaceted impact in AECO organisations.

1. Introduction

AECO organisations must adopt BIM in order to increase productivity, improve costs and reduce time overrun in projects [1]. Realising BIM's inherent benefits, governments worldwide have mandated BIM adoption, and so consequently, the global BIM market is projected to reach US$22.1 Billion by 2030, with a compound annual growth rate (CAGR) of 16.3% [2]. However, despite the imperative of BIM adoption, AECO organisations exhibit ambivalence regarding the benefits of BIM [3–5]. Moreover, small-to-medium enterprises (SMEs) continue to lag in BIM adoption [6–8]. Consequently, the degree and level of BIM adoption, and BIM-enabled information-sharing capabilities vary across different types and sizes of organisations. The result is an inconsistency in achieving BIM-based performance gain [9,10].

Succar and Kassem [9] assert that organisations attain BIM readiness and reach the point of adoption (PoA) only after adopting the technology. They delineate a readiness phase, an adoption phase, and a PoA phase. Other studies also report BIM's interaction with organisations during the BIM adoption process. Papadonikolaki, et al. [11] note that organisations adjust inter-organisational level documentation in order to facilitate the adoption of BIM, indicating its interaction with organisations at the inter-organisational level. Similarly, Olatunji [12] show that organisations adjust their organisational structure to facilitate BIM. While this is one of several studies reporting this phenomenon [13–16], a holistic understanding of BIM's interaction with organisations across the adoption process remains lacking. In essence, existing review studies on BIM adoption within AECO organisations have hitherto failed to investigate BIM's interaction with AECO organisations, and rather focus on specific issues. For instance, Abbasnejad, et al. [17] identify a list of enablers that promote BIM adoption. While the identification of enablers is important, the authors [ibid] did not go on to provide any insights on BIM's interaction with AECO organisations per se.

It stands to reason that despite the contributions of existing review studies, BIM's interactions with AECO organisations in the BIM adoption process remain unclear. Without an understanding of how BIM interacts within organisations unintended consequences impacting the adoption process will result. As evidence, Matthews, et al. [18] observed resistance to BIM adoption and recorded that when confronted with change, project teams revert to their previous (and well-established) *modus operandi*. This confirms that unintended consequences are indeed

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emerging in the BIM adoption process. Hence, there is a pressing need for a deeper understanding of how BIM interacts with AECO organisations throughout the adoption process. This comprehension is crucial for mitigating unintended consequences and optimising the extraction of tangible benefits from BIM.

Snyder [19] and Roberts, et al. [20] state that reviewing and synthesising existing literature provides an opportunity to uncover under-researched areas and promote theory building. Existing literature does not provide a holistic understanding of AECO organisations' BIM adoption process, nor yet how BIM interacts with organisations in that process. Therefore, the present study conducts a systematic scoping review of AECO organisations' BIM adoption literature, to map BIM's interaction with AECO organisations in the BIM adoption process. Interaction in this context refers to any scenario where organisations (or part thereof) influence BIM, and vice versa.

To contextualise this study, the following research question was formulated viz. *What is known from the literature about BIM's interaction with AECO organisations in the BIM adoption process?* Given the broad nature of the research question, a scoping review is deemed more appropriate than a systematic literature review. This approach facilitates the mapping of BIM adoption literature within AECO organisations, providing a comprehensive understanding of BIM's interaction with these organisations and highlighting potential knowledge gaps.

Based on organisational theory and technology adoption knowledge domains, this study formulated a framework for the scoping review. By using the framework, the perception of the adoption process of technology and understanding of technology's interaction with organisations can be clarified. The study first discusses the theoretical positioning of technology adoption within organisations and explores the adoption process of BIM within AECO organisation literature. Second, a scoping review based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews (PRISMA-ScR) is undertaken to map the existing literature's breadth, with a view to answering the formulated question via descriptive statistics analysis and qualitative content analysis. Third and finally, by identifying knowledge gaps, the research points the way forward for future studies.

2. Adoption of BIM technology within AECO organisations

As a technological innovation, BIM is a platform that AECO organisations use for planning, designing, constructing and managing projects in object-based information-embedded parametric 3D models [21]; it enables AECO organisations to execute projects by taking informed decisions, accessing all project information, and facilitating better coordination, collaboration and communication among project teams – thus, improving productivity and efficiency [22]. Moreover, AECO organisations' adoption of BIM results in cost reductions, time savings and improved coordination and communication [23]. For example, Poirier, et al. [24], in examining 35 construction projects, record a 75%–240% increase in labour productivity due to BIM adoption.

Succar and Kassem [9], define BIM adoption as the decision and utilisation of BIM, and this definition is used here. Therefore, the present study also considers the pre-PoA phase, where organisations formulate the final decision to achieve readiness for BIM adoption. The readiness phase is the same as the phase Rogers [25] denoted as the decision-making phase in the innovation adoption process. Following PoA phase, the present study also considers the organisations implementation of BIM in order to leverage capability and maturity of this technology [9].

2.1. Technology adoption theories and BIM

Technology adoption theories, such as the technology acceptance model (TAM) and unified theory of acceptance and use of technology (UTAUT) theory, focus on the individual-level technology adoption [26]. By contrast, diffusion of innovation theory (DIT) [25] and technology–organisation–environment (TOE) framework [27] focus on the organisational-level adoption of innovation. Individual-level models discuss factors influencing individuals' behaviour towards the use of new technology [26]. While, organisational-level models discuss the influence of contexts in the adoption process [27] and different phases of adoption, such as the decision-making and implementation phases [25]. With regards to BIM, existing studies explore the full range of individual, project, organisation, industry, and market level adoption of BIM [9].

In the two-phase adoption process, BIM technology interacts with individuals and organisations, which together shape practices [28–30]. Orlikowski [31] used the structuration theory of technology to argue that human actors (technology developers, users), institutional properties (government, professional body, unions), as well as organisations, all both influence and are influenced by technology usage. Orlikowski and Gash [32] concluded that users shape the technology via their perception of it and resultant associated sense-making. In the case of BIM, Linderoth [33] emphasised clarifying the framing of technology and how users make sense of BIM in order to enable BIM adoption. According to the structuration theory of technology — in practice — users shape and construct the use of technology in different ways (technology in use) rather than its prescribed use (technology as an artefact) [31]. This indicates that technology and its materiality (norms, rules, standards, and documents) interact with users, organisations, and institutions. If this is true, then any innovative technology will interact with organisations and individuals, and the use of technology will itself evolve in the process of technology adoption. The dynamic evolutionary trajectory will inevitably generate unintended consequences. Indeed, Rogers [25] acknowledged the presence of unintended consequences, pointing out that social systems influence the technology adoption process.

Additionally, Latour [34] used Actor-Network Theory (ANT) to show that actors and networks in which the technology is utilised influence its use and vice versa. However, Rogers [25] did not consider technology's influence on adoption. Hence, understanding technology and the social system's interaction with technology is essential, because it shapes the course of the technology adoption process. For this present study, BIM's interaction with organisations indicates any situation where BIM, together with the materiality of BIM (rules, standards and/or norms), influence organisations, individuals or institutions, and vice versa.

2.2. BIM's interaction with AECO organisations

Existing review studies have considered BIM adoption within AECO organisations for varied applications [17,35]. Table 1 presents a review of existing studies of BIM adoption within AECO organisations. For instance, Abbasnejad, et al. [17] explored pre-PoA adoption phases and identified enablers of BIM adoption. Most review studies, however, do not explore BIM's interaction with AECO organisations and instead focus on identifying enablers to adoption [17], or create a unified taxonomy of drivers of BIM adoption [35].

As seen in Table 1, Faisal Shehzad, et al. [38] used innovation diffusion theory (IDT) to explore BIM adoption, identifying individual, organisational, technological and environmental factors. These factors were discussed merely in the initial three phases of the adoption process. Consequently, an overall gap exists in understanding organisations' interaction with BIM in the adoption process.

2.2.1. Framework of BIM's interaction with AECO organisations

In the effort to understand technology's interaction with organisations, the present study develops a hybrid and novel conceptual framework by combining the PoA model developed by Succar and Kassem [9], structuration theory as discussed by Orlikowski [31], and IDT as elucidated by Rogers [25]. As indicated in Fig. 1, IDT and the PoA model have been combined to better represent the BIM adoption phase. According to the framework, organisations proceed through two major adoption phases viz.; *phase 1*: the decision-making and readiness phase

Table 1
Studies on BIM adoption within AECO organisations.

Reference	Review method	Organisational perspective	PoA
Abbasnejad, et al. [17]	Systematic literature review (SLR)	The study identifies key enablers in the BIM adoption and implementation process. It explores factors such as strategic initiatives, cultural readiness, learning capacity, knowledge capability, leveraging IT, network relationships, process management, change management, and performance management.	Before PoA
Saka and Chan [36]	SLR	The study investigates the challenges, drivers, and benefits associated with BIM adoption for SMEs. It draws insights from existing literature, exploring the internal and external environmental characteristics of SMEs and key BIM attributes. Additionally, the study delves into the characteristics of the initial BIM adoption phase for SMEs.	Considered before the PoA phase
Ahmed and Kassem [35]	SLR	This review paper has constructed a comprehensive BIM adoption taxonomy, organising drivers into three clusters: characteristics of BIM, external environment characteristics, and internal environment characteristics. The study categorises factors and their determinants and delves into the factors influencing the decision-making phase of BIM adoption. The primary objective is to gain insights into how these factors impact the initial stages of the adoption process.	Considered before the PoA phase.
Ullah, et al. [37]	SLR	This study investigates the BIM adoption process for public authorities, specifically focusing on the building permit process. It delves into the various stages of BIM adoption, including initiation, planning, execution, and evaluation. The examination identifies factors that influence the BIM adoption process, drawing insights from technological, organisational, and environmental perspectives.	Considered before and after PoA
Faisal Shehzad, et al. [38]	SLR	The review primarily focused on extracting information regarding the theories commonly used to comprehend BIM adoption. It categorised the various constructs and factors into dependent and independent categories.	The consideration of the PoA has not been clarified.
Makabate, et al. [39]	Scientometric analysis	The review study delved into existing literature with a specific focus on SMEs' BIM adoption. It identified that the adoption of BIM by SMEs is a less-explored area in the research sector.	Not clear
He, et al. [40]	Scientometric analysis	Propose five key research areas for the future, encompassing organisational stakeholders and people, the adoption process, conceptual frameworks, work environments, and application approaches. Emphasise aligning organisational strategies with the complexities of the project environment.	Not clear

(before PoA); and *phase 2*: the implementation phase (after PoA). These are indicated by the yellow arrow, yellow box and blue arrow in Fig. 1.

The present study considers organisations as a socio-technical systems, and this lens is underpinned by the conceptual framework of organisational theory produced by Hatch and Cunliffe [41] (refer to Fig. 1 and Table 2). They utilise the framework to discuss organisational theories, notwithstanding that the framework is not a theory per se. Instead, it constitutes an umbrella concept capturing all aspects — of organisations — that organisational theories consider. A justification for utilising the framework is premised upon the fact that it presents a broader understanding of organisations, whereas any specific organisational theory tends to target a specific part of organisations. Hence, Fig. 1 indicates the organisation's environment, power, social structure, culture, and technology, while Table 2 explains the components of the framework (refer to Table 2).

In Fig. 1, the layer of rectangles represents the different ways in which AECO organisations can utilise BIM to pursue set objectives. Considering the structuration theory of technology, in these two phases of the adoption process, technology and materiality of technology have been shown as a yellow circle, in Fig. 1. In addition, BIM technology's interaction with organisations' environment, power, culture, social structure, and vice versa, have also been represented as dotted lines. Institutions and governments all fall into the organisations' environmental domain.

The framework in Fig. 1 is used to execute the scoping review on the existing BIM adoption within AECO organisations' literature. The framework is appropriate because it will facilitate understanding of the interaction of BIM with organisations in the adoption process. Based on the framework, the study will categorise the existing literature as pre-PoA and post-PoA. Moreover, this study will organise the literature based on topic of exploration in regard to BIM's interaction with organisations. For instance, studies examining BIM and organisations' environments are categorised in the BIM's interaction with organisational environment section.

3. Research methods and design

A scoping review based on PRISMA-ScR was conducted (see PRISMA [44] for details). Due to the broad nature of the research question, a scoping review is considered more appropriate than the conventional systematic literature review [45]. A scoping review assists in understanding the breadth of the available literatures [46] and, in case of the present study realising BIM's interaction with AECO organisations. In addition, scoping reviews assist in identifying the research gaps in the literature [45,46]. Studies investigating BIM adoption within AECO organisational settings were selected for the review. A PRISMA-ScR checklist was formulated [44] containing 22 reporting items in various sections of the review. Appendix A contains the list of reporting items considered in this study. Table 3 lists the search string and eligibility criteria sourced from initial manual reviews to identify relevant key words, such as adoption, implementation, and diffusion. In formulating the eligibility criteria, the publication year includes all available years, and any journal article considering BIM adoption within AECO organisations was considered. The study omitted grey literature, conference papers and book chapters; and thus the study's results thus has limitations in terms of literature scope [47].

Searching two databases, Web of Science (WoS) and Scopus on 08.09.2022 with the keywords (Table 3) resulted in 1236 articles (WoS) and 3012 articles (Scopus). Later, in the database the search results were limited using the provided filtration options, such as, language, study area, document type. Table 3 reflects the filtered search string which resulted in 796 articles (WoS) and 933 articles (Scopus). After filtering the results, all the records were exported in the reference management software, Endnote. In Endnote, combining the record lists resulted in a total of 1729 articles. A total of 589 duplicate files were identified through the automated duplication removal function and manual screening. In the identification stage (refer to Fig. 2), 1140 articles were identified to further consider for the screening stage. In the screening stage, 33 review articles were first removed as the study's aim did not focus on reviewing the existing review studies, following the recommendations by Oraee, et al. [48].

1107 articles were initially considered in the title and abstract screening. However, some, 469 articles were subsequently removed for two reasons. Eliminated works were either: 1) focused on the specific application of BIM, incorporating BIM with sustainability, lean management, historic BIM; or 2) were primarily concerned with country-

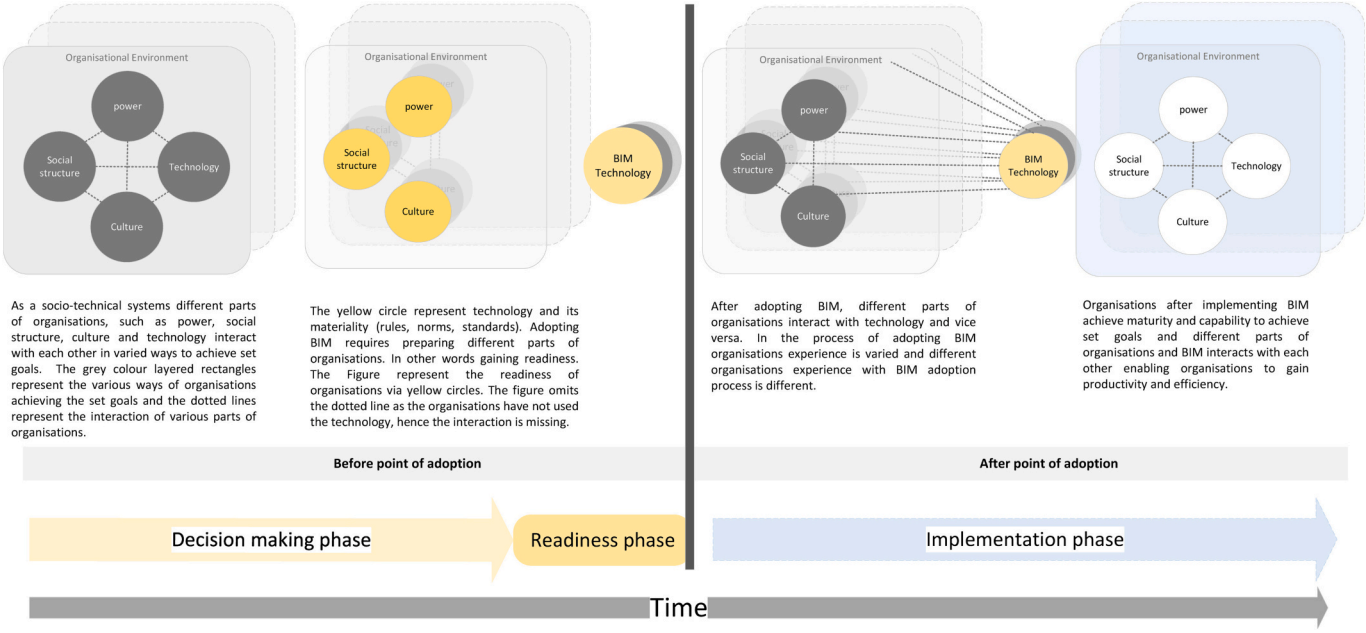


Fig. 1. Framework incorporating socio-technical perspective, structuration theory of technology, diffusion of innovation and Hatch and Cunliffe [41] framework.

level BIM adoption or project-level BIM application. This process was undertaken in Endnote utilising the labelling options. Appendix B indicates the grouping of the studies of similar topic in Endnote. The remaining 206 papers were exported to Excel and considered for full screening in the eligibility stage. Here, 4 further studies were removed as full text were not retrieved. Out of 202 studies, 34 studies were removed for not considering BIM or AECO organisations. In addition, 22 articles focusing on the benefits, challenges and enablers of BIM adoption were excluded as these papers did not align with the research question. The final sample constituted 146 articles for subsequent analysis.

3.1. Data charting and analysis

Descriptive statistical analysis and qualitative content analysis techniques were used. According to Arksey and O'Malley [46], the descriptive analytical method of scoping review aims to collect standard information on each research study to understand the existing literature discourse broadly. Standard information indicates information on authors, year of publication and deployed methodology [46]. Descriptive analysis is essential because it reveals the general characteristics of existing BIM adoption within AECO organisational literature.

3.1.1. Descriptive statistics analysis and content analysis

For descriptive statistics analysis of BIM adoption within AECO organisational literature, the following information was sought viz.: information on authors, year of publication, consideration of BIM adoption phase or PoA, study location, employed methodology, level of data source, types of cases and utilised theories. Table 4 presents an

Table 2
Description of Hatch and Cunliffe [41] framework components and AECO organisations' perspective (adapted from Trice and Beyer [42] and Tannenbaum [43]).

Framework component	Definition	Inclusion	AECO organisations in perspective
Environment	An organisation is part of a supersystem denoted as the organisational environment.	Suppliers, competitors, customers, regulatory agencies, unions. Inter-organisational networks, stakeholders, and the supply chain.	AECO organisations' environment is complex due to the multi-disciplinary nature of the organisations. Hence, based on the types of organisations, the environmental conditions differ.
Social structure	The social structure/structure indicates the relationships between people and the roles and responsibilities of organisations.	Division of labour, a hierarchy of authority, coordination mechanism, formalised rules, and procedures include position descriptions, job classifications, management systems, and organisational charts.	Project-based nature created fragmentation. Temporary project-based teams dominate the project execution phase.
Technology	Organisations use a specific technology or interrelated groups of technology to secure the uninterrupted flow of resources and sustain the organisations.	The technology of organisations can be considered from different analytical levels, for instance, tasks, jobs, units, and organisational level technology. Task interdependence, mechanisms of coordination, and information processing influence technology.	Technological advancement or digitalisation is slow. Established technologies are CAD. Emerging technologies are BIM, web-based collaboration tools, AR, and VR.
Culture	Cultures are collective phenomena that encapsulate people's responses to the uncertainties and chaos inherent in human experience.	Sub-culture, artefacts, values, assumptions.	An adversarial culture is often observed. AECO organisations, due to their multi-disciplinary nature, often focus on their individual goals.
Physical structure	The physicality of the built spaces of the organisations.	Organisational geographies, space, time, layout.	Apart from physically built space, AECO organisations also work virtually.
Power, control and conflict	The control process aids organisations in circumscribing idiosyncratic behaviours, ensuring conformity to the rational plans of the organisation.	Work dependency, control of information flow, decision-making process, cooperation and coalition buildings and politics, control mechanism.	The power dynamics of AECO organisations are complex. Project-based nature is dominant. The contractual basis work execution process is typical.

Table 3
Search string, inclusion and exclusion criteria.

Search string	(TITLE-ABS-KEY ("BIM") OR TITLE-ABS-KEY ("Building Information Modelling") OR TITLE-ABS-KEY ("Building Information Modelling") OR TITLE-ABS-KEY ("Building Information Model") OR TITLE-ABS-KEY ("Building Information Management") AND TITLE-ABS-KEY ("Adoption*") OR TITLE-ABS-KEY ("adopting*") OR TITLE-ABS-KEY ("adopt") OR TITLE-ABS-KEY ("implementation") OR TITLE-ABS-KEY ("implement") OR TITLE-ABS-KEY ("diffusion") OR TITLE-ABS-KEY ("integration") OR TITLE-ABS-KEY ("utilisation") OR TITLE-ABS-KEY ("utilisation") OR TITLE-ABS-KEY ("use") OR TITLE-ABS-KEY ("strategy*") OR TITLE-ABS-KEY ("process") OR TITLE-ABS-KEY ("procedure") OR TITLE-ABS-KEY ("change*") OR TITLE-ABS-KEY ("organisational change*") OR TITLE-ABS-KEY ("organisational change") OR TITLE-ABS-KEY ("requirements") OR TITLE-ABS-KEY ("organisational requirement*") OR TITLE-ABS-KEY ("organisational requirement*") AND TITLE-ABS-KEY ("organisation*") OR TITLE-ABS-KEY ("organisation*") OR TITLE-ABS-KEY ("company") OR TITLE-ABS-KEY ("enterprise") OR TITLE-ABS-KEY ("small and medium enterprise") OR TITLE-ABS-KEY ("large organisation*") OR TITLE-ABS-KEY ("large organisation*") OR TITLE-ABS-KEY ("organisational structure") OR TITLE-ABS-KEY ("culture") OR TITLE-ABS-KEY ("firm*") OR TITLE-ABS-KEY ("institution")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "DECI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j"))
Inclusion criteria	Consider studies exploring BIM adoption within organisations. Consider 'Journal article.'
Exclusion criteria	Exclude studies focusing on specific BIM application. Exclude studies focusing on BIM technology development. Exclude studies considering project-specific BIM adoption. Exclude conference papers. Exclude non-English language studies

explanation of data items, purpose, and reasoning for charting the data for descriptive statistics analysis of the identified literature. All the data items were plotted in an Excel spreadsheet. Later, extracted data were synthesised and visualised using Tableau.

For qualitative content analysis, studies were grouped based on the BIM adoption phase. For instance, $f = 47$ (or 32%) studies were grouped into *before the PoA phase*, $f = 85$ (or 58%) studies *after the PoA phase*, and $f = 15$ (or 10%) studies were aggregated into *both before and after the PoA phase*. Information on the BIM adoption phase and BIM's interaction with organisations were extracted in an Excel spreadsheet underpinning the framework in Fig. 1. Later, information on indicated requirements, changes, and tools for enabling BIM adoption was extracted and plotted in an Excel spreadsheet. Table 4 describes the purpose and explanation of data items. All the extracted information was visualised in Microsoft Visio.

The following section discusses the findings of descriptive statistical analysis and qualitative content analysis.

4. Landscape of BIM adoption literature

This section identifies the worldwide distribution of studies exploring BIM's interaction with AECO organisations (refer to Figs. 3 and 4). The section further identifies the types of organisations and types of cases examined (refer to Fig. 5), utilised methodology and methods (refer to Fig. 6), and underpinning theories (refer to Fig. 7) for investigating BIM's interaction with organisations. The following sub-sections discuss the key findings.

4.1. Study location and BIM's interaction with organisations across the BIM adoption phases

Fig. 3 illustrates the distribution of the 144 studies in respect of their location (two studies, however, did not reveal study location). Of the 144, 18% were China-based, 17% from the UK, and 10% examined Australia. The remaining studies were variously located, as indicated in Fig. 3.

Underpinning the conceptual framework, Fig. 4 presents the categorisation of studies based on their consideration of BIM's interaction with organisations and PoA, revealing that most studies were undertaken after 2015. Frequency (f) = 50 articles (or 34%) explored BIM's interaction with organisations' social structure. Another major category is organisation technology, which aggregated BIM studies through a technology adoption lens. This category contains $f = 44$ no (or 30%) studies. BIM and organisations' culture are the least explored category, as only $f = 8$ studies (or 5%) have been conducted over the last 15 years.

Fig. 4 further reveals that for pre-PoA, $f = 23$ (or 15%) studies explored BIM technology adoption, $f = 8$ (or 5.4%) studies examined organisational environment, $f = 5$ (or 3.4%) explored organisational power, $f = 7$ (or 4.7%) considered social structure, and $f = 3$ (or 2%) studies investigated the culture of AECO organisations. By contrast, most of the post-PoA studies ($f = 38$ or 26%) have been undertaken to understand BIM's interaction with organisational social structure, followed by organisational power ($f = 15$ or 10%) and the environment ($f = 16$ or 11%). Few studies explored both pre and post-PoA in understanding BIM's interaction with organisations. For instance, $f = 10$ (or 6.8%) studies in the organisation technology category, along with $f = 5$ (or 3.4%) studies in the social structure category, have considered BIM's interaction with the organisation encompassing before and after PoA together.

Overall, Fig. 4 depicts the uneven exploration of BIM adoption within AECO organisations Importantly, it further represents a lack of consideration in examining pre and post-PoA together, and a lack of holistic understanding of BIM adoption within AECO organisations. Exploration of a single dimension of organisations, such as organisational environment, or social structure, or culture, further confirms the absence of a holistic approach towards understanding AECO organisations' BIM adoption process. This indicates that existing literature examines BIM adoption within AECO organisations through a narrowly scoped 'tunnel vision' approach.

4.2. BIM's interaction with various types of organisations

Fig. 5 represents the types of organisations explored in investigating BIM's interaction — with organisations. Out of 146 studies, $f = 35$ (or 24%) examined varied types of organisations, $f = 27$ (or 18.4%) studies explored project participant organisations, $f = 19$ (or 13%) studies investigated SMEs, $f = 9$ (or 6%) studies observed client organisations, and $f = 13$ (or 9%) of studies explored architectural organisations. In contrast, only one study, $f = 1$ (or 0.6%), explored developer organisations, and $f = 4$ (or 2.7%) explored engineering consultation organisations. Overall, studies explored BIM's interaction across a wide range of organisations.

Fig. 5 further illustrates types of cases of organisations investigated in attempting to understand BIM's interaction with organisations. For instance, while investigating varied organisations, $f = 20$ (or 13.6%) studies investigated BIM users, $f = 12$ (or 8.2%) studies explored varied professionals, $f = 3$ (or 2%) studies investigated non-BIM users, $f = 2$ (or 1.3%) studies observed BIM projects, while only $f = 1$ (or 0.6%) study examined the project data of varied types of organisations. Similarly, $f = 1$ (or 0.6%) of studies considered organisational data of construction organisations. Fig. 5 therefore, depicts an overall picture of the cases explored to understand BIM's interaction with organisations, and further provides information on what part of organisations (category) was investigated. As shown in Fig. 5, the colours and numbers indicate the

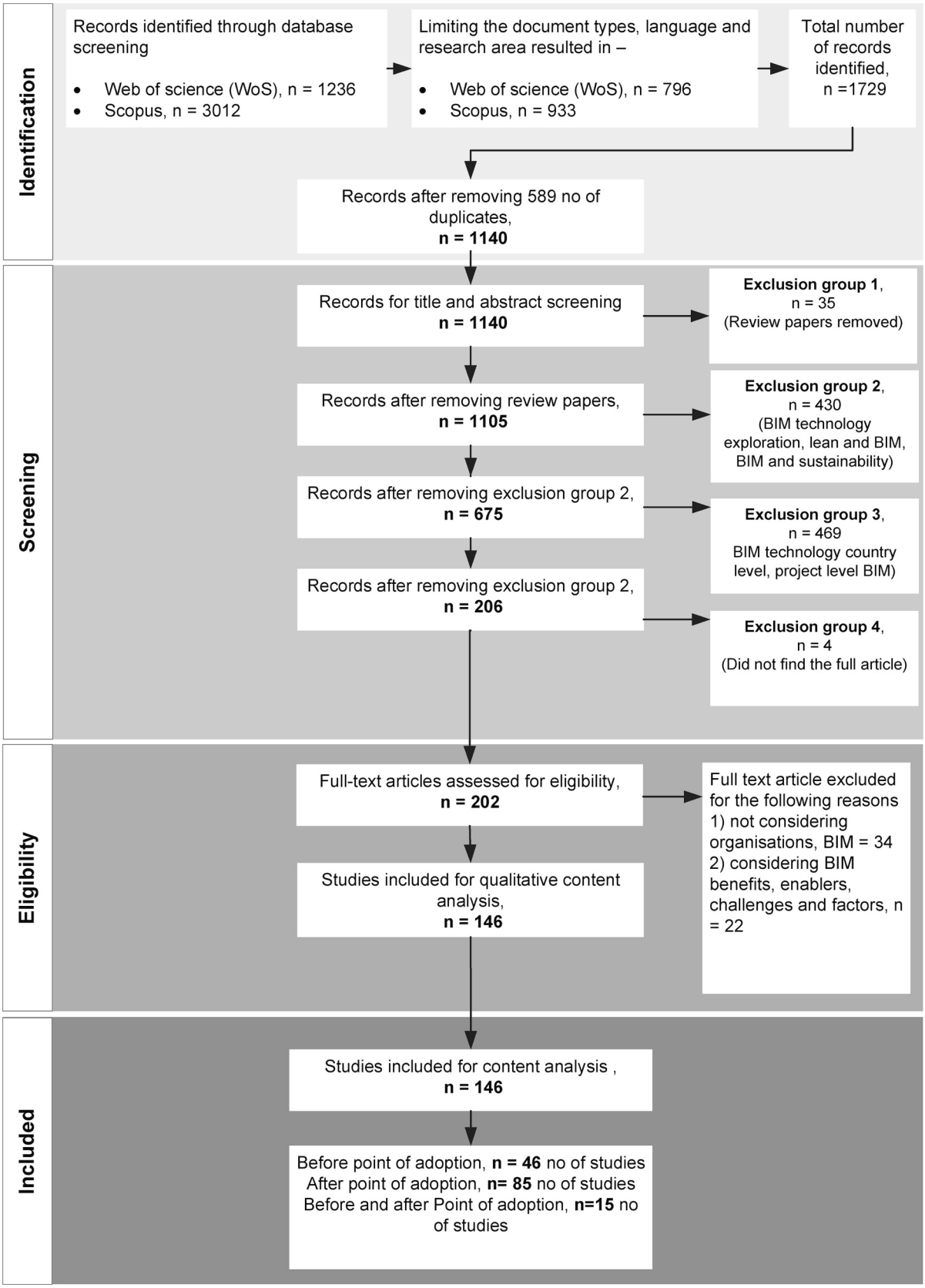


Fig. 2. Illustrating the research methodology of the present study based on PRISMA-ScR guidelines.

Table 4
List of data items, description, and purpose.

Data items	Explanation	Purpose and reasoning
Category	The item category includes information on what part of organisations' existing studies considers while exploring BIM adoption within AECO organisations. The category is generated based on the formulated framework. That means studies are categorised in organisation environment, organisation power, organisation culture, organisation's social structure and organisation technology.	The category data items will reveal what parts of the organisation's existing studies explored to understand BIM's interaction with AECO organisations in the BIM adoption process.
Author name, publication year	The item includes information on the author and publication year of the study.	The author and year information will lead to understanding the key researcher on the field and research timeline.
BIM adoption phase/PoA	The item includes information on considering the BIM adoption phase for organisations. For instance, whether literature explores before or after the PoA phase of organisations while investigating BIM and AECO organisations.	The information will reveal the existing literature exploration of BIM's interaction with AECO organisations in terms of the BIM adoption phase.
Country	The item includes information on the study location	The data item will reveal the countries exploring the BIM adoption within AECO organisations
Methodology	The item includes data on the existing study's methodology to explore BIM adoption within AECO organisations.	To get an overview of the standard methodology deployed to investigate BIM adoption within the AECO organisation.
Level of data source	This section indicates the source of data existing studies utilises to execute research.	The knowledge of data sources will represent the most utilised data source for research.
Types of case	Reveal data on the study case, such as types/sizes of organisations and projects.	This data will assist in understanding what types of organisations, projects, or individuals have been explored to understand BIM adoption within AECO organisations.
Theory utilised	This item includes consideration of any theory to explore BIM adoption within the AECO organisation.	The information will reveal the primarily utilised theories to explore BIM adoption within AECO organisations.
BIM's interaction with organisations	Information was extracted on BIM's interaction with the organisational environment, culture, social structure, and power via content analysis.	The information will unearth a deeper understanding of BIM's interaction with organisations.
BIM adoption phase	This data item seeks information on understanding the exploration of the BIM adoption phase.	The data item will provide a broader understanding of the exploration of BIM adoption within AECO organisations.
Requirements, changes and tools	This data item contains information on the indicated requirements, changes, and tools for enabling BIM adoption within AECO organisations.	The information further reveals the in-depth understanding of BIM's interaction with AECO organisations during the adoption phase.

considerations of BIM's interaction within organisations. For example, only $f = 4$ studies (or 2.7%) explored engineering consultation organisations through a technology adoption lens. However, BIM's interaction with engineering consultation organisations' culture, environment, power, and social structure, has not been examined. In addition, $f = 8$ (or 5.4%) studies explored construction organisations, $f = 1$ (or 0.6%) educational organisations, $f = 1$ (or 0.6%) project participant organisations, $f = 1$ (or 0.6%) two unspecified types of organisations, $f = 1$ (or 0.6%) various other organisations, and $f = 4$ (or 2.7%) culture and BIM's interaction. Only $f = 20$ (or 13.6%) of studies explored BIM's interaction with architectural organisations, $f = 1$ (or 0.6%) construction organisations, $f = 4$ (or 2.7%) project participant organisations, $f = 1$ (or 0.6%) quantity surveying organisations, ($f = 1$ (or 0.6%) SMEs, $f = 5$ (3.4%) two types of organisations, $f = 2$ (or 1.3%) other varied organisations. Fig. 5 illustrates BIM's interaction with these different types of organisations.

Fig. 5 illustrates the types of organisations and cases considered in the effort to understand BIM adoption, and reflects upon the limited consideration of BIM users, organisational data, and historical data. Overall, Fig. 5 shows that despite BIM's interaction with different parts and types of organisations, most studies do not consider a holistic approach to BIM adoption within AECO organisations.

4.3. BIM's interaction with organisations: methodology, methods, and underpinned theories

To understand BIM's interaction with AECO organisations, 143 studies out of 146 outlined the deployed methodology and methods, as indicated in Fig. 6. Out of 143, $f = 4$ (or 2.7%) studies used action research, $f = 24$ (or 16.7%) studies used mixed methodology, $f = 49$ (or 34%) used qualitative methodology, and $f = 66$ (or 46%) conducted quantitative methodology.

Fig. 6 further reveals the data collection methods of the 143 studies. For instance, out of $f = 66$ quantitative studies, $f = 55$ (or 38%) studies used survey methods. In contrast, $f = 9$ (or 6.2%) studies executed case studies, $f = 1$ (or 0.6%) study conducted data mining, and $f = 1$ (or 0.6%) study deployed modelling. Whereas, for action research, $f = 1$ (or 0.6%) study deployed interviews, $f = 1$ (or 0.6%) study conducted a longitudinal case study, and $f = 2$ (or 0.6%) studies utilised multiple methods.

As indicated in Fig. 6, studies explored BIM's interaction with organisations' culture utilising mixed methodologies $f = 4$ (or 2.7%), qualitative, $f = 1$ (or 0.6%), and quantitative $f = 3$ (or 2%). In contrast, BIM's interaction with the organisation's social structure explored utilising action research $f = 2$ (or 1.3%), mixed methodology $f = 5$ (or 3.4%), qualitative $f = 21$ (or 14.6%), and quantitative $f = 21$ (or 14.6%).

Fig. 6 illustrates the varied methodologies and methods used by the 143 studies. However, action research and mixed methodologies studies are relatively few, compared to the most utilised quantitative methodologies.

$f = 80$ (or 54.7%) studies underpinned a wide range of theories in exploring BIM's interaction with organisations during the BIM adoption process, as indicated in Fig. 7. Of the 80 studies, some explored theories at the individual level $f = 17$ (or 21%), others at the inter-organisational level f = 16 (or 20%), multiple levels $f = 17$ (or 21%), and the organisational level $f = 30$ (or 37.5%). Fig. 7 further depicts the list of theories utilised. For instance, out of 80, $f = 11$ (or 13.7%) studies referred to the technology acceptance model (TAM) theory, $f = 5$ (or 6.2%) studies utilised technology organisation environment framework (TOE), $f = 5$ (or 6.2%) studies deployed institutional theory (INT), and $f = 5$ (or 6.2%) studies used diffusion of innovation (DOI) theory. Fig. 7 further indicates theories used to investigate BIM's interaction with organisations. For example, $f = 4$ (or 5%) studies deployed absorptive capacity theory (AC), out of which $f = 2$ studies (or 2.5%) explored BIM's interaction with the organisation environment and $f = 2$ (or 2.5%) examined organisation power and BIM.

Overall, Fig. 7 reflects the utilisation of varied theories. $f = 80$ (or

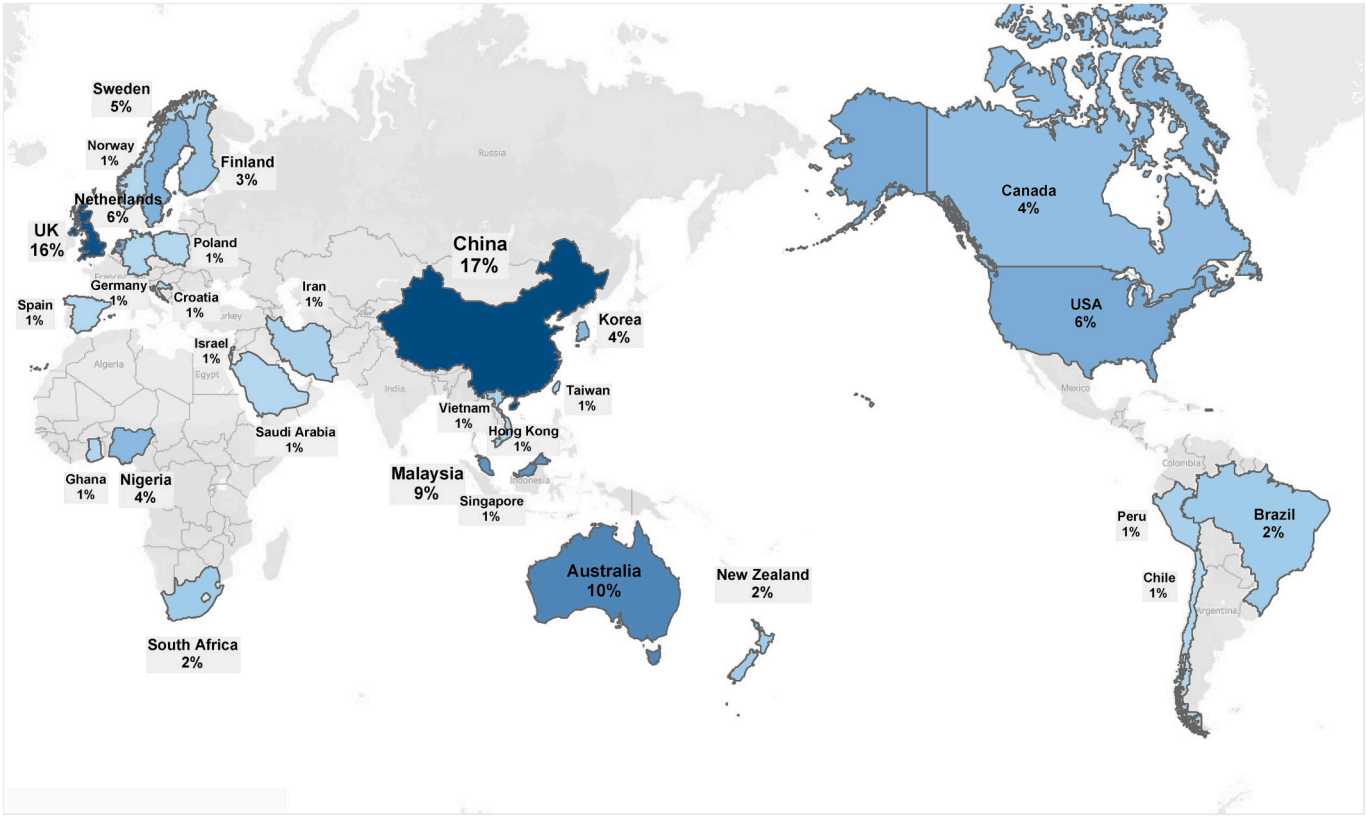


Fig. 3. Distribution of BIM adoption within AECO organisations literature, based on study location.
Note: Map was generated based on longitude and latitude. The variation of colours is generated based on the count of the authors. The percentage is calculated considering the number of studies in each country and total number of studies. Details are shown for the study location. The view is filtered on study location, which excludes not applicable.

54.7%) studies investigated BIM's interaction with different parts of organisations. Theories like TAM $f = 11$ (or 13.75%), TOE $f = 5$ (or 6.25%), and DOI $f = 5$ (or 6.25%) are utilised to explore organisational environment, social structure, and technology. Nonetheless, a conspicuous deficiency exists. This deficiency pertains to the ability to grasp and elucidate the entirety of organisational constituents, encompassing all facets and components thereof. Furthermore, it is worth noting that a mere 17 studies, constituting 21.25% of the total, delved into investigations encompassing multiple levels. This observation underscores the importance of shifting the focus, in order to gain a deeper multifaceted understanding of the intricacies inherent in the interplay between BIM and organisations during the process of BIM adoption.

Overall, Figs. 4–7 summarises 146 studies that explore BIM's interaction with different types of organisations across varied countries. However, most studies explored BIM's interaction with organisations across only a single dimension, such as environment, power, social structure, or culture. In addition, studies either consider before the PoA phase of adoption or after the PoA phase of adoption. Very few studies examined both the before and after PoA phases together. This observation serves as compelling evidence to support the contention that studies pertaining to BIM adoption within the AECO domain have predominantly adopted a limited and myopic perspective, namely a 'tunnel vision', failing to comprehensively account for the confluence of all influencing factors. The next section explores the 146 multi-directional and heterogenous studies on BIM adoption within AECO organisations, based on the BIM adoption phase underpinning the conceptual framework (refer to Fig. 1).

4.4. BIM's interaction with AECO organisations before PoA

4.4.1. Explored topics before PoA

$f = 47$ (or 32%) studies have explored BIM's interaction with organisations. Fig. 8 paints an overall picture of the multi-directional interaction of BIM and AECO organisations before the PoA. As indicated in Fig. 8, studies examined BIM's interaction with organisational environment by studying institutional (government, professional body, BIM-using organisations) influence on BIM adoption activities in projects and SMEs [49,50]. In examining BIM's interaction with organisational culture, studies investigate BIM's alignment with the culture [51], and document the influence of cultural factors in adopting BIM [52,53]. Studies have also examined the cost and performance of BIM and its impact on decision-makers [54] while also investigating BIM's interaction with organisation power. Other studies have assessed the risk and rewards of BIM adoption for SMEs' decision-makers [55], as indicated in Fig. 8. On the other hand, BIM and social structure studies have examined individual professionals' acceptance of BIM [56,57], behaviour intention towards accepting BIM [58], and BIM awareness [59].

Other studies investigated organisational readiness [60–62] and examined drivers and hindering factors influencing the uptake of BIM [63,64]. In addition, the literature has assessed the BIM uptake of organisations through a technology adoption lens [6]. The exploration of BIM with AECO organisations shows how BIM interacts with organisational environment, power, social structure, and culture. Thus, BIM adoption's decision-making and readiness phase within AECO organisations is complex. The comprehensive exploration of the existing literature indicates that the decision-making phase involves achieving readiness, assessing associated risks and costs, users', and organisations' intention to adopt BIM, and governments and institutional initiatives.

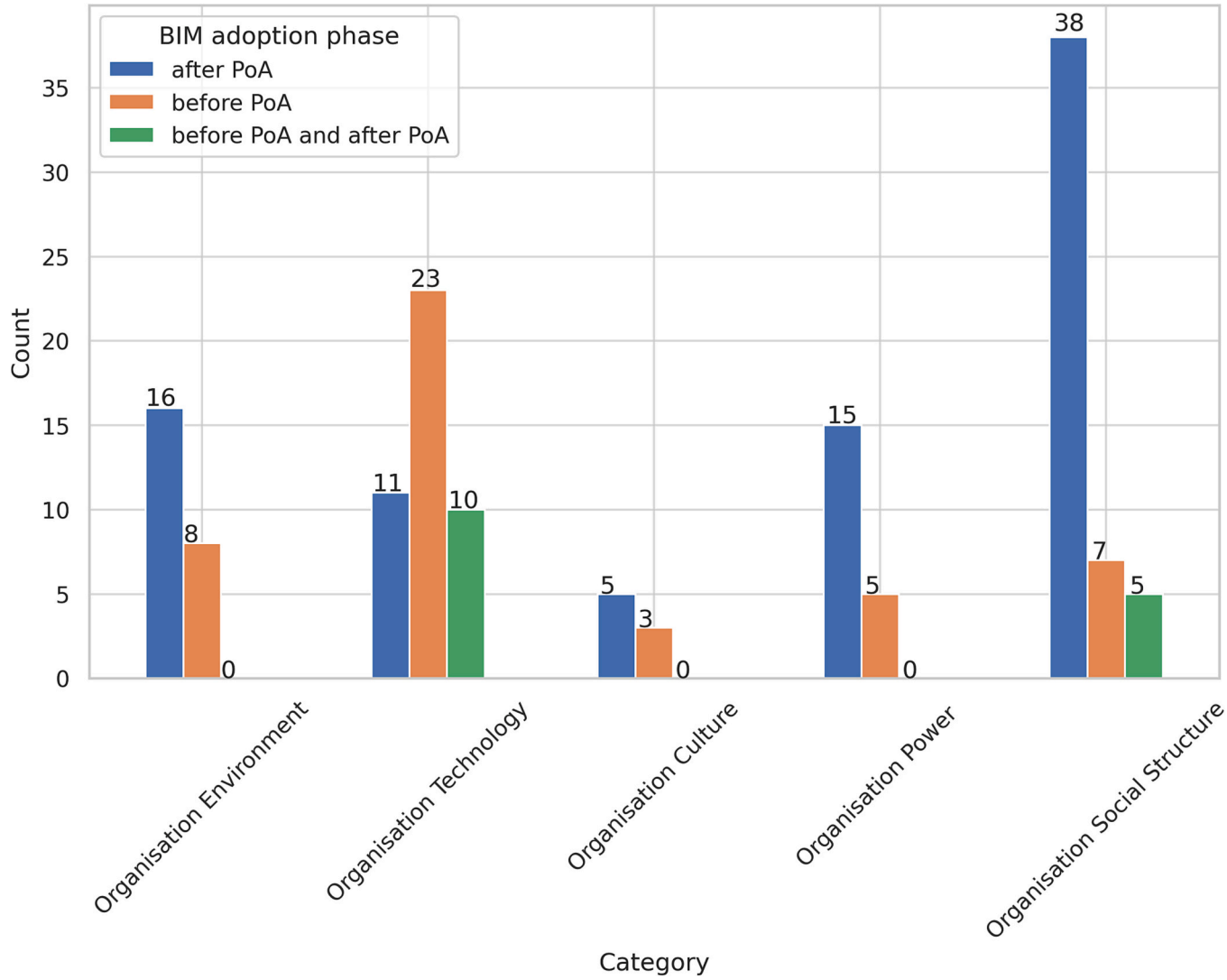


Fig. 4. Distribution 146 publications based on categories and PoA over the timeline.

4.4.2. *Indication of requirements, changes and tools before PoA*

According to Fig. 8, BIM adoption within AECO organisations is not an isolated incident. Instead, AECO organisations need various requirements, changes, and tools for enabling BIM adoption within AECO organisations before PoA. For instance, some studies underscore the significance of clients' early involvement [68], standards and policies [52], BIM execution plan [59], alternative procurements [55], and realisation of benefits and barriers [6]. Studies examining BIM's interaction with the organisation's environment, social structure and culture highlight training, workshops and seminars [52,53,56,69]. According to Saka, et al. [50] and Ma, et al. [77], both bottom-up and top-down approaches are needed for BIM adoption. Although the significance of the above-mentioned requirements for enabling BIM adoption and AECO organisations' decision-making process and achieving the readiness phase is undeniable, it is unclear how organisations will achieve the listed requirements, changes, and tools. Moreover, how the requirements and change will impact the complex BIM decision-making and readiness phase is vaguely understood.

Studies have also proposed a BIM readiness assessment framework [60], a BIM acceptance model [82], and a predictive model to assess BIM readiness [61]. For instance, Tong and Phung [84] readiness model includes criteria sch as strategy, organisational structure, process, people, technology, and information management. Alternatively, Wang, et al. [58] proposed a behavioural model suggesting different paths of intention and behaviour towards BIM acceptance, and examining BIM's interaction with organisations' social structure (refer to Fig. 8). Similarly, Hong, et al. [54] developed a two-stage stochastic optimisation model designed to aid organisations in evaluating the costs associated with BIM adoption and in optimising the BIM implementation strategy at a strategic level. Despite the significance of these tools, they have been developed focusing on only one dimension of organisations.

In brief, Fig. 8 presents that BIM's interaction with AECO organisations before PoA has been examined in isolation. The mapping of existing literature in Fig. 8 shows that despite developing practical tools and identifying requirements, BIM adoption's decision-making — and readiness — phase lacks a holistic approach.

4.5. *BIM's interaction with AECO organisations after PoA*

4.5.1. *Explored topics after PoA*

$f = 85$ (or 58%) studies have explored muti-directional topics of BIM's interaction with organisations and various aspects of the BIM adoption phase after PoA, as indicated in Fig. 9. One groups of studies examined BIM's interaction with the organisational environment considering inter-organisational level BIM use [13,88–90] and BIM's integration with the supply chain [11,91]. Post-PoA, studies consider BIM's interaction with organisational culture and examine existing patterns of behaviours and values, cultural traits, attitudes, as well as

Types of organisation	Types of cases	organisation culture	Organisation environment	organisation power	organisation social structure	Organisation technology	Grand Total
Architecture organisation	Architects		1		2	5	8
	BIM users			1	2	2	5
	Total		**1**	**1**	**4**	**7**	**13**
Client organisation	organisational participants				2	2	4
	BIM using project				2	2	4
	project data				2	1	3
	non-BIM projects					1	1
	BIM users				1		1
	Total				**5**	**4**	**9**
Construction organisation	organisational participants	1		2	1	1	5
	BIM users			2	1	2	5
	BIM using project				4		4
	project data				2		2
	varied professionals					1	1
	Suppliers		1				1
	organisational data				1		1
	Total	**1**	**1**	**4**	**6**	**4**	**16**
Developer organisation	Developers		1				1
	BIM users					1	1
	Total		**1**			**1**	**2**
Educational organisation	BIM users	1					1
	Total	**1**					**1**
Engineering consultation organisation	Not applicable					1	1
	MEP professionals					1	1
	Engineers					1	1
	BIM using project					1	1
	project data					1	1
	Total					**4**	**4**
listed organisation	organisational data					1	1
	Total					**1**	**1**
Multidisciplinary organisation	project data		1				1
	BIM using project		1				1
	Total		**1**				**1**
Not applicable	Not applicable				3	2	5
	Total				**3**	**2**	**5**
Project parcipant organisation	BIM using project	1	12		8		21
	Project data		6	1	6		13
	BIM using project		1				1
	Total	**1**	**13**	**1**	**12**		**27**
Quantity surveying organisation	Quantity surveyors			1		1	2
	BIM users				1	1	2
	Total			**1**	**1**	**2**	**4**
SMEs	varied professionals		1		1	4	6
	BIM users			4	1	1	6
	Contractors					3	3
	Architects				2		2
	varied stakeholders					1	1
	organisational participants			1			1
	Total		**1**	**5**	**4**	**9**	**19**
Two types of organisation	BIM users	1			2	1	4
	Contractors					2	2
	BIM using project			2			2
	organisational participants					1	1
	Engineers					1	1
	Developers					1	1
	Total	**1**		**2**	**2**	**4**	**9**
varied organisation	BIM users	1	6	5	6	2	20
	varied professionals	2		1	4	5	12
	non BIM users		1	1	1		3
	BIM using project				2		2
	project managers	1					1
	project data				1		1
	Job adversitements				1		1
	Total	**4**	**6**	**6**	**12**	**7**	**35**
varied stakeholders	historic data				1		1
	Total				**1**		**1**
Grand Total		**8**	**24**	**20**	**50**	**44**	**146**

Distinct count of Author (colour) broken down by Category vs. Types of organisationandTypes of cases.

1 12

Fig. 5. Consideration of types of organisations and types of cases of BIM adoption with AECO organisations' literature.
Note: Distinct count of Author (colour) broken down by category vs types of organisation and types of cases.

Methodology	Methods	Grand Total	organisation culture	Organisation environment	organisation power	organisation social structure	Organisation technology
			Category				
Action research	Interview	1			1		
	Longitudinal case study	1			1		
	multiple methods	2				2	
Mixed methods	Case study	6	1	3		2	
	Embedded case study	1					1
	Field study	1					1
	Focus group	1					1
	Interview	12	3			1	8
	Longitudinal case study	2			1		1
	Modelling	1				1	
	Multiple methods	1				1	
	Survey	13	3			2	8
Qualitative	Case study	23	1	4	1	12	5
	Discussion	2				1	1
	Embedded case study	4		2		2	
	Field study	2		1		1	
	Focus group	1				1	
	Interview	13		3	2	4	4
	Longitudinal case study	1					1
	Survey	5		1	1	1	2
Quantitative	Case study	9		3	3	2	1
	Data minning	1				1	
	Interview	1					1
	Modelling	1				1	
	Survey	55	3	8	10	18	16
Grand Total		143	8	24	20	49	42

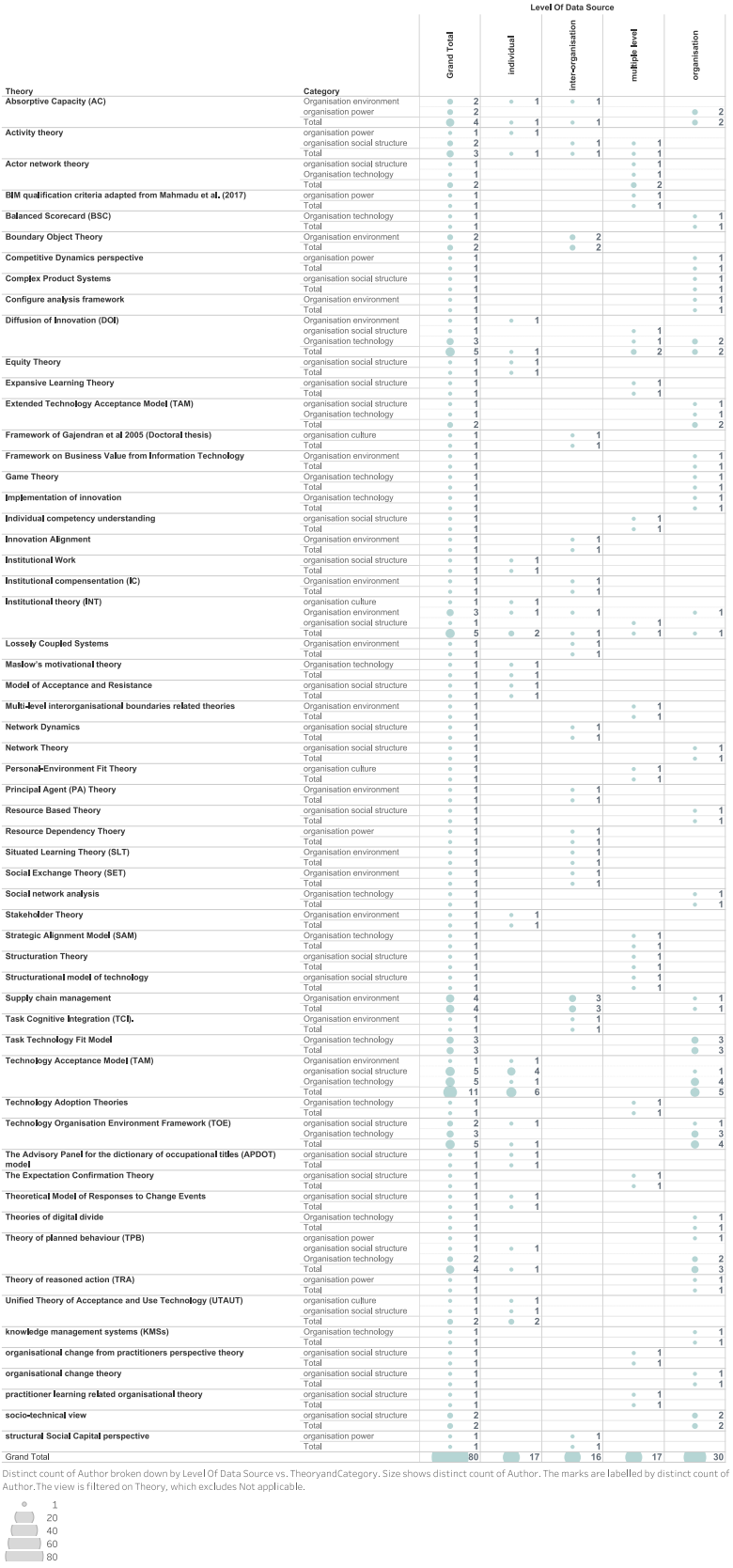
Fig. 6. Deployed methodology and data collection methods of studies exploring BIM adoption within AECO organisations.
Note: Distinct count of author (colour) broken down by category vs. methodology and methods. The view is filtered on methodology, which keeps action research, mixed methods, qualitative and quantitative.

BIM's impact on culture [92–95]. Additional research has scrutinised the interplay between BIM and organisational power structures, focusing on the costs and risks associated with BIM [96–98], BIM maturity and organisational learning [99–101], BIM's impact on performance and productivity [24,102,103] and BIM's relation with organisational power dynamics and competitiveness [14,104–106]. Regarding BIM's interaction with organisation social structure, studies examined organisational structure and hierarchy [12,107,108], individual and professionals' resistance and behaviour, and explored BIM roles [109–112]. Some research studies have also examined organisations' transformation strategy and contextual impact on BIM practice [107,113] (Fig. 9). Studies, through the technology adoption lens, have investigated organisational type-based BIM uptake [114], analysed factors influencing the adoption process [115], and explored BIM collaboration and maturity level [116].

Like pre-PoA studies, post-PoA studies examine the multi-directional interaction of BIM and AECO organisations. Despite identifying several key findings, such as continuous changes [15,28,30] and heterogeneity experience of BIM benefits of organisations [113], these studies overlook a holistic approach to examine AECO organisations' BIM adoption process post PoA. For instance, studies examine BIM maturity [101], and costs associated with BIM maturity gain [54], evaluate BIM-based performance achievements [24], signify organisational learning [99] and scrutinise BIM roles [109]. Debate exists among scholars regarding the viability of BIM-based roles [14,109,117]. Despite exploring BIM's interaction with AECO organisations post-PoA, knowledge regarding BIM adoption is still scattered. Moreover, project-level BIM adoption and its impact at the inter-organisational levels complicate the overall BIM adoption in post-PoA phase [7].

4.5.2. *Indication of requirements, changes and tools after PoA*

Past research has also highlighted a wide range of requirements, as illustrated in Fig. 9. For example, studies examining BIM's interaction with the organisational environment refer to developing inter-firm cooperation, shared BIM vision and BIM guidelines [88,118–120]. Moreover, some studies suggest having top-down and bottom-up implementation strategies, joint BIM learning, well-defined contractual arrangements, and operational and strategic approaches for enabling BIM-integrated supply chain management [11,91,121]. Another group of studies examine BIM's interaction with organisational culture and emphasise developing a collaborative business model and positive cultural traits [92,93,122]. In the context of BIM and its interface with organisational power dynamics, several scholarly investigations have shed light on its significance. Notably, these studies have underscored BIM's capacity to foster a culture of knowledge-sharing, cultivate a receptiveness to change, and inform managerial strategies, particularly in the context of business affiliations [99]. Furthermore, a number of scholarly inquiries have highlighted specific prerequisites, including training initiatives and unequivocal support from top-level management. These delineated prerequisites hold



Theory	Category	Grand Total	individual	inter-organisation	multiple level	organisation
Absorptive Capacity (AC)	Organisation environment	2	1	1		
	organisation power	2				2
	Total	4	1	1		2
Activity theory	organisation power	1	1			
	organisation social structure	2		1	1	
	Total	3	1	1	1	
Actor network theory	organisation social structure	1			1	
	Organisation technology	1			1	
	Total	2			2	
BIM qualification criteria adapted from Mahmadu et al. (2017)	organisation power	1			1	
	Total	1			1	
Balanced Scorecard (BSC)	Organisation technology	1				1
	Total	1				1
Boundary Object Theory	Organisation environment	2		2		
	Total	2		2		
Competitive Dynamics perspective	organisation power	1				1
	Total	1				1
Complex Product Systems	organisation social structure	1				1
	Total	1				1
Configure analysis framework	Organisation environment	1				1
	Total	1				1
Diffusion of Innovation (DOI)	Organisation environment	1	1			
	organisation social structure	1			1	
	Organisation technology	3			1	2
	Total	5	1		2	2
Equity Theory	organisation social structure	1	1			
	Total	1	1			
Expansive Learning Theory	organisation social structure	1			1	
	Total	1			1	
Extended Technology Acceptance Model (TAM)	organisation social structure	1				1
	Organisation technology	1				1
	Total	2				2
Framework of Gajendran et al 2005 (Doctoral thesis)	organisation culture	1		1		
	Total	1		1		
Framework on Business Value from Information Technology	Organisation environment	1				1
	Total	1				1
Game Theory	Organisation technology	1				1
	Total	1				1
Implementation of innovation	Organisation technology	1				1
	Total	1				1
Individual competency understanding	organisation social structure	1			1	
	Total	1			1	
Innovation Alignment	Organisation environment	1		1		
	Total	1		1		
Institutional Work	organisation social structure	1	1			
	Total	1	1			
Institutional compensentation (IC)	Organisation environment	1		1		
	Total	1		1		
Institutional theory (INT)	organisation culture	1	1			
	Organisation environment	3	1	1		1
	organisation social structure	1			1	
	Total	5	2	1	1	1
Lossely Coupled Systems	Organisation environment	1		1		
	Total	1		1		
Maslow's motivational theory	Organisation technology	1	1			
	Total	1	1			
Model of Acceptance and Resistance	organisation social structure	1	1			
	Total	1	1			
Multi-level interorganisational boundaries related theories	Organisation environment	1			1	
	Total	1			1	
Network Dynamics	organisation social structure	1		1		
	Total	1		1		
Network Theory	organisation social structure	1				1
	Total	1				1
Personal-Environment Fit Theory	organisation culture	1			1	
	Total	1			1	
Principal Agent (PA) Theory	Organisation environment	1		1		
	Total	1		1		
Resource Based Theory	organisation social structure	1				1
	Total	1				1
Resource Dependency Theory	organisation power	1		1		
	Total	1		1		
Situated Learning Theory (SLT)	Organisation environment	1		1		
	Total	1		1		
Social Exchange Theory (SET)	Organisation environment	1		1		
	Total	1		1		
Social network analysis	Organisation technology	1				1
	Total	1				1
Stakeholder Theory	Organisation environment	1	1			
	Total	1	1			
Strategic Alignment Model (SAM)	Organisation technology	1			1	
	Total	1			1	
Structuration Theory	organisation social structure	1			1	
	Total	1			1	
Structurational model of technology	organisation social structure	1			1	
	Total	1			1	
Supply chain management	Organisation environment	4		3		1
	Total	4		3		1
Task Cognitive Integration (TCI).	Organisation environment	1		1		
	Total	1		1		
Task Technology Fit Model	Organisation technology	3				3
	Total	3				3
Technology Acceptance Model (TAM)	Organisation environment	1	1			
	organisation social structure	5	4			1
	Organisation technology	5	1			4
	Total	11	6			5
Technology Adoption Theories	Organisation technology	1			1	
	Total	1			1	
Technology Organisation Environment Framework (TOE)	organisation social structure	2	1			1
	Organisation technology	3				3
	Total	5	1			4
The Advisory Panel for the dictionary of occupational titles (APDOT) model	organisation social structure	1	1			
	Total	1	1			
The Expectation Confirmation Theory	organisation social structure	1			1	
	Total	1			1	
Theoretical Model of Responses to Change Events	organisation social structure	1	1			
	Total	1	1			
Theories of digital divide	Organisation technology	1				1
	Total	1				1
Theory of planned behaviour (TPB)	organisation power	1				1
	organisation social structure	1	1			
	Organisation technology	2				2
	Total	4	1			3
Theory of reasoned action (TRA)	organisation power	1				1
	Total	1				1
Unified Theory of Acceptance and Use Technology (UTAUT)	organisation culture	1	1			
	organisation social structure	1	1			
	Total	2	2			
knowledge management systems (KMSs)	Organisation technology	1				1
	Total	1				1
organisational change from practitioners perspective theory	organisation social structure	1			1	
	Total	1			1	
organisational change theory	organisation social structure	1				1
	Total	1				1
practitioner learning related organisational theory	organisation social structure	1			1	
	Total	1			1	
socio-technical view	organisation social structure	2				2
	Total	2				2
structural Social Capital perspective	organisation power	1		1		
	Total	1		1		
Grand Total		80	17	16	17	30

Distinct count of Author broken down by Level Of Data Source vs. TheoryandCategory. Size shows distinct count of Author. The marks are labelled by distinct count of Author.The view is filtered on Theory, which excludes Not applicable.

1
20
40
60
80

Fig. 7. Underpinned theories, level of analysis and BIM's interaction with organisations.
Note: Distinct count of authors broken down by level of data source vs theory and category. Size shows distinct count of author. The marks are labelled by distinct count of authors. The view is filtered on theory, which excludes not applicable.

BIM's interaction with organisations	Topic	BIM adoption phase	requirements	changes	tools
Organisational environment	Stakeholder	Stakeholders perspective of BIM Client org expectations	Early involvement of clients Strategy to increase project revenue	Stakeholders mindset Existence of cultural resistance	
	Supplier	Suppliers capability/readiness assessment	Training program, incentives to encourage collaborative behaviour, change management		
	Institution	Factors influencing acceptance of BIM Institutional factors influencing BIM adoption in project, SMEs	Detail action plan Organisational innovativeness, resources Bottom up strategy and top down approach	Project process	
Organisational culture	Cultural alignment	Individual's culture and task alignment.	Knowledge and skills to conduct the tasks	Organisational culture and task design change.	
	Cultural factor	Factors enabling or constraining intention to adopt BIM Assessed cultural orientation and strategic capability of construction organisations to enable adoption of BIM.	Training, incentives, joint awareness Standards and policies Information delivery Leadership visionary	Change in procurement and design incentive schemes Series of organisational change	
Organisational power	Cost of BIM and Performance	Examined how to assist decision makers in terms of cost associated with BIM adoption.			2 stage stochastic optimisation model for BIM implementation planning at strategic level
	Risk assessment	Risk and reward assessment for SMEs ' BIM adoption decision making	Alternative procurement methods Integrated project delivery	Traditional relationship between client and SMEs are changing	Risk and reward framework for SMEs to decide to adopt BIM
	Organisational capability	Examined organisations' capability to absorb new information	Organisational learning	Changes in organisational culture	
Organisational social structure	Individual and professional	Professional's acceptance of BIM Professional's perception of BIM Different roles of public clients Behaviour of professionals of SMEs	Creating awareness of BIM through workshop, seminar and training Training professionals Guidance document and procurement templates BIM policy, Organisational support, gov. BIM policies affect the acceptance	Changing incentives	Behaviour model to suggest different path of intention and behaviour
	Formalised rules, procedure and practices	Awareness of BIM implementation among professionals	Development of guidelines and standards BIM execution plan	Incorporating change management	
Organisational technology	Readiness	Assess preparedness of organisations Examined organisational readiness Assess and create readiness for change	Gov policy, technological support, incentive support the willingness to adopt BIM Readiness criteria include strategy, organisational structure, process, people, technology and information management	Readiness for change Organisational change	Readiness assessment framework Predictive model to assess readiness BIM acceptance model
	BIM adoption phase	Assess BIM uptake of organisations Organisational competence, professionals competence Factors impacting BIM adoption decision Factors influencing BIM adoption Examined lack of homogeneity of BIM adoption	Staff engagement in the implementation process Realising benefits and barriers Top-down and bottom- up approach Prioritise resources Return on investment Top management support	People resist to change traditional workflow Cultural change Organisational change Changes in processes Willingness to change	User acceptance model

Before point of adoption

Decision making phase → **Readiness phase**

Fig. 8. BIM's interaction with AECO organisations before PoA phase.
BIM and organisational environment studies - [65,49,66,67,50,68,69], BIM and organisational cultural studies- [51,52,53], BIM and organisational power studies - [70,54,55,71], BIM and organisational social structure studies - [56,57,59,72,58,73], BIM through technology adoption lens studies- [74,8,75,6,76,64,77,78,63,79,80,81,60,61,82,62,83,84,85,86,87].

BIM's interaction with organisations	Topic	BIM adoption phase	requirements	changes	tools
Organisational environment	Institution	Investigated institutional pressure on BIM adoption	Top management support	Organisational change	
	Inter-organisational level BIM	Perception of trust on BIM Examined misalignment of technology Boundary -spanning roles and activities Explore Inter-organisational/ project level BIM use	Inter-firm coperation Inter-firm power dynamics Inter-firm knowledge mobility Corporate compatibility Shared BIM vision New tasks, adjust task sequence and create new tasks BIM guideline at organisational level	Changes in roles and responsibilities Inter-firm process change Change business process Changes in organisational boundaries	Outcome linked benefit sharing model
	BIM and supply chain	BIM's impact on supply chain relations Supply chain integration with BIM Formal and informal relation of BIM related supply chain partnerships	Top-down and bottom-up implementation of BIM Joint BIM learning and trust building Well-defined contractual arrangements Operational and strategic approach to BIM planning Joint BIM operation BIM protocol	Changes of mentality Cultural change Changes in supply chain management practices Changing work task	
Organisational culture	Cultural traits, attitudes and behaviour transmission BIM impact on culture	Understanding existing patterns And values Cultural analysis of project team BIM influence on culture	Developing positive cultural traits Develop collaborative business model Top management support	Changes of mind-set Changes in attitude to collaborate Changes in roles and responsibilites	
Organisational power	BIM maturity and organisational learning	Relationship of organisational learning and BIM maturity	Openness to change Knowledge sharing culture Training Running pilot project Post training evaluation Organisational learning	Industry wide changes Behavioural change	
	BIM cost and risk	Forecasting net cost associated with BIM implementation at different level of development (LOD) Examined BIM return on investment			Neural network model for decision makers to predict cost of BIM implementation of different level of development (LOD)
	BIM impact on performance and productivity	Post selection performance of organisations delivering BIM project BIM's impact on project participating organisations' performance	Organisational culture Engaging members in the change activities BIM related skilful human resources	Change work processes	Tool for benchmarking BIM Performance (quick scan organisation and management, mentality and culture, information flow, tools and applications)
	BIM and organisational competitiveness	BIM role effectiveness BIM maturity and SMEs	Managerial strategies around business ties	Change in project delivery system Changes in hierarchies and authority structure Leadership may change based on current demand	
Organisational social structure	Individual/ professionals	User resistance, competencies, behaviour and beliefs Investigation of BIM role Project network BIM use exploration Contextual factors and behavioural responses	Attitude, user competency Organisational support Upskilling model for training New policies aligning BIM adoption with systemic evolution of business practices Top management support Professional knowledge	Change in organisations way of working Change traditional work practice establishment	
	Hierarchy/ organisational structure	BIM influence on organisational hierarchy/ structure.	Creating new practices Common goals of the projects Incentivise collaboration and revise contracts	Changes in the roles and relationships	Knowledge base decision making tool Organisations' BIM implementation measuring tool
	Formalised rules and procedures	Organisation transformation strategy BIM's impact on professional work practices Relationship between context, motivation and BIM implementation Examine practices Public client strategy and BIM	BIM department BIM supporting organisational structure Training and education Reflective learning and ready to change	Changes in the roles and relationships Changes in work practices Organisational change Practitioners change practices Sense making of technology change	
Organisational technology	Adoption	Organisational type based exploration of BIM adoption Exploration of factors influencing the BIM adoption process.	Top management support Innovation supporting corporate culture Redefining roles and relationships	Changes in work practice Changes in organisational structure Changes in strategy and culture	
	BIM implementation	Level of adoption, BIM collaboration, maturity Adoption phases for home builders Organisational type based exploration of BIM implementation	BIM based workflow BIM execution process Standardised methods for model developing Guideline of the overall process Tools and configurations for integration	Changes in work methodology	
	Diffusion	During the diffusion of BIM innovation and organisation context continuously changing	Centralisation of technology management Standardisation of digital working practices	Change in organisational structure Organisational change Change in organisational environment	

After point of adoption

Implementation phase

Fig. 9. BIM's interaction with AECO organisations after PoA studies.
BIM's interaction with organisational environment [4,11,13,88–91,118–121,125,126], BIM's interaction with organisational culture [92–95,122], BIM's interaction with organisational power [14,96–106,127–129], BIM's interaction with organisational social structure [3,5,12,28–30,107–111,113,123,124,128–138], BIM through technology adoption lens[7,15,16,114–116].

substantial importance in the context of adopting BIM. Nonetheless, there remains a dearth of clarity regarding the precise mechanisms by which organisations endeavour to satisfy these requisites for successful BIM adoption.

Fig. 9 illustrates that post-PoA studies highlight a wide range of changes exploring BIM's interaction with organisational environment, culture, social structure, and power. For instance, these studies focus on changes in roles and responsibilities and mindset [92], changes in work practice [30], and changes in strategies and culture. Despite indicating a wide range of changes, how these changes evolve in PoA phase is not clarified. Studies that have proposed tools, such as knowledge-based decision-making tools [123], tools for organisations' BIM implementation measuring [124], and outcome-linked benefit-sharing models [120]. The means by which these tools facilitate organisations in attaining BIM maturity and realising their intended BIM utilisation objectives continue to elude comprehensive understanding.

With the above in mind, both pre-PoA studies and post-PoA studies exhibit a limited scope when investigating BIM adoption within AECO organisations. Consequently, a comprehensive approach is imperative to thoroughly scrutinise BIM adoption within the AECO sector.

4.6. BIM's interaction with AECO organisations before and after PoA

$f = 15$ (or 10%) studies examined AECO organisations' BIM adoption considering the pre- and post-PoA phases together. Nevertheless, these studies lack clarity regarding the decision-making, readiness and after-PoA phases. In this stream, some studies developed a framework of implementation [139], a systemic BIM adoption model [140], BIM implementation steps (specific to a case project) [141], and action research steps for BIM adoption exploration [142,143]. These studies for the most part have considered BIM adoption for specific case organisations [139], or have developed generic models without considering the adoption phase [140].

These studies also identified requirements and changes like those that have considered pre PoA and post PoA. These requirements encompassed top management support [142], training, changes in inter-firm and intra-firm work practices [140], organisational architect roles [144], and change management approaches [142], as illustrated in Fig. 10. Arayici, et al. [142] holistically considered BIM adoption and assessed one architectural organisation's current situation in engaging people in the adoption process, building organisations' capability and introducing change management strategies. However, the study examined only one type of SME. Hence, further exploration is required to examine BIM adoption within AECO organisations, considering both pre- and post-PoA phases.

4.7. BIM technology and materiality

4.7.1. BIM as 'technology in use'

Existing studies observe BIM either as 'technology in use,' or, as 'technology as artefact'. When discussing BIM technology in use, various vases are observed. For instance, Kokkonen and Alin [28] argue that practitioners construct and deconstruct BIM's meaning while using and shaping practices according to convenience. Davies, et al. [5] observed hybrid practices using BIM in combination with traditional ways of working on projects. Due to the multi-disciplinary nature of organisations, the task level of BIM use varies. For instance, managing projects via BIM requires executing different sets of tasks compared to performing design tasks via BIM [13]. Zomer, et al. [137] argue that due to the socio-historical context of work practice, users are prone to return to traditional way of executing tasks. Consequently, the BIM-based work process is difficult to enact. In line with this argument, Brewer and Gajendran [93] assert that conventional work methods have been institutionalised and remain difficult to change. Understanding BIM within AECO organisations is a complex phenomenon as users shape its usage based on the nature of work. In so doing, they reconstruct the meaning of usage and create a wide range of practices incorporating existing working processes [14,29]. Therefore, due to variances in experience, knowledge, institutionalised practices, and disciplinary backgrounds, users encounter a diverse spectrum of experiences when engaging with BIM.

4.7.2. BIM as 'technology as artefact'

Apart from technology in practice, studies also have considered BIM as an artefact (such as BIM execution plan, BIM protocol, and model developing standards). Regarding technology artefacts, BIM has specific rules and processes for executing tasks [14,137]. In contrast to traditional work processes, BIM demands the collaboration of project teams right from project initiation [48]. Object-based modelling requires users to provide detailed information about objects to represent projects accurately. Hence, material artefacts of BIM have specific rules and norms for using object-based elements, work processes and project execution steps [137]. For instance, ISO 19650 guides information processing through BIM [146]. Based on technology artefacts, BIM requires different sets of rules, norms, and work processes for executing projects compared to traditional work methods, where these regulations, standards and artefacts vary based on the nature of the discipline and tasks. Moreover, users may use other complementary technologies in conjunction with BIM in order to execute tasks [147].

The above discussion indicates that existing literature observes BIM both as 'technology as artefact' and 'technology in practice'. Papadonikolaki, et al. [119] support the structuration view of BIM and acknowledges BIM artefacts. However, Dossick, et al. [130] examine BIM via a socio-technical view. Where as Poirier, et al. [7] identify BIM as a disruptive innovation, BIM adoption is more accurately a complex process and a complicated social activity [49,67,69]. Murguia, et al. [140] argue that BIM adoption is a multilayered and contextually influenced process. Shibeika and Harty [15] observe that BIM and its organisational context are continuously changing due to the impacts of BIM diffusion processes. Therefore, BIM adoption is a nonlinear process. Hence, existing literature reveals vigorous debate surrounding different understandings of BIM within AECO organisations.

5. Discussion and research agenda

In alignment with the conceptual framework depicted in Fig. 1, a comprehensive scoping review encompassing 146 studies on BIM adoption within AECO organisations underscores the intricate, multi-faceted, and evolving nature of the BIM adoption process. The ensuing sections encapsulate the overarching insights distilled from the extensive mapping of extant studies on this subject.

5.1. Connecting the dots: a holistic understanding of BIM adoption

Figs. 8, 9, 10, and the synthesised Fig. 11 revealed that certain requirements and changes were repeated. For example, top management support, organisational support, and training programs, are mentioned several times. Similarly, cultural change, organisational process change, and work practice change, are referred to repeatedly. Moreover, studies frequently emphasise training programs. Apart from training, working on shared BIM visions, joint awareness creation, or joint BIM operations are indicated across the adoption process along with the necessity of BIM policy, guidelines, and standards.

Combining all the requirements, changes and tools, Fig. 11 summarises the present synthesised understanding of BIM adoption within AECO organisations.

A synthesis of the findings elucidates that BIM adoption constitutes an ongoing voyage wherein AECO organisations employ diverse tools for informed decision making, introduce a plethora of prerequisites, and undergo a perpetual cycle of transformations, learning, and tool integration. The ensuing sections expound upon the discerned gap in existing knowledge.

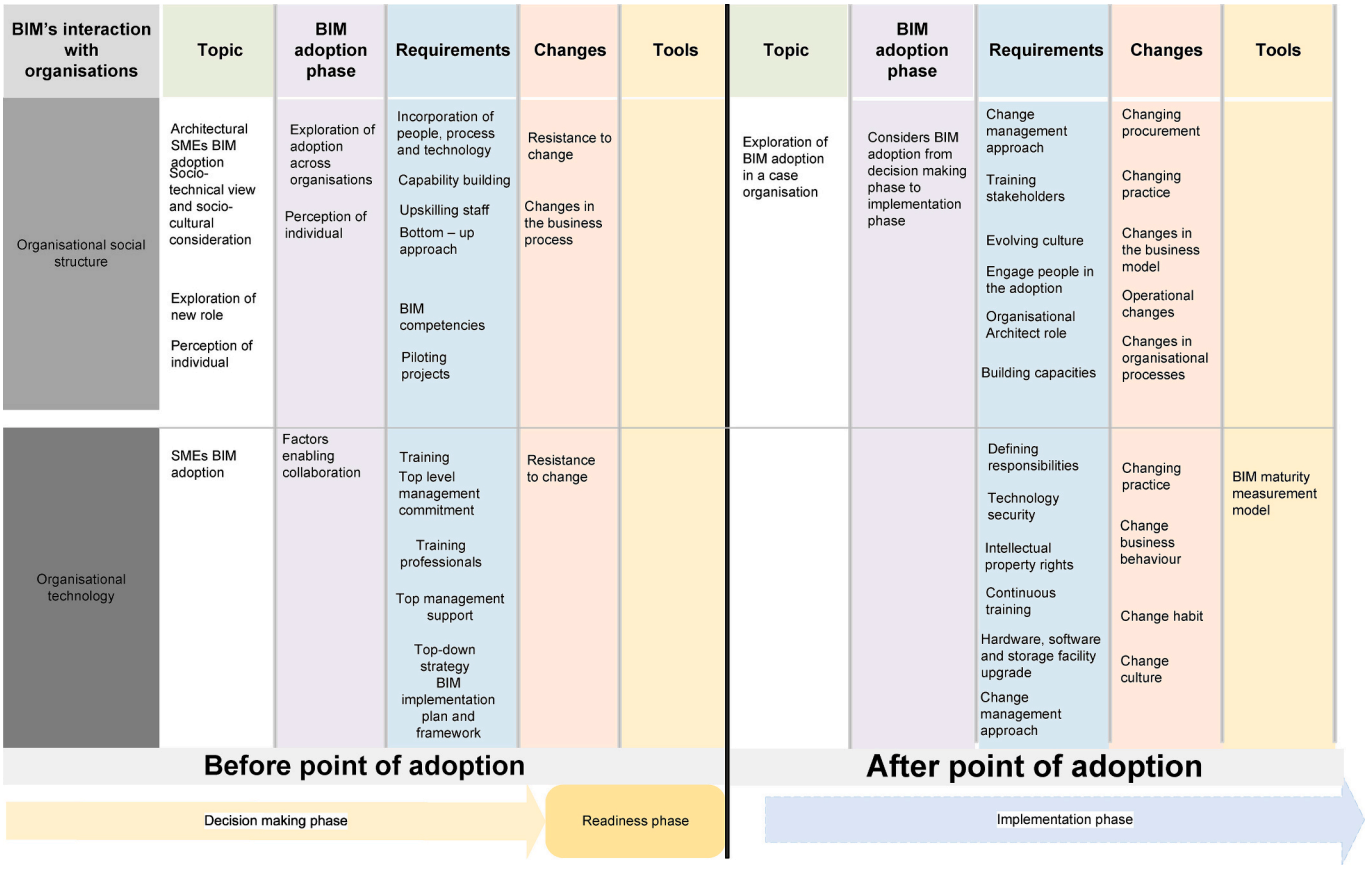


Fig. 10. BIM's interaction with AECO organisations before and after PoA.
BIM's interaction with organisational social structure [142–144] and BIM through technology lens [9139-141,145].

5.2. *Knowledge gaps in the AECO organisations' BIM adoption literature*

A broader understanding of BIM's interaction with AECO organisations during the BIM adoption process uncovered a plethora of studies investigating BIM adoption within AECO organisations, albeit through a tunnel vision approach. Despite identifying key findings, such as the occurrence of changes and the indication of a wide range of requirements and tools, a holistic approach is missing regarding AECO organisations' BIM adoption process. Moreover, the fragmented nature of the industry, unique nature of projects, multi-disciplinary work practices, temporary formation of project teams, and advancement in the BIM technology, overcomplicate the adoption process. The present study identified several existing knowledge gaps, as follows.

5.2.1. *Lack of widely accepted framing of BIM technology within AECO organisations*

Despite several vital studies explaining the perception of BIM technology, a widely accepted framing of BIM technology within AECO organisations remains lacking. Linderoth [33] emphasises the importance of BIM users sense-making of BIM, and Husain, et al. [67] highlights the significance of understanding BIM. Wang, et al. [69] argue that in practice the interpretation of BIM varies, and suppliers take a 'passive wait and see stance'. Therefore, it is essential to clearly articulate the concept of BIM across professionals, organisations, and industry. Chen, et al. [66] argue that an insufficient understanding of BIM creates corporate culture resistance. Thus, a knowledge gap exists in regard to framing BIM technology within AECO organisations.

5.2.2. *Limited knowledge of changes associated with BIM adoption*

Despite highlighting several changes occurring within multiple levels of organisations, the existing literature lacks an in-depth understanding of the changes associated with BIM adoption. Akintola, et al. [14] assert that changes are connected, while Cidik, et al. [29] identified the dynamics of changes. Nevertheless, knowledge on change is still scattered and lacking in coherence. Therefore, further studies are needed to explore the changes in detail.

5.2.3. *Holistic approach to BIM adoption within AECO organisations is missing*

The descriptive and content analysis reveals that existing studies have unevenly explored the BIM adoption phase. Moreover, a selective research approach leads to a scattered and heterogenous understanding of BIM adoption. Hence, a holistic understanding remains wanting. According to Poirier, et al. [7], the adoption and implementation of BIM defy facile categorisation within a singular innovation model. Consequently, a lack of theory exists for exploring the complex and dynamic phenomenon of BIM adoption within AECO organisations. Fig. 7 reflects this lack of a holistic theory. Xu, et al. [145] argue that BIM adoption requires a human, organisational, and technological consideration that takes a holistic perspective.

5.3. *Future research directions*

This study outlines a research agenda for future investigations into BIM adoption within AECO organisations, as depicted in Fig. 12 and elaborated upon below:

The agenda calls for a theoretical contextualisation of BIM within AECO organisations, aiming for an in-depth exploration of the conceptual frameworks that underpin BIM integration. This includes identifying gaps and synergies with existing organisational structures and processes. Additionally, a comprehensive literature synthesis on the evolution of BIM is proposed, focusing on a systematic review that

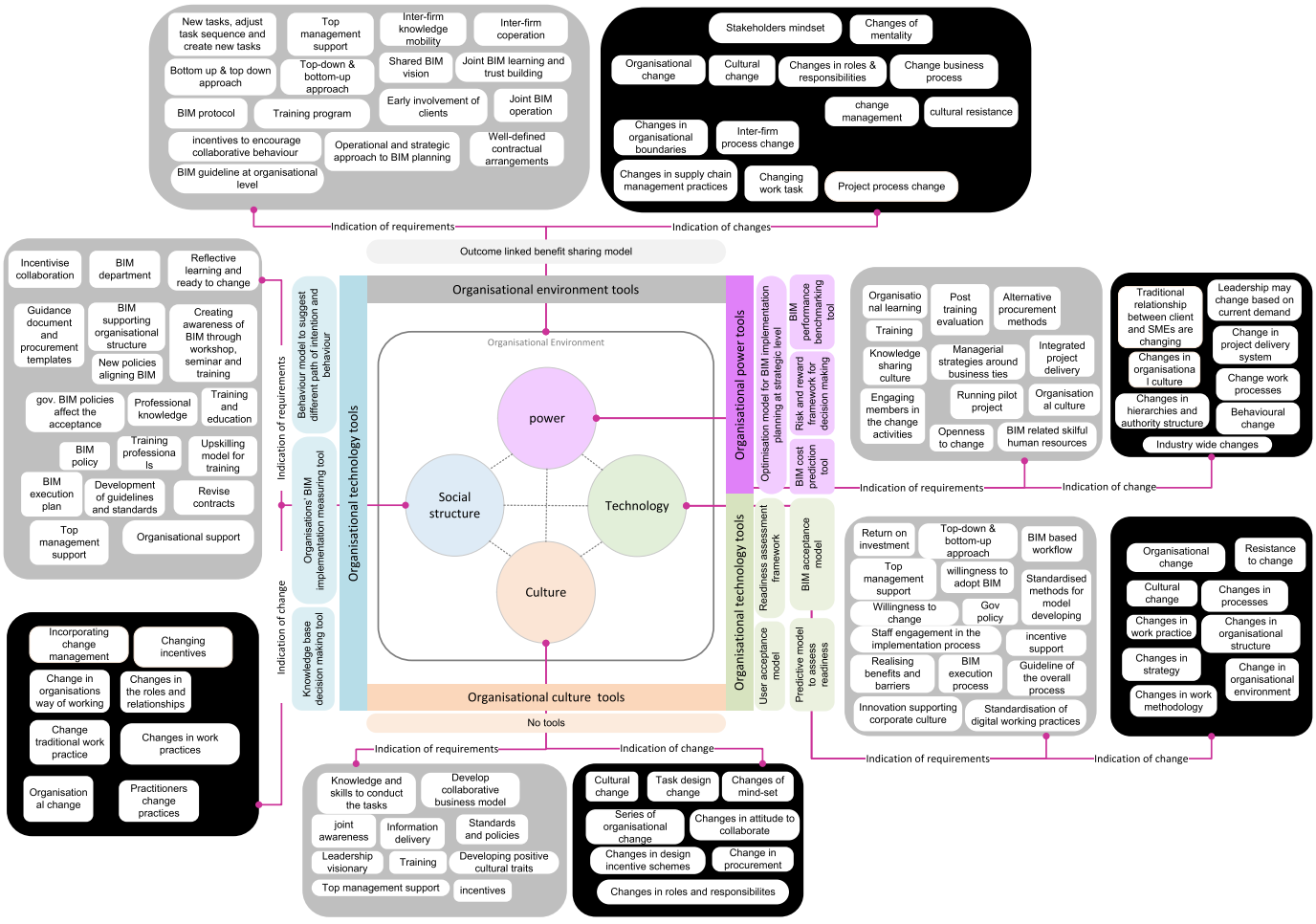


Fig. 11. Synthesised understanding of BIM adoption relevant requirements, changes and tools.

delineates the development of BIM technologies and the corresponding shifts in management practices essential for its adoption in AECO settings.

A holistic examination of BIM adoption in AECO entities is also recommended. This inquiry should consider the amalgamation of requirements, tools, organisational changes, and impacts across all organisational sectors. Furthermore, the development of a robust theoretical framework for analysing the complex, dynamic, and multi-layered processes of BIM adoption is essential. This framework should integrate knowledge from various domains, including organisational change management, information systems, and complexity theory.

Methodological diversification in BIM adoption studies is another key area of focus. Investigating the multifaceted nature of BIM adoption through diverse methodological lenses, such as multi-level analyses and systematic approaches, will capture the intricate dynamics of the adoption process. Finally, empirical investigation of BIM user interactions is crucial. Utilising data from organisational records, historical precedents, and project-specific case studies will enable a comprehensive examination of the complexities of user interaction with BIM technologies. Special emphasis should be placed on the implications for productivity, collaboration, and innovation in the AECO sector.

In summary, current theories on technology adoption do not adequately encapsulate the intricacies of the BIM adoption process, which is complex, dynamic, and operates on multiple levels. As depicted in Fig. 12, the cube symbolises the multi-faceted and fluid nature of BIM adoption. The figure underscores the necessity for a comprehensive approach when examining the adoption of BIM in AECO organisations. Such an approach must encompass an exhaustive spectrum of prerequisites, including the necessary tools and change management strategies essential for the effective implementation of BIM within these organisations.

6. Conclusions

This paper aims to understand BIM's interaction with AECO organisations through a scoping review of the BIM adoption process. The study identifies extant literature that examines AECO organisations' BIM adoption, the majority of which takes a narrow 'tunnel vision' approach. That is, existing studies tend to only explore one dimension of organisations, while overlooking or ignoring other dimensions. However, it is apparent that AECO organisations need a wide range of changes, requirements, and tools, for enabling BIM if multifaceted benefits are to be realised.

This paper presents an insightful examination of the change process inherent in the adoption of BIM. The findings not only contribute a fresh cognitive framework but also establish a discursive arena for fruitful discussions on how research can effectively support organisations in harnessing the advantages of transitioning to BIM-enabled workflows. Recognising the transformative potential of collective BIM implementation, this study underscores the significance of understanding and facilitating the adoption of BIM as a means to shaping the future of the industry.

In addition to its broad contributions, this study presents a significant advancement in the field by introducing a comprehensive framework that encapsulates the intricate, dynamic, and multifaceted nature of the BIM adoption process. The proposed cube model serves as a guide

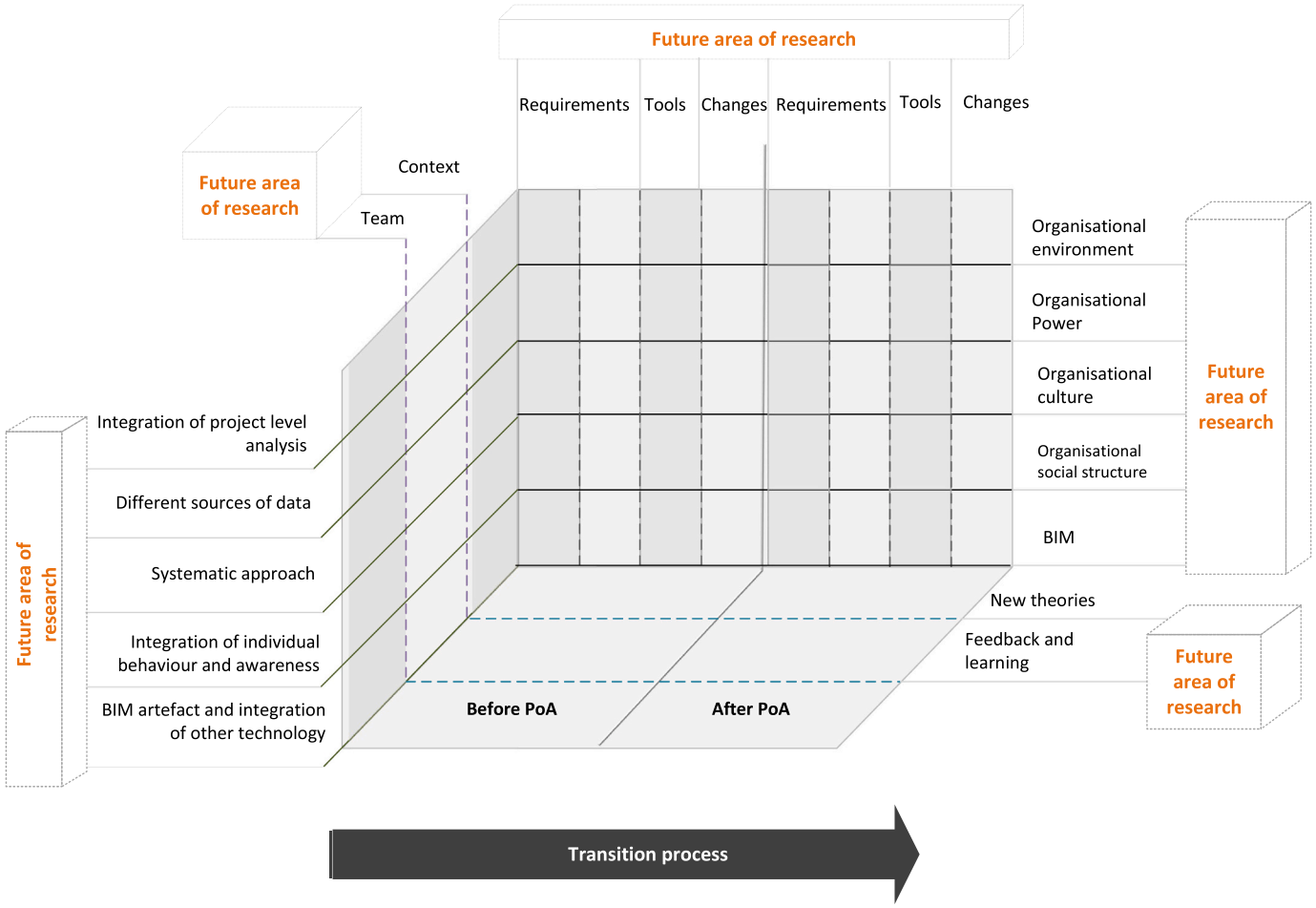


Fig. 12. Research agenda cube indicating different dimension or combined holistic approach to explore BIM adoption.

for future research endeavours, highlighting specific areas that warrant further investigation. It argues for the adoption of a holistic approach in future studies, emphasising the need to consider key elements such as defined requirements, change management strategies, assessment tools, and feedback mechanisms, as well as a continuous learning process, in order to fully facilitate the implementation of BIM within organisations.

So too, the consequences of a fragmented approach are underscored, as it can lead to unintended outcomes and hinder the realisation of the full benefits of BIM. Without concerted efforts, the long-standing productivity issues, and lack of digitalisation faced by organisations will persist and potentially worsen. A persistent, fragmented BIM adoption process may encounter unresolved issues and unforeseen challenges, impeding the industry's progress. Consequently, businesses and the overall industry will lag in harnessing the productivity and performance gains offered by BIM adoption. It is imperative to take proactive measures to address these issues and propel the industry forward towards enhanced productivity and performance through an effective, holistic implementation of BIM.

Notwithstanding its valuable contributions, this study is not without its limitations. Foremost among these is the exclusion of grey literature, which signifies a potential limitation in terms of the breadth and diversity of findings. Additionally, the study did not encompass literature that spans multiple dimensions of organisational contexts, potentially resulting in the omission of certain valuable insights. To address these limitations, future research studies should endeavour to incorporate all forms of publications and extract tacit knowledge from domain experts, thereby enhancing the comprehensiveness and depth of the investigation.

CRediT authorship contribution statement

Mahmuda Chowdhury: Data curation, Formal analysis, Software, Visualization, Writing – original draft. **M. Reza Hosseini:** Conceptualization, Investigation, Validation, Writing – review & editing. **David J. Edwards:** Supervision, Validation, Writing – review & editing. **Igor Martek:** Supervision, Writing – review & editing. **Sarah Shuchi:** Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.autcon.2024.105301.

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