The interplay of IPD and BIM: a systematic literature review

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Abstract

Purpose – Integrated project delivery (IPD) and building information modeling (BIM) have been discussed as prominent collaborative concepts in recent architecture, engineering and construction (AEC) literature, thus recommended for more advanced value creation. However, they have been studied predominantly as discrete even though they are typically highly interrelated. This study aims to enhance collaboration in AEC projects by tracing recent trends in IPD and BIM literature by making sense of trends and by exploring how their interplay has been discussed and conceptualized.

Design/methodology/approach – This systematic literature review draws on Scopus and Web of Science as the primary databases. In total, 120 academic papers and review articles were sourced. Yet, the final sample includes 71 sources from the past decade (2011–2020), focusing on both IPD and BIM.

Findings – This study identifies 11 interrelated and overlapping themes that are indicative of trends in the recent IPD and BIM literature. This research found that among the identified themes, the clusters of sustainability, transformation and increasing the competence level of staff in the AEC industry, in addition to the concept of quality, require more extensive research in the context of IPD and BIM. Additionally, this study identifies four different approaches to the interplay of IPD and BIM, indicating an absence of scholarly consistency.

Originality/value – Based on the systematic analysis of the recent literature, this study indicates that IPD and BIM have several joint fundamental cornerstones. It is evident that both concepts support the implementation of each other. The success of implementing either one is strongly related to the other. Additionally, we have not found earlier systematic literature reviews that examine the interplay between IPD and BIM in the recent AEC literature.

Keywords Architecture, engineering and construction, Systematic literature review, Collaboration, Building information modeling, Integrated project delivery, Interplay

Paper type Literature review

1. Introduction

Chronic low productivity and poor construction project performance have prompted architecture, engineering and construction (AEC) scholars and professionals to search for alternatives to traditional project delivery models and practices (Walker and Rowlinson, 2020a; Eastman *et al.*, 2008). In particular, failures of collaboration and integration, which are crucial for enhancing and managing value creation (Aapaoja *et al.*, 2013), have been identified as some of the main root causes of these performance challenges (Davies and Mackenzie, 2014). However, effective collaboration poses challenges for construction projects, which typically involve high levels of interdependence within and between organizations (Thompson, 1967), and each stakeholder's actions typically affect others (Morris, 2013).

Integrated project delivery (IPD) and building information modeling (BIM) have both been advanced as solutions that enhance integration and collaboration by supporting early involvement of key parties, transparent financials, shared risks and rewards, joint decision making and collaborative multiparty agreement (Lahdenperä, 2012; Hietajärvi, 2017).

Some countries have a relatively more solid background in IPD and BIM (Walker and Rowlinson, 2020a). For instance, the framework arrangements have been used by local councils in the UK for several decades (Khalfan and McDermot, 2006), in addition to the government's target to introduce level 2 BIM to all central government-sponsored projects (Chang *et al.*, 2017). Project partnering as a predecessor of IPD has been used in Australia since 1994 (Sakal, 2005; Morwood *et al.*, 2008) and has been widely adopted in the country soon after the positive experiences (Lahdenperä, 2012). Additionally, positive experiences resulted in ample sources of literature about Alliance Projects as an IPD form in Australia (Walker and Rowlinson, 2020a). However, the use of BIM has not been cemented yet even though IPD has a comparatively strong background (Stride *et al.*, 2020). Overall, despite the considerable promise of IPD and BIM and scarce but significant progress toward their adoption, their full potential is yet to be achieved globally (Azhar *et al.*, 2012; Rowlinson, 2017; Holzer, 2011; Walker and Rowlinson, 2020a).

As key elements of inter-organizational collaboration in AEC practice, IPD and BIM have attracted increasing research interest over the last two decades (Yalcinkaya and Singh, 2015; Walker and Rowlinson, 2020a). However, although closely interrelated in practice, the two methods have typically been investigated separately, with little discussion or conceptualization of their interplay. While these in-depth studies are clearly important, they need to be grounded in a broader overview, especially in what is still a relatively novel area of research. To address this issue, the present study seeks to develop a fuller understanding of the interplay between IPD and BIM, contributing to better collaboration and integration in major construction projects.

Fragmented and disintegrated processes have been identified as the main driver of the paradigm shift from traditional construction practices (Lahdenperä, 2012) to collaborative approaches like IPD and BIM, which the AEC industry sets great store by (Rowlinson, 2017; Elghaish *et al.*, 2019). IPD has been characterized as a highly effective and efficient procurement strategy (Rowlinson, 2017) as compared to traditional project delivery arrangements, which typically involve bi-contractual relationships. The IPD approach provides for a multi-party agreement between the project owner, designer and contractors, with shared risks and rewards and joint goals (AIA, 2010).

One of the most, if not the most, common IPD definitions belongs to AIA (2007):

> [. . .] project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.

However, this definition could classify partly integrated but still traditional project deliveries, such as design-build, as collaborative approaches (Mesa *et al.*, 2019). In this paper, we adopted the definition of AIA (2010) because traditional and collaborative procurement forms are distinguished more explicitly and cover other collaborative delivery forms that Walker and Lloyd-Walker (2015) classified, namely: partnering, integrated project delivery, alliancing, early contractor involvement and framework arrangements.

With the adoption of AIA (2010)'s definition, we used IPD as an umbrella term for the aforementioned collaborative delivery forms that were classified in Walker and Lloyd-Walker (2015). AIA (2010) defines IPD as:

> [. . .] a project delivery method distinguished by a contractual agreement between a minimum of the owner, design professional, and builder where risk and reward are shared, and stakeholder success is dependent on project success.

IPDs are eventualized with the following fundamental principles: multiparty agreement, mutual respect and trust, shared benefits and rewards, collaborative decision making, early involvement of key stakeholders, early goal-setting, intense planning, open communication and effective organization and leadership (Kent and Becerik-Gerber, 2010; Mihic *et al.*, 2014; Cox *et al.*, 2016). Another distinguishing feature of IPD is its particular focus on BIM (Lahdenperä, 2012), which is widely regarded as one of the construction industry's most influential methods (Oraee *et al.*, 2017).

Because BIM has been defined in various ways by different disciplines, there is no agreed definition, either among practitioners or in the literature (Mansoori and Haapasalo, 2019). Watson (2011) takes the discussion of BIM definition to another level and stresses ambiguity in the Building Information Modeling term itself questioning whether the term "Building" in BIM is verb or noun. Building information modeling and information modeling of the building reflect two different approaches toward BIM, namely, BIM as a process and BIM as a product. BIM as a product was viewed as a virtual representation of a building and information database of the whole project lifecycle (Kymmell, 2008; Zuppa *et al.*, 2009), while the stream of research that takes BIM as a process indicates that BIM is beyond being a technological tool and being a change in process with a new way of thinking and behavior (Turk, 2016; Hardin and McCool, 2015). Azhar (2011) defines BIM as a representation of a new paradigm within the AEC industry, one that encourages the integration of all stakeholders roles on a project. Therefore, successful implementation of BIM requires not only a change in technology but also a change in process (Eastmen *et al.*, 2008; Azhar *et al.*, 2012; Sacks *et al.*, 2018). This paper adopts Bryde *et al.* (2013)'s description: BIM can be characterized as an innovative data-driven technology that supports the procurement, construction, pre-fabrication and facilities management aspects of project management.

As a natural consequence of this paradigm shift, IPD and BIM have been widely studied through various theoretical lenses (Yalcinkaya and Singh, 2015; Halttula *et al.*, 2015; Bilge and Yaman, 2021). Although IPD and BIM are natural companions (Azhar *et al.*, 2012), research on the two methods has remained largely discrete. Numerous recent studies (Love *et al.*, 2017; Elghaish *et al.*, 2020a; Mei *et al.*, 2017; Piroozfar *et al.*, 2019; Keskin *et al.*, 2020; Nawi *et al.*, 2014; Sepasgozar *et al.*, 2019) have reported evidence of their mutually reinforcing effect, but the nature of this interplay remains unclear. For example, both Azhar *et al.* (2012) and Chang *et al.* (2017) have argued that BIM is a prerequisite for IPD and lowers barriers to implementation while other studies note the performance-enhancing and value-additive effects of the relationship (Govender *et al.*, 2018; Halttula *et al.*, 2015).

In short, even though IPD and BIM are closely interlinked and have various attributes in common, we surprisingly have not found a systematic literature review that would examine the interplay of IPD and BIM in the recent AEC literature. Thus, the acceleration in the research area invites a systematic review of the existing literature to gain a comprehensive overview of current thinking, with particular reference to the neglected issue of the interplay between IPD and BIM. To that end, the present study addresses the following research questions.

RQ1. What themes can be identified in studies of IPD and BIM over the last decade?

RQ2. How has the existing literature addressed the interplay of IPD and BIM?

To address RQ1, the study sought to identify and categorize themes in the extant literature, including those that have been less extensively researched in addition to making sense of themes and their relation to advanced value creation. To address RQ2, the study explored the relationships between IPD, BIM and other independent variables. The overarching objective was to situate the contribution of IPD and BIM to construction project management in terms of their interplay. By mapping and analyzing the content and themes of relevant publications, we were able to identify underlying trends and links not previously articulated in the literature, and these insights provide an improved foundation for future research.

2. Methodology

The present study contributes to AEC research in two ways: by identifying IPD- and BIM-related themes in the existing literature with exploring the themes' relationship and by clarifying the nature of the interplay of IPD and BIM. The systematic literature review (SLR) methodology was deemed appropriate in light of the study objectives, focusing on peer-reviewed academic papers and review articles published in the last decade. SLR is more systematic, transparent and reproducible than traditional narrative literature reviews (Cook *et al.*, 1997). SLR, originally used extensively in the medical and health care field as the basis for policy decisions, was adopted by organization and management scholars over two decades ago (Cook *et al.*, 1997; Pilbeam, 2013). In addition to outlining the study, reference guides for SLR (Tranfield *et al.*, 2003; Kitchenham, 2004) specify two main phases: performing and reporting. Although the present study differs slightly, it adheres closely to these guidelines (Figure 1).

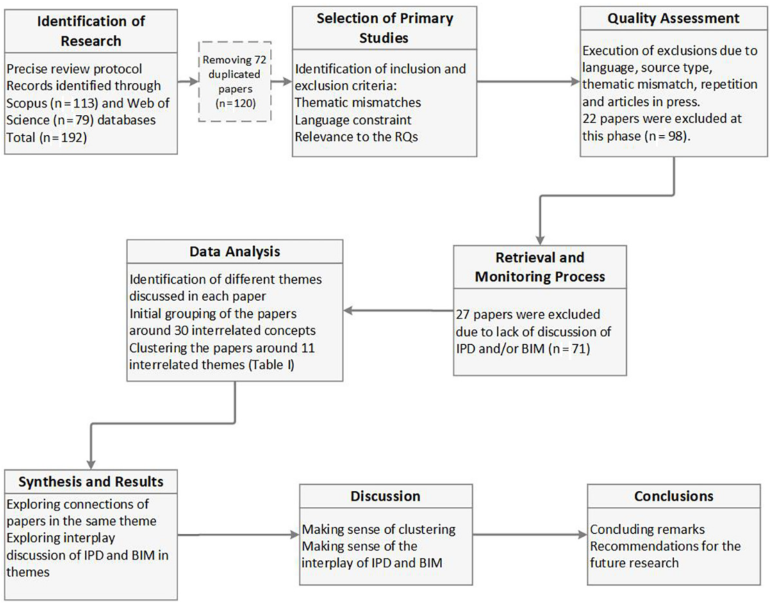

Figure 1.
Research process

Before the performing stage of the study, the existing IPD and BIM literature was scanned by the principal author to identify any research gaps, and the research questions were formulated on that basis. We then specified key search terms and constraints and selected Scopus and Web of Science as primary databases. Although Scopus covers a wider range of construction project management journals (Oraee *et al.*, 2017), the use of both databases extended the range of relevant sources.

Performing a systematic search begins with the identification of key search terms that are as extensive as possible at this stage (Mulrow, 1994). Search strings should be decided in conjunction with search strategy (Tranfield *et al.*, 2003); the first search string was designed to identify academic articles and reviews from the last decade that referred to both IPD and BIM. The search included peer-reviewed articles and reviews but did not extend to conference papers because of their uncertain reliability. To locate papers related to BIM, we used the terms "BIM" and "building information model*". As a second search criterion, we also scanned "IPD" and "integrated project" in abstracts, titles or keywords of papers. The period 2011–2020 was selected because these concepts are relatively new in the field. To be more precise, our search string included all of the collaborative delivery forms specified in Walker and Lloyd-Walker (2015), namely partnering, integrated project delivery, alliancing, early contractor involvement and framework arrangements. IPD is used as an "umbrella term" in this study referring to all the mentioned terms. Additionally, to ensure that we captured studies that used more comprehensive terms to refer to IPD, the string also included "collaborative framework", "collaborative form," "collaborative project delivery" and "collaboration framework." We located 113 studies from Scopus and 79 studies from Web of Science. As 72 papers appeared in both databases, Web of Science provided an additional seven papers. In total, 120 academic papers and review articles were sourced from the two databases. To be more specific, Scopus and Web of Science databases were scanned via the following search strings.

Search string for Scopus:

> TITLE-ABS-KEY (("BIM" OR "building information model*") AND ("integrated project" OR "IPD" OR "partnering" OR "allianc*" OR "early contractor involvement" OR "framework arrangement" OR "collaborative framework" OR "collaborative form" OR "collaborative project delivery" OR "collaboration framework")) AND PUBYEAR > 2010 AND PUBYEAR < 2021 AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")).

Search string for Web of Science:

> TS=(("BIM" OR "building information model*") AND ("integrated project" OR "IPD" OR "partnering" OR "allianc*" OR "early contractor involvement" OR "framework arrangement" OR "collaborative framework" OR "collaborative form" OR "collaborative project delivery" OR "collaboration framework")) AND PY=(2011-2020) AND DT=(Review OR Article).

SLR studies should be based on structured inclusion/exclusion criteria. As these may be relatively subjective, Kitchenham (2004) suggested that this step should be performed by more than one researcher to ensure objectivity. A quality assessment provides more detailed inclusion/exclusion criteria; the term "quality" is a little vague but relates to minimizing bias and maximizing internal and external validity (Kitchenham, 2004). After the first retrieval phase, some papers were excluded based on a language other than English (5), irrelevant discipline (health science) (3) and repetition (4). Additionally, two sources were excluded because they were book chapters, and eight papers were excluded because they were still in press. In total, 22 papers were excluded manually at this stage.

The retrieval and monitoring process involves the design of data extraction forms to record and monitor data retrieved from primary studies (Tranfield *et al.*, 2003). A further exclusion criterion specified that all selected papers must include some meaningful discussion of IPD (or other collaborative project delivery methods) and BIM. Each of the 98 papers was read carefully and 27 studies were excluded that did not discuss at least one of the focal concepts; for example, Chidambaram (2019) was excluded because it mentions "integrated project delivery" three times, but these mentions were descriptive and did not discuss the interplay of IPD and BIM. Following the retrieval and monitoring progress, the research pool contained 71 high quality peer-reviewed academic articles or review papers that discussed both IPD and BIM.

The final element of this phase, data synthesis, collated and aggregated findings related to a topic or research question (Mulrow, 1994). This phase acquires tools and techniques of qualitative data synthesis. The goal was not to create a new theory but to explore how IPD and BIM were comprehended in different contexts, and how their interplay was discussed in different themes. Using Microsoft Excel and Mendeley, the extracted papers were coded and the main discussion areas for each paper were determined. All the discussion points of IPD and BIM interplay were highlighted and collated for each paper. Initially, the papers were grouped around over 30 interrelated concepts and were then clustered around 11 high-level themes. The themes are interrelated and overlapping by their nature, and papers discussed more than one theme in most cases. Yet, the methodology of clustering was seeking the most prominent theme, and enough evidence was always found to cluster each paper in a certain theme. The interplay of IPD and BIM was aggregated, analyzed and analytically synthesized in each theme and overall. Finally, we made sense of clustering of the themes and interplay of IPD and BIM in subsequent chapters.

The areas that need more research were also identified. Rather than taking the measure of the number of articles in each theme, we strived to find gaps or areas of improvement regarding IPD and BIM in their relation to advanced value creation for construction projects. We asked the following questions to spot areas of improvement in IPD and BIM research:

Q1. How many papers does the theme include?

Q2. What are the reasons for coverage of the theme?

Q3. Does the theme receive growing attention in the AEC literature?

Q4. Is the theme discussed at a saturated level under other themes?

Q5. How critical is the theme for advanced value creation in a construction project?

3. Results

Table 1 summarizes the main discussion areas and the number of studies related to each theme, along with references. The sample studies are clustered around 11 interrelated themes, noting data relations and big picture trends under each theme in terms of the interplay of IPD and BIM. In other words, the following 11 interrelated themes emerged from qualitative analysis of the carefully selected 71 research papers and review articles that discussed both IPD and BIM between 2011 and 2020.

3.1 Adoption of integrated project delivery and building information modeling

Papers included in the category "adoption of IPD and BIM" looked for ways to overcome barriers to IPD and/or BIM implementation in construction projects. The exception was Fakhimi *et al.* (2017), who investigated BIM capabilities in another project context (the oil, gas and petrochemical industry), noting that experience of IPD can facilitate BIM adoption.

We also explored whether IPD facilitates BIM adoption (or vice versa). A majority of papers in this cluster clearly identified IPD as an antecedent to BIM (Holzer, 2011; Fakhimi, 2017; Lam *et al.*, 2017; Boon *et al.*, 2019; Li *et al.*, 2019; Salleh *et al.*, 2019); only three studies suggested that IPD and BIM mutually facilitate and strengthen each other (Azhar, 2011; Azhar *et al.*, 2012; Piroozfar *et al.*, 2019). Chang *et al.* (2017) confirmed the positive effects of BIM on IPD adoption and implementation. One study stressed the project owner's (PO) role

Table 1. Themes and main discussion areas that were emerged from the references

Theme emerging from the SLR	Main discussion areas that were combined from the references	No. of sources	References
Adoption of IPD and BIM (Section 3.1)	Small–medium size enterprises, raising awareness, non-building projects, IPD and BIM as enablers, barriers, problems	11	Azhar (2011), Holzer (2011); Azhar *et al.* (2012), Chang *et al.* (2017); Fakhimi *et al.* (2017), Lam *et al.* (2017); Govender *et al.* (2018), Boon *et al.* (2019); Li *et al.* (2019), Piroozfar *et al.* (2019); Salleh *et al.* (2019)
Contractual models for project delivery (Section 3.2)	Legislation, alliance contracts, BIM partnering, framework arrangements, partnering, team integration, comparison of project delivery forms, design-bid-build, design-build, social capital, risk/reward compensation model, risks of IPD	11	Kim and Dossick (2011), Porwal and Hewage (2013); Zhang and Li (2014); Eadie *et al.* (2015), Franz *et al.* (2017); Albano and Di Giuda (2018), Ariffin *et al.* (2018); Bahram (2019), Salim and Mahjoob (2020); Zhang *et al.* (2020), Chen *et al.* (2020)
Cost management and finance (Section 3.3)	Cost estimation, profit distribution, activity-based costing, earned value management, 5 D BIM and integration with 4 D BIM, blockchain technology, change orders	8	Harrison and Thurnell (2015), Love *et al.* (2017); Ma *et al.* (2017), Teng *et al.* (2019); Elghaish *et al.* (2019; 2020a, 2020b); Elghaish and Abrishami (2020a)
Sustainability (Section 3.4)	OptEEmAL, IPD and BIM as sustainability tools, sustainable building design, sustainable socio-cultural benefits of IPD and BIM	7	Bynum *et al.* (2013), Wong and Fan (2013); Oduyemi *et al.* (2017), Cohen and Snell (2018); Ma *et al.* (2018b); Maskil-Leitan and Reychav (2018); García-Fuentes *et al.* (2019)
Technology (Section 3.5)	IPD as BIM's eventual goal, KanBIM quality control system, model-driven software engineering	7	Isikdag (2012), Goulding *et al.* (2014); Hiyama *et al.* (2014), Monteiro *et al.* (2014); Liu and Shiv (2017); Götz *et al.* (2020); Keskin *et al.* (2020)
Collaboration (Section 3.6)	Collaboration platform, knowledge exchange, intensive Big Room, drivers of collaborative behavior, rent-seeking behavior, motivations for hazard behavior, incentive payments/penalties	6	Alhava *et al.* (2015), Ma and Ma (2017); Mei *et al.* (2017), Staykova and Underwood (2017); Ma *et al.* (2018a); Du *et al.* (2019)
Increasing the competence level of staff in the AEC industry (Section 3.7)	Incorporating IPD and BIM in the AEC curriculum, pilot programs, construction collaboration process	5	Forgues and Becerik-Gerber (2013), MacDonald and Mills (2013); Solnosky *et al.* (2014, 2015); Jin *et al.* (2020)

(*continued*)

Theme emerging from the SLR	Main discussion areas that were combined from the references	No. of sources	References
Supply chain integration (Section 3.8)	Supply chain partnership, types of supply chain partnering, prefabrication, off-site construction	5	Papadonikolaki *et al.* (2016), Li *et al.* (2017); Papadonikolaki and Wamelink (2017), Hall *et al.* (2018); Jin *et al.* (2018)
Early integration (Section 3.9)	Facilities management, fragmentation, integration of construction in design, BIM as a catalyst, early involvement	4	Nawi *et al.* (2014), Mayo and Issa (2016); Olatunji and Akanmu (2015), Pishdad-Bozorgi *et al.* (2018)
Scheduling (Section 3.10)	Four-dimensional BIM, delay, activity-based costing, scheduling and cost performance of IPD coupled with BIM and lean construction	4	Umar *et al.* (2015), Nguyen and Akhavian (2019); Sepasgozar *et al.* (2019); Elghaish and Abrishami (2020b)
Transformation (Section 3.11)	Industrial transformation, liminal roles, exemplar projects	3	Kraatz *et al.* (2014), Rowlinson (2017); Gustavsson (2018)

Table 1.

in barriers to IPD and BIM (Govender *et al.*, 2018). Specifically, the study identified the main barriers as PO's resistance to change and failure to identify the benefits of IPD and BIM adoption, and raising awareness was seen as the first step in addressing this issue (Govender *et al.*, 2018). Although IPD and BIM are mutually reinforcing, Holzer (2011) drew attention to the use of IPD as a "buzzword" and as an excuse for BIM's shortcomings, citing this as one of the seven "deadly sins" of BIM uptake.

Two studies focused in particular on BIM adoption in small and medium-sized enterprises. According to Li *et al.* (2019), lack of awareness of BIM is one of the barriers to adoption, and IPD was identified as a key strategy in this context. Lam *et al.* (2017) referred to IPD as a way for small and medium-sized enterprises to maximize benefits and minimize risks when adopting BIM.

Adoption of IPD and BIM is one of two clusters in which a majority of papers identify IPD as enabling BIM adoption to overcome challenges (Salleh *et al.*, 2019; Boon *et al.*, 2019; Piroozfar *et al.*, 2019; Fakhimi *et al.*, 2017) and increasing the chances of realizing BIM's full potential (Holzer, 2011).

3.2 Contractual models for project delivery

As well as the role of IPD in reinforcing BIM or vice versa, this category also includes studies that compare different contractual models for project delivery in terms of their coherence with BIM. The creation of a separate cluster for "contractual models for project delivery" reflects these papers' more detailed discussion of project delivery forms and characteristics.

These sources represent a different approach to BIM, in which even tough BIM was commonly referred to as a process (Porwal and Hewage, 2013; Eadie *et al.*, 2015; Franz *et al.*, 2017; Ariffin *et al.*, 2018; Bahram, 2019). BIM was also discussed as a tool (Kim and Dossick, 2011; Zhang and Li, 2014; Salim and Mahjoob, 2020) or as a technology (Chen *et al.*, 2020; Zhang *et al.*, 2020) in this context. Only Albano and Di Giuda (2018) characterized BIM as an approach, focusing on relational contracting and how IPD can enhance BIM by aligning with Italian legislation. Legislation and regulations were identified as the main source of risk for BIM-based IPD projects, as few laws and regulations take account of collaborative concepts (Chen *et al.*, 2020).

Among the contractual models discussed and compared under this heading, Bahram (2019) argues that alliance contracts afford greater collaboration through BIM, and Porwal and Hewage (2013) propose a "BIM partnering" procurement framework to achieve "best value." Zhang and Li (2014) also compare IPD and project alliance, arguing that IPD is a more advanced procurement model because it encourages early BIM adoption and facilitates the implementation of a risk/reward model of compensation. Exploring the proliferation of different project delivery forms and their alignment with BIM, Eadie *et al.* (2015) identify design-build (DB), framework arrangements, design-bid-build and partnering as the UK's most common delivery forms, noting that BIM users are more comfortable with DB. In Salim and Mahjoob's (2020) study, 14% of respondents confirmed that they used IPD, and a majority of respondents acknowledged BIM's coherence with IPD.

Finally, Kim and Dossick (2011), Franz *et al.* (2017) and Zhang *et al.* (2020) reviewed IPD and BIM in terms of teamwork. According to Franz *et al.* (2017), team integration is the link between project delivery method and performance, noting that while project delivery method did not have a direct effect on performance measures, IPD has a significant influence on team integration, which leads in turn to better performance. Kim and Dossick (2011) and Zhang *et al.* (2020) also emphasized IPD's direct positive effect on teamwork effectiveness. All asserted that BIM does not create integrated teams but reinforces project team integration (Kim and Dossick, 2011; Franz *et al.*, 2017; Zhang *et al.*, 2020). While IPD and BIM clearly affect teamwork, implementation of both concepts requires a degree of trust and technological capability within the supply chain (Ariffin *et al.*, 2018; Zhang *et al.*, 2020). In particular, Ariffin *et al.* (2018) found that IPD's BIM focus poses challenges for project managers and recommended that the construction industry should introduce IPD and BIM gradually, with support from government agencies.

Most of these studies discuss the interplay of IPD and BIM in sequential terms in the context of contractual models for project delivery and most characterize IPD as enabling BIM rather than vice versa.

3.3 Cost management and finance

This category, which includes eight papers, is among the most widely studied themes in IPD and BIM research. These papers focus predominantly on improving cost management and profit distribution and on combining various tools to achieve better financial results. IPD projects were seen to lack any accurate cost estimation methodology at the front-end of projects (Elghaish *et al.*, 2019) and fair profit distribution (Teng *et al.*, 2019) was identified as the key weakness in IPD cost management (Elghaish and Abrishami, 2020a). Discussion of IPD's cost management deficiency invoked integration of several concepts (Elghaish *et al.*, 2020b). By way of defense, Love *et al.* (2017) argued that cost certainty improved when BIM was coupled with IPD. However, this coupling alone cannot ensure more successful cost management, and integrating BIM with earned value management (EVM), activity-based costing (ABC) and blockchain technology were proposed as ways to improve cost estimation and ease financial transactions in IPD projects (Elghaish *et al.*, 2019; Elghaish *et al.*, 2020a). In particular, EVM and ABC were seen to support risk/reward sharing in IPD (Elghaish *et al.*, 2019).

Additionally, Harrison and Thurnell (2015) confirmed that IPD facilitates full exploitation of 5 D BIM and Elghaish *et al.* (2019) noted that integrating five-dimensional BIM with four-dimensional BIM supports optimal structuring of IPD's direct, indirect and overhead costs. Integration of BIM with blockchain technology was advocated as a means of improving control and tracking of financial transactions in IPD projects, so building trust among the involved parties (Elghaish *et al.*, 2020a). BIM-based IPD projects were also said to perform well in relation to cost overruns, which are all too common in construction projects (Love *et al.*, 2017; Ma *et al.*, 2017; Elghaish *et al.*, 2019). Acknowledging that change orders are a key reason for cost overruns, Ma *et al.* (2017) noted that BIM assists discovery of change orders before the construction stage and that IPD is effective in eliminating change orders. In conclusion, a majority of papers in this cluster viewed BIM as enabling IPD by easing information processing and promoting trust and collaboration, especially when juxtaposed with ABC, EVM and blockchain technology.

3.4 Sustainability

A majority of the papers reviewed here examined the sustainability of a particular project life cycle stage; four focused on building design (García-Fuentes *et al.*, 2019; Wong and Fan, 2013; Oduyemi *et al.*, 2017; Cohen and Snell, 2018) while two pursued a more comprehensive approach (Ma *et al.*, 2018b; Bynum *et al.*, 2013). All of these studies discuss IPD and BIM as a sustainability tool or practice rather than as an evolving process. However, one study (Bynum *et al.*, 2013) reported that practitioners perceive BIM's primary concerns as coordination and visualization rather than sustainability. Overall, it is worth noting that all of these studies agree that IPD and BIM contribute significantly to sustainability either through focusing on building design, procurement or overall.

Addressing the sustainable socio-cultural benefits of IPD and BIM, Maskil-Leitan and Reychav (2018) highlighted the importance of corporate social responsibility in BIM-enabled IPD projects. One article described the implementation of a tool (OptEEmAL) developed to improve the energy efficiency of the retrofitting design process (García-Fuentes *et al.*, 2019). The study also identified five pillars for the successful application of the tool, including IPD and BIM.

Four of the seven studies in the sustainability category acknowledged BIM's role as an enabler for IPD rather than vice versa. According to Wong and Fan (2013) and Oduyemi *et al.* (2017), IPD was "the benefit" of using BIM for sustainable building design.

3.5 Technology

Studies classified under this heading discuss how technological aspects of IPD and BIM facilitate early involvement through their ability to create intelligent input in early phases. These features accelerate frontloading of the design stage, which is seen to enhance overall productivity (Hiyama *et al.*, 2014). In this context, BIM is seen as a modeling tool for developing and enabling intelligent inputs (Goulding *et al.*, 2014), with IPD as the eventual goal of BIM (Götz *et al.*, 2020; Keskin *et al.*, 2020; Goulding *et al.*, 2014). However, Monteiro *et al.* (2014) noted that IPD was subject to change, both structurally and in terms of the functionalities of supporting applications, raising the issue of full integration of graphic (BIM) and written technical information as automated processes. From another perspective, Isikdag (2012) noted that BIM goes beyond providing information management support for IPD, as the BIM process continues even after demolition and supplies knowledge for future projects.

Liu and Shiv (2017) reported that the KanBIM system increases the efficiency of quality control and suggested that large and complex projects should adopt IPD to increase the likelihood of success in this regard. A review of the literature on model-driven software engineering in construction (Götz *et al.*, 2020) found that BIM was a natural choice for model-driven software engineering. In general, papers in this category come closest to a consensus regarding the interplay of IPD and BIM and the vast majority of these scholars supported the view that BIM is a key enabler for IPD or that IPD is the ultimate goal of BIM.

3.6 Collaboration

Two streams of research predominated in the "collaboration" cluster: developing collaboration platforms and improving collaborative behavior among stakeholders. Three of the studies (Alhava *et al.*, 2015; Ma and Ma, 2017; Ma *et al.*, 2018a) focused on developing the collaboration platform. In their study of knowledge exchange for collaborative performance assessment, Staykova and Underwood (2017) proposed a tool based on 20 characteristics of knowledge exchange for use in BIM-based IPD projects where collaboration is among the main goals. One study (Alhava *et al.*, 2015) proposed the use of an "intensive big room" to extend BIM beyond design to construction to facilitate IPD. They described this setup as a combination of BIM, integrated concurrent engineering and big room approaches (Alhava *et al.*, 2015). Exploring the need to develop an alternative to BIM servers and the "high-resource consuming" big room, Ma and Ma (2017) proposed a BIM-based collaboration platform to promote IPD adoption.

The second main research stream in this category deals with behavioral issues. Mei *et al.* (2017) showed that BIM-enabled IPD effectively reduces rent-seeking behavior. Du *et al.* (2019) showed that the use of incentive payments and penalties was strongly negatively correlated with hazard behavior as an underestimated failure factor for BIM applications in IPD projects. The paper (Du *et al.*, 2019) also noted that IPD and BIM were inseparable and highly interdependent. In general, most of these sources viewed BIM as enhancing IPD, either as a standalone tool or in combination with concepts like Big Room and integrated concurrent engineering.

3.7 Increasing the competence level of staff in the architecture, engineering and construction industry

The cluster of 6 studies in this category arguably indicates a pressing need to rethink AEC education in this area. According to Solnosky *et al.* (2014), the AEC industry is generally concerned that the current generation of professionals has limited knowledge of IPD and BIM. On that basis, Jin *et al.* (2020) and Solnosky *et al.* (2014) argue that academia must create appropriate pathways for the next generation of AEC professionals, adding to the existing pressures on academia following drastic changes in the industry (Forgues and Becerik-Gerber, 2013).

However, MacDonald and Mills (2013) note that academia faces certain difficulties in implementing proposals to integrate IPD and BIM in the AEC curriculum. In 2014, Penn State University successfully implemented an IPD- and BIM-influenced capstone pilot course to respond to industry needs (Solnosky *et al.*, 2014). The pilot program was so successful that it was repeated the following year (Solnosky *et al.*, 2015). After five years from Solnosky and his colleagues' (2014; 2015) studies, Jin *et al.* (2020) suggested the "Constructivism Collaboration Process" for IPD and BIM collaboration education.

In this context, several (Solnosky *et al.*, 2014, 2015; Forgues and Becerik-Gerber, 2013; Jin *et al.*, 2020) stressed that BIM enhances the IPD project life cycle and facilitates IPD goals and a more realistic IPD environment while IPD paves the way for more effective BIM implementation. Together, according to MacDonald and Mills (2013), IPD and BIM promise to improve construction project productivity.

3.8 Supply chain integration

The two main research streams in this category focused on supply chain partnership (Papadonikolaki *et al.*, 2016; Papadonikolaki and Wamelink, 2017; Hall *et al.*, 2018) and off-site construction (Li *et al.*, 2017; Jin *et al.*, 2018). In addition to IPD, "supply chain partnering" was also acknowledged as a delivery arrangement (Papadonikolaki *et al.*, 2016; Papadonikolaki and Wamelink, 2017). Framed as a supply chain integration practice, BIM was said to increase systematic innovation when applied in conjunction with IPD (Hall *et al.*, 2018), and one study reported that BIM-enabled supply chain partnering exhibited a distinct pattern of collaboration (Papadonikolaki *et al.*, 2016). According to Papadonikolaki and Wamelink (2017), BIM-enabled supply chain partnering may emphasize transactions or relations; the former is described as operational partnering and the latter as strategic partnering.

One study (Li *et al.*, 2017) showed that IPD and BIM have a significant impact on the successful implementation of prefabrication. Based on a review of the off-site construction literature for the period 2008–2018, Jin *et al.* (2018) confirmed that more research is warranted on the integration of IPD and BIM with off-site construction. More generally, a majority of studies in this category acknowledged BIM's role as an IPD enabler, and their joint role in facilitating off-site construction and prefabrication was also highlighted.

3.9 Early integration

Studies of early integration related to either inclusion of the facilities management stage or the construction stage into the design stage, focusing in particular on comprehensive design decisions and resolving inter-stage fragmentation. IPD and BIM were viewed as catalysts for process change in the AEC industry (Mayo and Issa, 2016). Even when not fully applied, the IPD philosophy was seen to improve collaboration by involving later-stage representatives earlier in the process (Pishdad-Bozorgi *et al.*, 2018). When coupled with BIM, this was seen to resolve fragmentation, as well as push designers (Olatunji and Akanmu, 2015) and owners (Mayo and Issa, 2016) to fulfill facilities management needs in the early stages of projects. In terms of interplay, this is the only category in which neither BIM nor IPD was characterized as the dominant enabler. Instead, they were seen to contribute jointly to reduced fragmentation by encouraging designers to gather the necessary information earlier.

3.10 Scheduling

Scheduling is a primary theme with a mere four articles. Given the significant incidence of delays in the AEC industry, scheduling might be thought of as an under-researched area at first glance. Yet, the theme of scheduling was discussed within the theme of cost management and finance as well (Harrison and Thurnell, 2015; Elghaish *et al.*, 2019). Thus, we did not classify scheduling as an under-research area.

Examining the synergistic effects of IPD, BIM and lean construction on schedule and cost performance, Nguyen and Akhavian (2019) found that these have a greater impact on the former. Sepasgozar *et al.* (2019) studied overlooked delaying factors in the AEC sector and referred to IPD and BIM in relation to the "overlooked effect of digital technologies." Describing an ideal strategy for optimizing tools for IPD, Umar *et al.* (2015) highlighted the importance of four-dimensional BIM. Elghaish and Abrishami (2020b) argued for the need to improve four-dimensional BIM and suggested coupling it with ABC to support IPD adoption. Two of the four studies in this category (Umar *et al.*, 2015; Elghaish and Abrishami, 2020b) referred to the interplay issue, characterizing BIM and especially four-dimensional BIM, as an enabler for IPD in the context of scheduling.

3.11 Transformation

Given the radical changes in the AEC industry, the theme of transformation was under-represented, yielding only three articles. While two of these (Kraatz *et al.*, 2014; Rowlinson, 2017) addressed industry-wide transformation, Gustavsson (2018) examined change in terms of the liminal roles of partnering manager, building logistic specialist and BIM coordinator. Both Kraatz *et al.* (2014) and Rowlinson (2017) suggested the creation of government steering agencies to facilitate industrial transformation and implementation of exemplar projects to promote IPD and BIM.

Rowlinson (2017) and Kraatz *et al.* (2014) discussed the interplay of IPD and BIM, but Gustavsson's (2018) position was unclear, as the paper discussed related roles but did not deal with IPD and BIM at a conceptual level. While Rowlinson (2017) was clear that BIM merely enables IPD, Kraatz *et al.* (2014) characterized the interplay as reciprocal and related the effects to industry transformation, noting that IPD leverages BIM while IPD is the final stage and ultimate goal of BIM.

4. Discussion

In attempting to deepen the existing understanding of IPD and BIM and their interplay, the present study makes two main contributions. First, the state of IPD and BIM research was elucidated, using SLR to cluster relevant papers from the extant IPD and BIM literature around 11 overlapping but distinct themes: adoption of IPD and BIM, contractual models for project delivery, cost management and finance, sustainability, technology, collaboration, increasing the competence level of staff in the AEC industry, supply chain integration, early integration, scheduling and transformation. Furthermore, meta-level analysis of the themes was carried out for the sake of advanced value creation in construction projects (Figure 2) and areas of improvement were spotted. Second, we explored the interplay of IPD and BIM more fully than previous SLR studies that treated these as standalone concepts (Yalcinkaya and Singh, 2015; Oraee *et al.*, 2017) by including both IPD and BIM as focal elements of the review.

As shown in Table 1, the most extensively studied research themes were adoption of IPD and BIM, contractual models for project delivery, cost management and finance, sustainability and technology. As well as IPD, we discussed features of other collaborative delivery forms like project alliances under contractual models for project delivery category. We found that many studies compared collaborative delivery forms with partially collaborative forms like DB and traditional delivery forms in terms of their alignment with BIM. Overall, we can conclude that IPD's focus on BIM ensures clear advantages over other project delivery forms in terms of coherence.

Beyond their role as collaborative methods, IPD and BIM were discussed as sustainable (Oduyemi *et al.*, 2017) and technological (Götz *et al.*, 2020; Isikdag, 2012) methods, highlighting their multidimensionality. Most of the reviewed studies advocated the coupling of IPD and BIM; additionally, some referred to the need to incorporate complementary methods such as ABC, EVM and target value design to enhance cost management performance. Another extensively discussed theme was adoption of IPD and BIM. Academic dissatisfaction with industry adoption of IPD and BIM focused on the associated barriers and complexities, which seem likely to remain a hot topic for the foreseeable future. Our review identified a significant number of good studies highlighting the neglect of emerging concepts like IPD and BIM in the AEC curriculum (Forgues and Becerik-Gerber, 2013; Solnosky *et al.*, 2014, 2015), as reflected in the limited knowledge of these approaches among current practitioners. The themes of early integration and supply chain integration were also discussed in relation to the longstanding issue of construction project fragmentation (Fellows and Liu, 2012), which has clearly preoccupied researchers over the last decade. Because they prioritize early involvement, IPD and BIM have been identified as effective solutions to the challenges of fragmentation (Nawi *et al.*, 2014; Pishdad-Bozorgi *et al.*, 2018). In particular, IPD and BIM were seen to counter designers' supposed hegemony in the early design phase by requiring them to involve contractors and facility managers in design decisions. The discussion of integration in this context extends beyond the design phase all the way back to the supply chain. Li *et al.* (2017) and Jin *et al.* (2018) linked IPD and BIM to the themes of prefabrication and off-site construction, and Papadonikolaki *et al.* (2016) recommended BIM-oriented supply chain partnerships.

Among the smaller clusters, it seems clear that more research is needed on the theme of transformation. Although the AEC sector is lagging behind other sectors in productivity terms and is under pressure to change, surprisingly few studies emphasized the issue of transformation in the context of IPD and BIM. We contend that a structured process of transformation can shift the prevailing traditional paradigm to IPD- and BIM-enabled collaborative projects. The theme of *scheduling,* as a primary theme, involves a limited number of papers in IPD and BIM research, especially considering the fact that delays are such a common feature of construction projects (Sepasgozar *et al.*, 2019). Yet, scheduling is highly connected to cost and discussed extensive enough in the cluster of cost management and finance as a secondary focus (Harrison and Thurnell, 2015; Elghaish *et al.*, 2019), thus we did not include scheduling to the group of themes that need more research in this study.

Based on the systematic analysis of the recent literature, this study indicates that IPD and BIM have several joint fundamental cornerstones. It is also evident that IPD and BIM support the implementation of each other. Furthermore, the success of either one is strongly related to the other. However, this relation does not mean that they cannot be implemented without another. For instance, BIM can be implemented without collaboration, merely as a tool of transferring data and design specifications, yet this study confirms that its full potential will not be exploited without integrated delivery models. Conformably, IPD can be implemented without BIM, however, collaboration in BIM results in better performance in AEC projects. Individual implementation of IPD or BIM results in only partial benefits. In a nutshell, synchronous implementation of IPD and BIM advances value creation through the concepts that have been presented in Figure 2. The themes and their relation toward advanced value creation presented in Figure 2 emerged from the synthesis of the analysis of IPD and BIM interplay in the recent literature.

Beyond the identified themes being interrelated and overlapping, we recognized the upstream root-cause relationship for advanced value creation of construction projects (Figure 2), which will be a significant area of further research and efficiency improvement at a practical level. One of the main practical benefits of IPD and BIM is shifting focus from parts to the entity. AEC projects have been suffering from fragmentation severely (Nawi *et al.*, 2014; Pishdad-Bozorgi *et al.*, 2018), while the practical implication of this contribution generates focus to the final cause, namely, advanced value creation, instead of suboptimization. One very fruitful avenue for this has been turning the revenue logic of suppliers depending on the quality of final end-result (Hietajärvi *et al.*, 2017). Comparably, as a theoretical implication, the former requires research on a more detailed root-cause relationship how and through which logic value creation will be improved. The earlier the mechanism starts to work the better the end-result will be, as can been from Figure 2 as well.

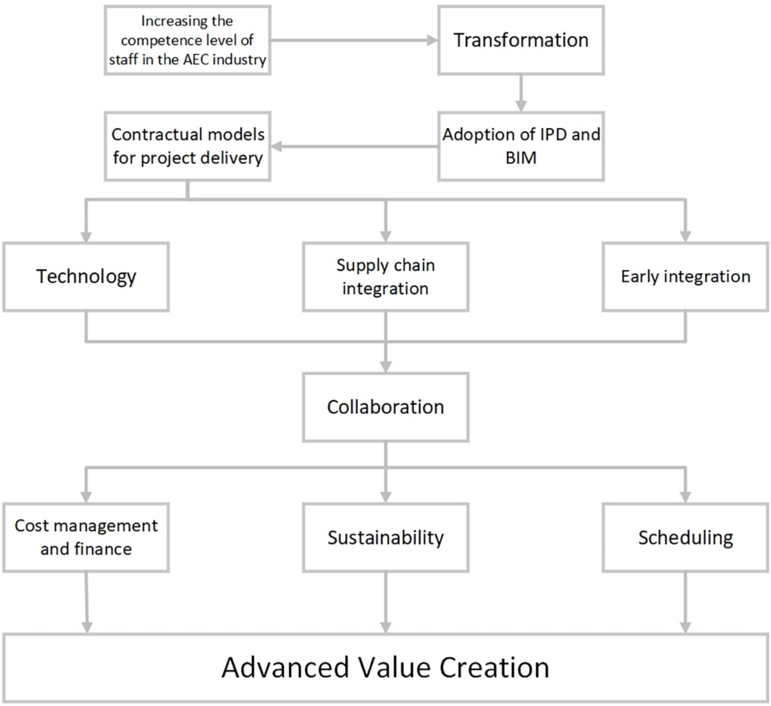

Figure 2.
Synthesis of the analysis of IPD and BIM interplay in the literature

Value creation is often measured by key performance indicators (KPI) (Moradi *et al.*, 2021). The themes of cost management and finance, sustainability and scheduling are directly connected to advanced value creation in the context of IPD and BIM and are classified as KPIs. Even though project performance can be measured by different combinations of KPIs (Moradi *et al.*, 2021), one of the most accepted bundles consists of cost, time and quality, namely the "iron triangle" (Walker and Rowlinson, 2020b). Even though scheduling consists of a limited number of articles, the theme was discussed in the cost management and finance cluster as well (Harrison and Thurnell, 2015; Elghaish *et al.*, 2019) because time and cost are inseparable KPIs for construction projects (Nguyen and Akhavian, 2019).

We found a mere one article wherein quality was one of the main focal concepts (Liu and Shiv, 2017), thus more research is called for IPD and BIM's relation to project quality which is one of the three pillars of the "iron triangle". Sustainability has been associated with project performance and has often been discussed as KPI especially in recent years (Silvius and Schipper, 2016). The sustainability theme involves a considerable number of articles in the context of IPD and BIM, still, this theme is identified as an area of improvement considering the growing attention of the AEC industry. We believe that what IPD and BIM can offer for sustainability and how IPD and BIM can be improved in terms of sustainability require more exploration.

Collaboration, particularly between key stakeholders, plays a vital role in improved KPIs in construction projects (Staykova and Underwood, 2017). We found that the technological maturity of construction projects has a high potential to facilitate early collaboration and connectivity between major stakeholders, supported by an integrated supply chain and early integration of later construction phases. While technological infrastructure paves the way for team collaboration and integrated process in construction projects (Goulding *et al.*, 2014; Papadonikolaki and Wamelink, 2017), supply chain integration practices intend to organize information, process people and/or firms for the purpose of collaboration among the whole supply chain (Hall *et al.*, 2018). Thus, an integrated supply chain expresses a clear vision for collaboration (Papadonikolaki *et al.*, 2016). Early integration of later phases, such as facilities management, to the design phase increases collaboration from the very beginning (Pishdad-Bozorgi *et al.*, 2018). In this way, early amendments are aimed to be used throughout the project time span and risks and opportunities are aimed to be managed from the outset of construction projects.

When advanced value creation is aimed to be achieved through collaboration, IPD's stress on the integrated process and BIM as a process and technology make IPD an obvious choice among other project delivery forms in our sample (Zhang and Li, 2014). However, the benefits of IPD and BIM come with preconditions in both industrial and organizational levels (Govender *et al.*, 2018) that led researchers to search for ways to overcome barriers to adopting IPD and BIM. Despite the paradigm shift from traditional project environment to collaborative construction project management, the theme of transformation did not receive enough attention from IPD and BIM researchers in the last decade.

We believe that paradigm shift requires a systematic framework steered by governmental agencies and stakeholders of the AEC industry should be encouraged to adopt IPD and BIM and collaborate at a higher level. Yet, the transformation can be proceeded by only competent staff, thus numerous studies strive to find ways to increase the competence level of staff in the AEC industry that reveals the current low level of competence. However, because of the critical position of the theme and one-dimensional discussion, we defend that different aspects of increasing the level of competence of staff should be discussed. Overall, we believe there is a need for more research in transformation, sustainability, increasing the competence level of staff in the AEC industry and quality. We call for more research in creating new collaboration-centered roles in the AEC industry. Additionally, we found numerous articles that strive to improve the curriculum in AEC education in terms of collaboration (Jin *et al.*, 2020; MacDonald and Mills, 2013; Solnosky *et al.*, 2014, 2015; Forgues and Becerik-Gerber, 2013), which is crucial to increase the competence level of staff for future. However, we as researchers explicitly need to find ways to increase the competence level of the current staff as well because the transformation process cannot exclude them, at least in near future.

As mentioned earlier, the other main objective of the present study was to explore the interplay between IPD and BIM. In this regard, insights from existing studies clearly depended on the researchers' perspective. Existing scholarly inconsistency on BIM description (Kymmell, 2008; Zuppa *et al.*, 2009; Turk, 2016; Hardin and McCool, 2015) continues in our sample papers as well. Studies that treated IPD and BIM separately tended to view BIM as a tool (Kim and Dossick, 2011; Zhang and Li, 2014; Salim and Mahjoob, 2020), a technology (Chen *et al.*, 2020; Zhang *et al.*, 2020), a process (Porwal and Hewage, 2013; Eadie *et al.*, 2015; Franz *et al.*, 2017; Ariffin *et al.*, 2018; Bahram, 2019) or an approach (Albano and Di Giuda, 2018), while IPD was discussed mainly as a method (Keskin *et al.*, 2020; Bynum *et al.*, 2013), a practice (Ma *et al.*, 2018b), an approach (Salim and Mahjoob, 2020), a process (Isikdag, 2012) or a mindset (Pishdad-Bozorgi *et al.*, 2018; Holzer, 2011).

We identified four types of the interplay between IPD and BIM in the 71 papers in our sample. A majority (48) discussed this interplay as sequential, with either IPD or BIM playing the role of enabler. Of these, 30 papers clearly stated that BIM enables IPD while 18 advanced the reverse view. A further 12 papers did not address the relationship between IPD and BIM but focused instead on their effects on independent variables – in other words, this type of interplay could be characterized as pooled. In ten studies, IPD and BIM were seen to enable each other. Additionally, six of these ten papers stressed the joint role of IPD and BIM as enablers for another independent variable and these papers were classified as reciprocal and pooled interplay, while the rest of the papers (4) are classified as reciprocal but not pooled because IPD and BIM were defended to enable each other but their enabling role for the independent variable was not mentioned.

Secondly, accounts of the interplay between IPD and BIM varied by theme. For instance, while the dominant argument in adoption of IPD and BIM and contractual models for project delivery is that IPD enables BIM, the dominant view in cost management and finance, sustainability, technology, increasing the competence level of staff in the AEC industry, supply chain integration and scheduling is that BIM enables IPD. Only one category (early integration) emphasizes pooled interplay, IPD and BIM enabling an independent variable. The limited number of studies in the transformation category varied in their approach to the issue of interplay. In one case (Gustavsson, 2018), the author's position was unclear; Rowlinson (2017) was in no doubt that BIM enables IPD and Kraatz *et al.* (2014) adopted the pooled and reciprocal approach, wherein IPD and BIM enable each other and they also enable an independent variable jointly.

While some studies questioned the direct impact of IPD and BIM on performance indicators, it was generally agreed that coupling BIM and IPD (and in some cases, other complementary methods) undoubtedly influences trust, early involvement, team integration and collaboration, paving the way for improved performance. However, as trust was regarded as a precondition for IPD and BIM implementation, this may be a vicious circle.

In summary, the AEC industry is clearly undergoing a paradigm shift from traditional modes toward more collaborative, sustainable, technological models like IPD and BIM and both academics and practitioners are aware of this change. Second, as the construction industry is constrained by legislation and public sector agendas, it is reasonable to infer that awareness and implementation of IPD and BIM vary from country to country. IPD in particular is complex and preconditions may take years to fulfill. For that reason, some researchers view IPD with suspicion and focus instead on delivery forms like DB, which are easier to implement.

5. Conclusions

This review of the recent literature extracted and analyzed differing perspectives on the interplay of IPD and BIM. While our findings confirm the absence of consensus on this issue (Rowlinson, 2017; Piroozfar *et al.*, 2019; Sepasgozar *et al.*, 2019; Du *et al.*, 2019; Azhar, 2011), it seems clear that IPD and BIM facilitate and complement each other. Our analysis indicates that project owner initiatives to promote collaborative behavior are preferable to random emergence (Govender *et al.*, 2018) while also acknowledging that attitudes to collaboration are influenced by national legislation and public agencies' agenda.

While project owners play a key role in the transition to a more collaborative approach, collaborative concepts must be established and validated, as construction organizations necessarily respond to known demands. This vicious circle can only be broken if the industry learns to exploit the full potential of IPD and BIM and as a number of studies have shown, that will depend on increasing the competence level of staff in the AEC industry.

In addressing system-level issues, the present study paves the way for further detailed research on the interplay of IPD and BIM. We aim to enhance the body of knowledge via two main contributions: First, we identified 11 overlapping themes in the recent literature of IPD and BIM (see Table 1), including a discussion of the relation of the themes (Figure 2). The identified themes highlight trends and future spaces that more fully comprehend the nature of IPD and BIM and appropriate research frames. Based on the 11 themes identified here, future researchers can select relevant clusters for further analysis. Among the identified themes, we deduce that the themes of sustainability, transformation and increasing the competence level of staff in the AEC industry require more attention from IPD and BIM researchers. Additionally, we also confirm that future studies should focus on IPD and BIM's relation to the concept of project quality, which received very limited attention from IPD and BIM researchers even though it is one of the most accepted KPIs (Moradi *et al.*, 2021). Quantitative methods should also be used to further illuminate the interplay of IPD and BIM in developing a systematic framework to guide the AEC industry adoption of a collaborative approach.

This study inevitably has a number of limitations. First, it includes only publications in English. Second, the dependence on abstracts, titles and keywords in search excludes papers that discuss IPD and BIM only within the text. Third, the choice of search terms may have excluded some relevant studies; for instance, we used the term "BIM" but not "virtual design and construction" or "building product model." Fourth, we included only articles or review papers while excluding conference papers and book chapters. Additionally, some papers identified in our first search were excluded because the discussion of the target concepts was found to be too limited. In this regard, exclusions were determined by more than one researcher to guard against subjective bias. Finally, it must be noted that clusters that returned more papers were the most popular in the existing literature rather than necessarily the most important.

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