An integrated model of factors and barriers influencing BIM and Lean construction adoption

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Abstract

Building Information Modelling (BIM) and Lean construction are developing rapidly in terms of knowledge and application. BIM facilitates a more integrated process for construction project delivery that provides significant benefits for projects and the stakeholders, mainly clients, including improved project collaboration and quality as well as reduced construction duration and project lifecycle costs. Likewise, Lean construction deeply influenced by lean thinking, has two common goals of minimising waste (*muda*) and maximising the value to the client. Conceptually there are significant opportunities for synergising the two practices. Although attempts were made to draw the links between the two for better improvement, a lack of an integrated model including influential factors and barriers to BIM and Lean construction adoption was identified in the existing literature. To bridge the gap, this chapter aims to develop an integrated model for BIM and Lean construction adoption. Mixed methods systematic review was employed in this study. Quantitatively, it was found that there is no link between BIM adoption and Lean construction or Lean production. Moreover, this study reviewed the extant literature on the barriers/issues of BIM and Lean construction adoption and proposed an integrated framework including the influential factors for the adoption of BIM and Lean Construction in the construction industry. This study concluded that most of the factors influencing BIM and Lean Construction adoption overlapped across three categories, including supply chain (industry and institutional), organisational and project.

Keywords

Lean construction, BIM, implementation, barriers, review, bibliometric, scientometrics

1. Introduction

The construction industry, despite being an important industry, traditionally experiences many losses during its performance, through factors such as time delays, cost over-runs and low building quality (Forsythe, 2016, Love et al., 2016). These losses occur due to the fragmentation of the industry into smaller parts, which entails the lack of effective collaboration, and the lack of sharing of accurate and updated information among the various disciplines and professionals, including architects, engineers and contractors (Papadonikolaki et al., 2016). The industry's geographically dispersed character has been facilitated by Building Information Modelling (BIM) that was introduced into the contemporary professional language, referring to a technology-driven approach that includes integrated digital solutions for the industry (Sacks et al., 2018). In other words, the specific nature of construction work requires an acceptable BIM process that can only be achieved through the purposeful negotiation of intervention plans to fully support multiple end-users' goals (Sackey et al., 2015). Apart from seeking technologies to addressing the abovementioned issues, the construction practitioners are also inspired by the lean concept which was originated in the Toyota Production System, hoping to explore the potentials in the project-based construction sector. Ever since the term lean construction (LC) was coined in the early 1990s, various research efforts have been undertaken. Although lean construction is still in its infancy, a set of practices have been proposed, tested, and implemented (Paez et al., 2005, Jørgensen and Emmitt, 2008). Noticing the synergy between the two, there were attempts made by BIM and lean construction researchers to recognise the potential links of the two when planning their lean and BIM adoption strategies. One of the early efforts was made by Sacks et al. (2010) by using a matrix that juxtaposes BIM functionalities with prescriptive lean construction principles (derived from the Toyota Way model), 56 interactions have been identified, all but four of which represent constructive interaction. More recently, Tezel et al. (2020) acknowledged that increasing BIM and LC adoption amongst SMEs is a key condition for achieving the transformation of the construction industry through BIM and LC. However, existing literature on these topics indicates the lack of integrated framework including the influential factors for the adoption of BIM and LC in the construction industry. To bridge the gap, this study aims to develop an integrated model for BIM and Lean construction adoption.

2. Background

2.1. BIM

The concept of Building Information Modelling (BIM), as identified by the AEC industry in recent years, refers to a set of interacting processes and technologies that are used to integrate and manage essential construction project information in digital format throughout the project life cycle (Succar, 2009, Holzer, 2016). BIM is promoted as "a multiple stakeholder collaboration platform" and also seen as a panacea for working in-silo problems in the AEC industry, given its capabilities in providing a central data repository for the storage, sharing and integration of information for a project's entire life cycle (Pärn et al., 2017, Zhang et al., 2017). With the advent of web-based networks and the propagation of information technology (IT) into construction activities (Hosseini and Chileshe, 2013), the nature of team working has undergone a radical change over the past decade (Walker et al., 2017). In essence, computer-based collaboration has become the norm for contemporary construction projects where team members are scattered across several locations (Solihin et al., 2016) but use a shared database (Hu et al., 2016, Alreshidi et al., 2018). However, despite the rise of BIM tools and technologies, BIM implementation within the industry is identified as a problematic area.

The comprehensive reports by McGraw-Hill Construction across the three most developed regions in the world (Europe, North America and Australia), regarding the adoption of BIM in their projects, identified that BIM is yet to be fully adopted by the construction industries in these regions (McGraw-Hill Construction, 2017). According to the findings in their studies, BIM users in North America (including Canada and the US), Europe (including the UK, France and Germany) and Australia and New Zealand believe that BIM has not yet fully adopted in all within the AEC organisation and on construction projects. This poor adoption of BIM within the industry has resulted in the ineffectiveness and lack of performance in project teams, eventually leading to design clashes, omissions and errors (Sackey et al., 2015).

In addition to the McGraw Hill Construction reports' findings, the recent existing literature in the BIM context identified that the success of construction projects in achieving their goals relies upon project teams working collaboratively and project data being seamlessly shared across all the organisations involved (Bassanino et al., 2014, Merschbrock, 2012). This highlighted the crucial role of BIM implementation in the industry (Hu et al., 2016). The necessity of framing the project environment and shifting common practices to foster BIM adoption has also been emphasised repeatedly throughout the literature (Alreshidi et al., 2018, Poirier et al., 2016). Nevertheless, implementation of BIM in the construction industry is a multifaceted complex phenomenon manipulated by a wide range of factors such as technologies, people and the environment (Alreshidi et al., 2018).

2.2. Lean Construction

Lean construction results from the application of a new form of production management to construction (Howell, 1999). Originated from Toyota, lean is a methodology and philosophy with the primary objective of waste elimination and linking all steps that create value (Womack et al., 1990). Koskela et al. (2002) observed two schools of thoughts – one is focusing on the application of the methods of lean production to construction, and the other interpretation views lean production as a theoretical inspiration for the formation of a new, theory-based methodology for construction. The former includes the application of various lean tools and techniques, many are from manufacturing, and some are construction born such as the last planner system (LPS). The latter combines three perspectives of construction, namely transformation (T), flow (F) and value (V) generation (TFV). Each of them has its own practical methods, tools, and production templates (Koskela, 2000). According to Koskela (2000), the transformation model of production was not challenged until the 1980s, with Shingo's (1988) theoretical rationale of the just-in-time (JIT) movement. JIT not only introduces time as an input in production but also distinguishes two types of activities: transformation (work) and non-transformation (waste) activities, in terms of the time they consume. Work processes are redesigned to eliminate waste (*muda)* by undertaking continuous improvement (*kaizen)*. Hence, it is paramount to identify the wastes to eliminate them. Wastes, according to Womack and Jones (1997), refer to "any activity which absorbs resources but creates no value". The eight types of *muda* can be classified using the widely known acronym DOWNTIME wastes.

In order to introduce aspects of lean production into construction projects, various research efforts have been undertaken. Jørgensen and Emmitt (2008) noted that "*implementation and application*" have emerged as a dominant theme in lean construction, in which numerous projects and process performances connected to lean initiatives were reported. However, it is commonly acknowledged that various shortcomings of lean construction frameworks, a more comprehensive framework for lean construction, which is based on the Toyota Way model, is proposed (Gao and Low, 2014) to solve some of the inherent limitations of the frameworks that are currently available in the lean construction domain. The Toyota Way is the "mother platform" of lean thinking (Gao and Low, 2012). Essentially the Toyota Way was developed in a pyramidal form which comprises of 14 high-level principles. As Gao and Low (2014) reminded us that the implementation of lean construction should balance both operational factor and human factors of the lean approach in the construction workplace, namely by thinking about implementing a management model in a holistic manner.

In terms of the advantage of implementing lean construction, Howell et al. (2010) summarised, "*cost and duration are often reduced more than 10%, overruns are extremely rare, accidents and injuries reduced by half, quality is improved with the time from occupancy to operation reduced, and no significant litigation*". This is in line with the observation made by Womack et al. (1990, p.13), who noted "*lean production is 'lean' because it uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time*".

2.3. Theoretical lens

Adoption of BIM and Lean Construction in the construction context has been identified as an innovative process (Hosseini et al., 2015, Kim and Park, 2006). Throughout the literature, BIM and Lean have been considered as innovative technological process and production-based approach respectively (Poirier et al., 2015, Sacks et al., 2017). Moreover, dealing with the adoption of innovative technologies through the lenses of innovation adoption is recommended as the most effective approach in the construction industry, and companies in particular (Murphy, 2014). Thus, the innovation diffusion theory (IDT) is identified as the most relevant theory for framing research questions related to the adoption of innovative technological processes in construction projects.

In the construction context, influential factors to the adoption of an innovative technological process belong to four different contexts. These factors are industry, institutional, organisational and project contexts following the innovation diffusion process as proposed by Poirier et al. (2015). The industry context included the regulatory and legal context. It acts as an external force on the organisation, and to a certain degree. The institutional context is defined by the practices, policies and procedures implemented by the various stakeholders in the AEC supply chain. As such, the institutional context intersects both the organisational and project contexts (Poirier et al., 2014). The institutional context refers to the policies, practices, knowledge and procedures implemented by various parties involved in the construction supply chain surrounding the organisation. The organisational context covers intentions, support and commitments of management and personnel with regard to BIM and Lean adoption, strategic objectives, resource allocation and addressing training needs. The factors in the project context category are related to project and contractual requirements and members' perceptions concerning BIM and Lean implementation. As recognised by Poirier et al. (2015) the associations between these factors indicate that industry and institutional contexts affect organisational context where there is a causal association between organisational context and project context.

Given the above discussions, the theoretical lens of the present study was developed as illustrated in Figure 1. It should be mentioned that the model provided by Poirier et al. (2015) was modified. That was because, the embedded contexts of industry and institutional, virtually covered the whole supply chain affecting the organisation, thus were merged into one single embedded context titled as Supply Chain (Hosseini et al., 2015). As a result, the theoretical lens of the study was based on three categories of barriers. These were (1) Supply Chain barriers (industry and institutional), (2) Organisational and (3) Project barriers as illustrated in Figure 1.

Figure 1: Theoretical lens of the study

3. Research methods

The method utilised in this study is a "mixed-methods systematic review" as termed by Harden and Thomas (2010). Systematic review is the most effective method when a study is focused on flagging up gaps in the body of knowledge and identifying where little research has been done (Petticrew and Roberts, 2008). However, mono-method manual systematic reviews might be biased and prone to problems of subjective judgment and interpretation (Harden and Thomas, 2010). This necessitates the use of mixed methods systematic review in synthesising the literature on a topic "*to enhance the depth and breadth of understanding*" (Heyvaert et al., 2016, Oraee et al., 2017). Mixed methods systematic review studies combine and apply quantitative and qualitative methods for integration and analysis of available literature on a topic (Harden and Thomas, 2010). This needs a protocol to show the methods, the processes and the sampling strategies for data collection to serve the defined objectives of the study (Heyvaert et al., 2016). Figure 2 illustrates the protocol followed for conducting a mixed-methods systematic review in the present study. The details of the succeeding stages as illustrated in Figure 2 are discussed next.

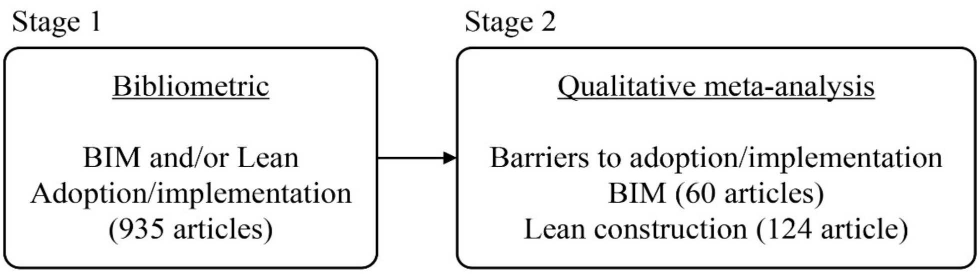

Figure 2: Mixed methods systematic review process

3.1. Bibliometric analysis (stage 1)

The first stage of analysis in this study involves the use of bibliometric analysis. Qualitative reviews of available studies on a topic are likely to be biased and can be limited in numbers to be reviewed by researchers, particularly with a large amount of literature (He et al., 2017). This necessitates the use of quantified systematic methods with the use of analysis software to analyse the body of knowledge in a specific field (Yalcinkaya and Singh, 2015). Of these, bibliometric analysis of literature has received a steady growth in various scientific areas and refers to mapping and visualisation of a particular large-scale scientific dataset in a knowledge domain. As stated by Cobo et al. (2011), bibliometric analysis enables researchers to analyse the intellectual landscape of a research area and fulfil the objectives of their research studies. In terms of bibliometric software, there are several programs for, of which VOSviewer (Van Eck and Waltman, 2010) has been considered and utilised in this research study.

Data for bibliometric analysis could be extracted from different datasets such as *Scopus, Web of Science*, *EBSCOhost* or *ProQuest*. However, Scopus is selected and utilised in this study as it covers a wider range of journals in the areas of construction and construction technologies and contains more recent publications compared to other databases such as Web of Science (Aghaei Chadegani et al., 2013). Moreover, the main topics of this bibliometric study are BIM and Lean, which are a relatively new and growing area of literature. This again justified the use of Scopus as the most relevant database to collect bibliometric data.

3.2. Qualitative meta-analysis (stage 2)

The qualitative analysis stage followed the objective proposed by Harden and Thomas (2010) for qualitative phases in mixed-methods systematic review studies. This entailed analysis of the themes, concepts and theories outlined in the content of selected studies via coding (Saldana, 2009) following the protocol of the systematic review and the study's theoretical lens (Figure 1). The purpose of this qualitative analysis was a qualitative synthesis in which authors do not create new theories but identify what different studies say and any respective barriers. This process typically occurs through the analysis of findings across the selected studies into a common language before offering any interpretation (Harden and Thomas, 2010). The theoretical lens in this study (Figure 1) offers the common language (protocol coding). The detailed procedure of selecting relevant studies, analysis and coding against the theoretical lens of the study are explained next in their relevant sections.

4. Findings

4.1. Bibliometric analysis (stage 1)

4.1.1. Adoption of BIM / Lean construction within the literature

The first stage of the analysis in this study involved the collection of data on Lean construction and BIM-related publications from Scopus. The targeted publications were all peer-reviewed journal articles published in the engineering and construction fields in the last 10 years (2011-2020). Other forms of research including books, conference proceedings, book chapters, and other forms of reports were excluded. The search was conducted in two different sets to find (1) BIM adoption related articles and (2) Lean construction adoption related articles, and the findings in each set were merged for the bibliometric analysis resulted in the preliminary outcome of 935 articles as of 15 July 2020. These articles have the term BIM or building information modelling or building information modelling, Lean construction, adoption or implementation in the abstract/title/keywords.

The preliminary data was submitted to *VOSviewer* software to create a network of publications based on direct citations. Direct citation is considered as a measure to identify the most influential studies in a field of research (van Eck and Waltman, 2014) and has become popular in the bibliometric analysis. To this end, the minimum number of citations for a study was defined as 20, to identify a sample of highly influential studies in the area of BIM and Lean construction. Thus, 131 studies met the threshold to be included in the network from which 48 were connected to each other and were used to create the density visualisation network as illustrated in Figure 3.

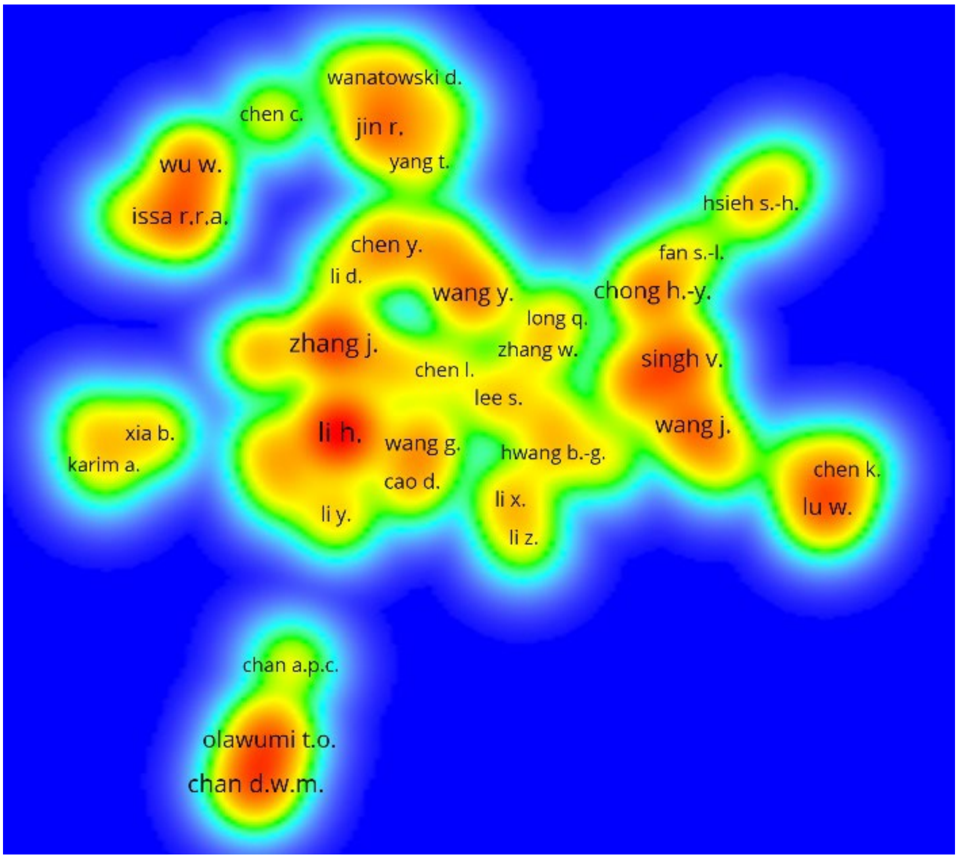

Figure 3: Influential studies in BIM and Lean construction body of knowledge

The density visualisation network created by VOSviewer is a distance-based map and shows the distances among nodes. The font size indicates the citation concentration where larger fonts showing a higher level of citations for a study (van Eck and Waltman, 2014). The colours of the network also demonstrate the focus of citations with red being the sign of the largest citation focus (Ibid). As shown in Figure 3: Influential studies in BIM and Lean construction body of knowledge, the studies located in red zones of the network were those studies on BIM adoption and Lean construction with a large number of direct citations which have been the source of information and the point of reference. According to Zhao and Strotmann (2015), citation analysis is a common method for evaluating the influence of studies in a particular field. These studies were carefully reviewed and none of them has investigated the integration of BIM adoption and Lean construction. In other words, analysis of the density visualisation network (Figure 3) revealed that influential studies are mainly investigated the adoption or implementation of BIM and Lean construction individually and not from an integrated point of view. As discussed earlier, although integration of BIM and Lean construction provides significant benefits to construction projects, organisations and the whole supply chain, it is not clearly investigated among the influential stream of BIM and Lean construction research and hence it has not yet driven a noteworthy change in BIM and Lean construction body of knowledge and practice.

To provide an in-depth view, the text-mining function of VOSviewer was utilised to create a co-occurrence network of keywords, as recommended by van Eck and Waltman (2014). This capability is applicable to the title and abstract of studies included in a dataset. To this end, the "full counting" method was applied, which indicates the total number of occurrences of a term in all documents (van Eck and Waltman, 2014). Out of the 5,747 terms identified, 138 terms met the threshold of the minimum number of co-occurrence above 10. As the default configuration of VOSviewer, 40% of these terms are excluded based on their relevance score. Also, generic research terms such as methods, survey, questionnaire, industry, and analysis were excluded from the list, which resulted in having 48 terms as shown in Figure 4.

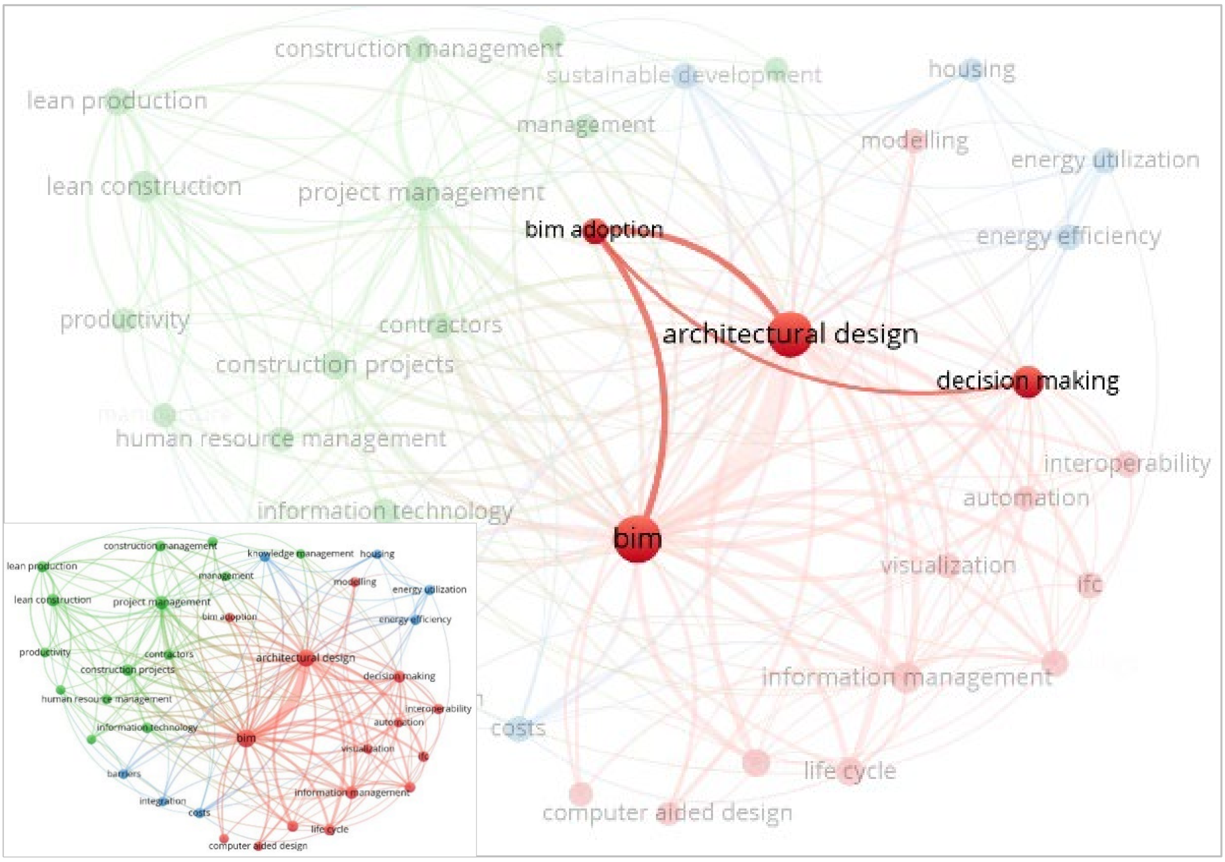

Figure 4: Co-occurrence network of terms in 'BIM and/or Lean adoption' literature

The distance-based networks created by VOSviewer (Figure 4) show the proximity of terms by their distance on the network. Smaller distances between two terms show a stronger relationship among terms based on their co-occurrences within the published studies (Van Eck and Waltman, 2011). As illustrated in Figure 4, it was found that there is no link between BIM adoption and Lean construction or Lean production. In other words, BIM adoption and Lean construction concepts were investigated in a silo with no connection. This was evidence of how existing scholarship on BIM adoption and Lean construction has overlooked the integration of these two concepts in relevant areas of research.

4.2. Qualitative analysis (stage 2)

To narrow down the dataset (935 articles) and identify the studies directly related to barriers to BIM adoption/implementation and/or Lean construction, the term 'barrier' was searched within the dataset using Scopus, resulting in 293 studies. In this stage, all 293 articles were thoroughly examined by the authors to identify the contents covered by each study. To this end, each study has been examined carefully via "protocol coding" (Saldana, 2009) to identify the relevance of each study to barriers to BIM adoption and barriers to Lean construction based on the proposed theoretical lens in this study (Figure 1). The final list of relevant articles was selected upon "intercoder agreement" of all the authors (Saldana, 2009) in examining the affinity of the 293 studies to barriers to BIM adoption/implementation and barriers to Lean construction. In other words, those studies for which barriers to adoption/implementation of BIM and/or Lean construction, following any of the three main areas in the theoretical lens, were not the focal point were eliminated (Figure 5). Upon finalising this examination process, a total of 76 (36+40) articles were identified as the studies clearly focused on barriers to BIM implementation and/or Lean construction.

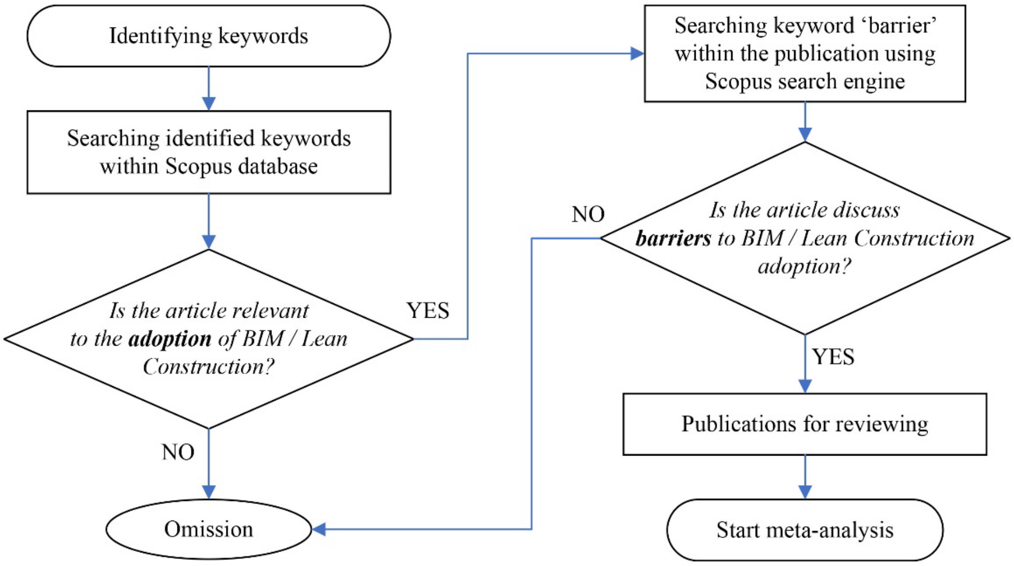

Figure 5: Procedure of the systematic review

These 76 articles were reviewed in-depth and coded in two cycles. As asserted by Punch (2005), "coding is the starting activity in any sort of qualitative analysis, and the foundation for what comes later". To this end, focusing on comparison and similarity against an existing theoretical framework or model in the interpretations process is identified as a well-established method for coding (Oraee et al., 2019). Such a qualitative analysis organises and shapes the coding system while leaving researchers open to discovery and modification. This is through creating a list of a priori codes (Saldana, 2009) and assigning the pieces of information to these codes. In this study, the coding list was based on the theoretical lens in which the authors reviewed the full texts of all 76 selected studies and assigned the content to the codes manifested in the theoretical lens (Figure 1). This resulted in classifying the factors and barriers to BIM/Lean construction adoption in the construction context, against the theoretical lens of the study.

4.2.1. Supply chain-related factors and barriers

The industry context included the regulatory and legal context. In acts as an external force on the organisation, and to a certain degree. The institutional context is defined by the practices, policies and procedures implemented by the various stakeholders in the AEC supply chain. As such, the institutional context intersects both the organisational and project contexts (Poirier et al., 2014). As shown in Table 1, the largest group of barriers to BIM adoption were those associated with government support, followed by BIM education and training, standards and regulations, and technology support from vendors. Similarly, for Lean construction, a set of barriers in relation to suppliers, training, government support, and technology was identified.

Table 1: Supply-chain related factors and barriers to BIM/Lean construction adoption

Area	Factor	Relevant Barrier	Total number of studies
BIM	Government support	• Lack of governments and their institutions support in setting proper infrastructure for BIM adoption	9
	Education and Training	• Lack of BIM education and training within the tertiary institutions	7
	Standards, Regulations and Libraries	• Lack of specified standards, guidelines, and BIM libraries	6
	Technology	• Technology and software related issues	4
Lean construction	Suppliers	• Lack of participation of supplier • Lack of availability and reliability of suppliers • Too many subcontractors • Supplier's resistance to change	9
	Education and Training	• Lack of training for both employees and managers	8
	Government support	• Inadequate government support • Lack of government policy and incentives to promote lean construction	6
	Technology	• Lack of advanced technology and facilities	3

Sources:
BIM: (Babatunde et al., 2020, Olawumi and Chan, 2020, Olanrewaju et al., 2020, Marefat et al., 2019, Girginkaya Akdag and Maqsood, 2019, Charef et al., 2019, Al-Yami and Sanni-Anibire, 2019, Hatem et al., 2018, Rogers et al., 2015, Roberts et al., 2019, Babatunde and Ekundayo, 2019, Doan et al., 2018, Khodeir and Nessim, 2018, Memon et al., 2014, Chan et al., 2019, McGibbney and Kumar, 2013, Belayutham et al., 2018, Meža et al., 2015)
Lean Construction: (Abusalem, 2020, Tayeh et al., 2018, Pandithawatta et al., 2019, AlSehaimi et al., 2014, Hussain et al., 2019, Bajjou and Chafi, 2018, Vignesh, 2017, Demirkesen and Bayhan, 2020, Ahmed and Wong, 2020, Kasiramkumar and Indhu, 2016)

The findings revealed that the lack of governments and their institutions supports as well as political and legal issues in developing proper infrastructure for BIM are regarded as the main challenges to BIM adoption within the construction industry. This observation is in arguments by Olanrewaju et al. (2020), Charef et al. (2019) and Rogers et al. (2015) of whom argued that inadequate government policies and efforts on developing BIM guidelines and encouraging the industry to implement BIM are the main barriers. Moreover, 7 studies argued that BIM education and training is another influential factor in BIM implementation. As discussed by Babatunde et al. (2020) and Doan et al. (2018), lack of training and education programs within the tertiary institutions for clients and construction practitioners have significantly impacted on stakeholders knowledge of BIM, and potentially on BIM adoption. Indeed, a community of practice that comprises of university academics and industry practitioners will have a significant influence on people's knowledge of BIM and BIM adoption accordingly (Roberts et al., 2019).

In addition to Government policies and BIM education barriers, other supply chain-related barriers referred to standards and regulations on BIM adoption and very few barriers identified in the software and technology context. As shown in Table 1, the challenges around lack of comprehensive BIM standards and relevant regulations are regarded as barriers to BIM adoption, as highlighted in studies by Chan et al. (2019) and Khodeir and Nessim (2018). Moreover, Memon et al. (2014) discussed that non-availability of parametric library impacted on the rate of BIM implementation within the industry and construction projects. Indeed, lack of or no parametric library will result in interoperability issues and poor interdisciplinary performance in developing building information models (Meža et al., 2015). Following BIM libraries and standards issues, a few studies have targeted technological challenges in BIM adoption. In the same vein, the study by Olanrewaju et al. (2020), argued that a lack of comprehensive BIM tools and software in the BIM process are barriers to BIM adoption.

Similarly, on lean construction, as shown in Table 1, these studies identify a set of supplier-related barriers. To be more specific, lack of availability and reliability of suppliers (Pandithawatta et al., 2019) or too many suppliers (AlSehaimi et al., 2014). Interestingly, both too many suppliers and lack of their availability are considered challenging. It also includes lack of participation of suppliers (Abusalem, 2020, Tayeh et al., 2018), and suppliers are resistance to make a change (Vignesh, 2017, Hussain et al., 2019). Abusalem (2020) noticed it is difficult to handle downstream players, suppliers in particular. Vignesh (2017) echoed that often top managers do not have enough influence over the entire parties including suppliers. The success of the Toyota way where lean was originated reminded us of the importance of integration of suppliers into its production system. Echoed by Low et al. (2015) whose study revealed that it is promising to marry early contractor involvement (ECI) with lean construction, by tapping on their specialist knowledge early in the design stage, ECI does contribute to elevating the productivity outcomes.

Another major barrier falls under this category is lack of proper training to lean concepts (Hussain et al., 2019, Abusalem, 2020, Aslam et al., 2020) which was expressed in 8 studies. Not surprisingly, it applies to both employees and managers (Tayeh et al., 2018). It is true that profound knowledge of lean principles is gained through Lean training. Many studies attribute lean training is one of the important success factors of Lean implementation (Demirkesen and Bayhan, 2020). These studies identify a set of barriers for the government factor group, namely lack of incentives by the government to promote lean (Ahmed and Wong, 2020), lack of policy and regulations, and lack of government support and commitment (Bajjou and Chafi, 2018). Interestingly, the contexts in which the government related barrier was identified were predominant from the developing countries, such as Nigeria, Malaysia, Morocco, Pakistan, and others. The implication is that the government should adopt policies that promote the efforts of companies that adopt lean concepts (Bajjou and Chafi, 2018). Lastly, it was found lack of advanced technology (Tayeh et al., 2018) and facilities also hinder the lean implementation, not necessarily of its initial high cost (Ahmed and Wong, 2020) but also of inadequate technical expertise (Tezel et al., 2018, Hussain et al., 2019, Kasiramkumar and Indhu, 2016).

4.2.2. Organisation-related factors and barriers

The organisational context is characterised by the permanent nature of its structure. It encompasses the organisation's management as well as the employees. As shown in Table 2, the largest group of barriers to BIM adoption in this category were those associated with resistance to change, followed by lack of knowledge, skills and abilities (KSAs), as well as uncertain return on investment (ROI). The least important barrier group was identified as an organisational structure/size. By the same token, major barrier groups to Lean construction adoption were identified as change management and initial adoption cost which were found in more than 10 studies. Other barriers in this category include KSAs, company work culture, and structure.

Table 2: Organisation related factors and barriers to BIM/Lean construction adoption

Area	Factor	Relevant Barrier	Total number of studies
BIM	Change management	• Weak top management support to adopt BIM • Organisations resistance to change from traditional working practices • Conservative nature of construction businesses	16
	Knowledge, Skills and Abilities (KSA)	• lack of understanding of the processes and workflows required for BIM and lack of well-trained personnel.	14
	Initial adoption cost	• The high cost of implementation in developing digital capabilities including BIM.	10
	Return on Investment	• The main barrier stem from the risks associated with an uncertain return on investment (ROI)	3
	Organisational structure/size	• Small-medium enterprises (SMEs) are less interested in adopting BIM	2

Lean construction	Change management	• Lack of leadership and commitment to supporting lean construction implementation • Resistance to change from traditional systems • Lack of motivation and incentive mechanism	18
	Initial adoption cost	• Inadequate funding • High implementation costs, i.e. cost to adopt technology, high professional consultation or coaching cost	10
	Knowledge, Skills and Abilities (KSA)	• Lack of technical expertise and insufficient know-how • Lack of responsibility towards quality and error-proofing	9
	Company work culture	• Lack of a supportive culture • Lack of kaizen environment • Short-term thinking and vision	7
	Company structure	• Poor communication chain within firms	5

Sources:
BIM: (Olawumi and Chan, 2020, Babatunde et al., 2020, Olanrewaju et al., 2020, Charef et al., 2019, Chan et al., 2019, Munir et al., 2019, Swallow and Zulu, 2019, Khodeir and Nessim, 2018, Olawumi et al., 2018, Hatem et al., 2018, Bosch-Sijtsema et al., 2017, Li et al., 2017, Kim et al., 2016, Hosseini et al., 2016, Meža et al., 2015, Arayici et al., 2011, Vidalakis et al., 2020, Roberts et al., 2019, Marefat et al., 2019, Vishnu Vardan and Raj Prasad, 2019, Fitriani et al., 2019, Hosseini et al., 2018, Belayutham et al., 2018, Rogers et al., 2015, Memon et al., 2014, London and Singh, 2013, Georgiadou, 2019, Arokiaprakash and Aparna, 2018)
Lean construction: (Abusalem, 2020, Nahmens and Mullens, 2011, Ankomah et al., 2020, AlSehaimi et al., 2014, Tezel et al., 2018, Bajjou and Chafi, 2018, Ahmed and Wong, 2020, Innella et al., 2019, Sholanke et al., 2019, Antony et al., 2019, Tayeh et al., 2018, Hussain et al., 2019, Noor et al., 2018, Pandithawatta et al., 2019, Alves et al., 2012, Demirkesen and Bayhan, 2020, Dakhli et al., 2016, Zaeri et al., 2017, Fernandez-Solis et al., 2013)

As indicated in Table 2, 'change management' that was discussed in 16 out of 36 studies was identified as the number one influential factor in BIM adoption in the construction industry. In other words, 'resistance to change' by senior managers in the organisations was considered as the most significant barrier to BIM adoption within the organisations. As discussed in the studies by Arayici et al. (2011) and Meža et al. (2015), resistance to change from the traditional project delivery approach to digitalization by the senior managers and also the conservative nature of the industry were identified as significant barriers to BIM adoption. Indeed, this challenge was identified as an unresolved challenge in the industry, as even the most recent studies on the topic argued that inherent resistance to change by the managers and stakeholders is still the influential barrier to BIM adoption within the organisations and potentially on construction projects (Babatunde et al., 2020, Olawumi and Chan, 2020, Chan et al., 2019). Moreover, knowledge, skills and abilities (KSAs) in BIM are regarded as the second influential factor in BIM adoption in the industry, as discussed in 14 out of 36 studies in this context. This observation is in arguments by Olawumi and Chan (2020) and Marefat et al. (2019) of whom argued that inadequate KSAs by the people in the industry and within the AEC firms, in particular, are still the main challenges to proper implementation of BIM. This indeed was identified as a significant factor to BIM adoption and thus a focus on training and education in BIM was proposed by the previous studies to address this challenge in the industry (Vidalakis et al., 2020, Hosseini et al., 2018, Rogers et al., 2015).

In addition to change management and KSAs factors, the financial sides of BIM adoption have attracted the interests of the previous studies. Indeed, the high implementation cost of BIM (Olanrewaju et al., 2020, Georgiadou, 2019) on one side and lack of reasonable return on investment (ROI) (Hosseini et al., 2018, Li et al., 2017) on the other side, were regarded as major challenges to the adoption of BIM within AEC firms and organisations. In addition to the abovementioned identified factors, organisational structure and size were also found to be influential in BIM adoption, though the number of studies discussing this factor was the least in the list. As stated in the studies by Vidalakis et al. (2020), the variations of small-medium enterprises (SMEs) in the adoption of BIM are mostly affected by their company size, in which SMEs are less interested in implementing BIM within their organisations (Hosseini et al., 2018).

The barriers to lean construction from this category exhibit a similar pattern. Close to half of the selected studies (18/40) identified resistant to change as one common barrier. It is a crucial factor in any improvement program of any organisation (Pandithawatta et al., 2019, Hussain et al., 2019). Taking continuous improvement (*kaizen*) for example, Nahmens and Mullens (2011) observed that employees are resistant to make even minor improvement. Similarly, Innella et al. (2020) discovered worker are not interested for continuous improvement. Pandithawatta et al. (2019) noted not only employees are resistant to change but also management (Innella et al., 2019). This is reflected in lacking leadership and lack of top management's commitment and support. It is widely acknowledged that leadership from the top management was key in driving the lean adoption process. Another barrier in this category is lack of motivation. Motivation is commonly sourced from intrinsic or extrinsic motives. Reportedly, incentive systems used mostly by the firms concentrate on material incentives particularly on financial incentives is common (Ankomah et al., 2020). Lack of intrinsic motivation may be evident in behaviour or attitude (Bajjou and Chafi, 2018) such as resistance to change (Innella et al., 2019). The next crucial factor is pertaining to adoption cost. Many companies, especially those operate in developing countries, face budget constraints to implementing a new and innovative system. On one hand, it is expensive to adopt BIM, IBS, KPI, TQM and other technologies and practice (Ahmed and Wong, 2020). On the other hand, high professional consultation or coaching cost (Noor et al., 2018) was also indicated.

What closely followed is the KSAs factor. Lack of technical expertise and insufficient know-how (Tezel et al., 2018, Pandithawatta et al., 2019) was identified as one critical barrier. Alves et al. (2012) discovered that the implementation of lean construction is very much lean tool focused. In another word, a holistic approach to lean construction implementation is absent (Ankomah et al., 2020). Tayeh et al. (2018) found partial or late implementation is common. Another barrier here unskilled human resources (Bajjou and Chafi, 2018, Tayeh et al., 2018) as construction professional whose organizations do not have formal training programs for lean implementation believe that people in their organizations are not skilled at using lean techniques (Fernandez-Solis et al., 2013). In countries like Malaysia, this allows companies to rely on foreign workers (Noor et al., 2018). Such cheap and short-term solution prevents companies to have a capable workforce in a sustainable way. Many scholars pointed out *work culture* is key to the successful adoption of lean construction. Of 7 studies, two types of culture were identified to be lacking which pose challenges to adoption, namely supportive organisational culture, and *kaizen* environment. These organisational cultures can help companies achieve organisational objectives. Companies shall develop policies and strategies to handle cultural barriers and to provide a better environment for their employees (Demirkesen and Bayhan, 2020). Another alarming barrier is *lack of long-term thinking and vision* as many researchers noted the construction firms are rather short-term thinking oriented (Alsehaimi et al., 2014; Tayeh et al., 2018). Kenney and Florida (1993) confirmed that successful implementation is heavily reliant on culture. Communication is critical to make Lean initiatives perform better (Demirkesen and Bayhan, 2020). 5 studies had a consensus on the poor communication chain resulted from the hierarchical organisation structure which poses potential hindrance to lean implementation. Interestingly, Aslam et al. (2020) recommended BIM and visual management as effective tools to address the lack of communication issue. In the case of LPS, data collection was found to be challenging (Dakhli et al., 2016), i.e. missing of data or no data (Zaeri et al., 2017) which prevents project team to analyses areas for improvement.

4.2.3. Project-related factors and barriers

According to Winch (2010), the project context is characterized by the temporary nature of its structure and uniqueness of its setting (requirements, contracts, scope, etc.). Central to the project context is the project team which encompasses the external project team that comprises the external stakeholders forming the supply chain and the internal project team which include the organization’s office and field personnel working on a given project. Findings of the present study revealed that project-related factors were regarded as influential and challenging factors in BIM and Lean construction adoption in the industry. As shown in Table 3, this can be traced to factors such as the client's interest and knowledge, project nature as well as intellectual property (IP) and security of data. Similarly, client and project nature are also identified as barriers to lean construction in the project-related category.

Table 3: Project-related factors and barriers to BIM/Lean construction adoption

Area	Factor	Relevant Barrier	Total number of studies
BIM	Client	• Lack of demand (clients are not interested in implementing BIM on their projects) • Poor knowledge about BIM benefits and poor understanding of the BIM process.	6
	Data and intellectual property	• Models ownership and intellectual property issues	2
Lean	Client	• Lengthy approval procedure by the client • Lack of clear job specification from the client • Lack of client involvement	5
	Project nature	• Inherent challenges on the project • Time pressure • Contractual requirements	4

Sources:
BIM: (Doan et al., 2018, Khodeir and Nessim, 2018, Bosch-Sijtsema et al., 2017, Khosrowshahi and Arayici, 2012, Hatem et al., 2018, Li et al., 2017, Olanrewaju et al., 2020, Munir et al., 2019)
Lean construction: (Tayeh et al., 2018, Ahmed and Wong, 2020, Sarhan et al., 2018, Samudio et al., 2011, Christensen et al., 2019, Koskenvesa and Koskela, 2012)

As presented in Table 3, the client's interest was regarded as the most influential factor in the implementation of BIM on construction projects. Indeed, the adoption of BIM on construction projects initially needs to be requested by the clients (ABAB, 2018). However, according to the findings of the present study, the lack of clients' demand for BIM implementation was found to be the most significant barrier in the BIM adoption process (Doan et al., 2018, Bosch-Sijtsema et al., 2017). This was found to be an ongoing challenge in BIM implementation as it was found in the earlier study by Khosrowshahi and Arayici (2012). Moreover, the lack of clients' knowledge of BIM and its benefits throughout the projects lifecycle and in the operation phase, in particular, was identified as another barrier to BIM implementation on construction projects and the industry (Hatem et al., 2018). Indeed, clients have limited knowledge and understanding of BIM and its benefits, except for its three-dimensional (3D) visualisation and in some cases some basic knowledge of its clash-detection capabilities (Li et al., 2017).

From the lean construction adoption perspective, the client factor was found to be the major factor in the adoption process. This factor comprises of lengthy approval procedure by the client (AlSehaimi et al., 2014, Abusalem, 2020, Tayeh et al., 2018), poor interpretation of client's brief (Sholanke et al., 2019) and lack of client involvement. Indeed, the client's brief is an essential input to design and planning. The undertaking the work without client's approval will likely result in rework which is a type of waste in the lean context. Lengthy approval procedures by clients (Tayeh et al., 2018) indicates lack of empowerment from the client to the project delivery team. Secondly, the project nature factor. As Koskenvesa and Koskela (2012) noted, in many cases, contractual difficulties are faced when people come together to plan a phase in a reversed-phase scheduled session.

5. Discussion of the conceptual model

According to Whetten (1989), the first step towards developing a conceptual model involves identifying the constructs to be included. In other words, factors that logically explain part of the phenomenon of interest need to be identified. The major constructs affecting BIM and Lean construction adoption in the AEC industry were categorised against the theoretical lens of the present study and presented in Table 1, Table 2 and Table 3. Indeed, these constructs were identified through synthesising the existing literature on the topic, in which all these constructs were supported by relevant studies from the literature. In addition to the influential constructs, barriers to BIM and Lean construction adoption were extracted from the existing literature and classified against the identified constructs for the implementation of BIM and Lean construction in the AEC industry. To this end, Figure 6 integrates the three major factors, their sub-factors and relevant barriers to each sub-factor, as identified in the previous sections and presents the conceptual model of the study.

Across the three major categories, we have identified a set of common factors between BIM and Lean construction adoption. As highlighted in Figure 6, the most common factors and barriers are related to organisational and supply chain. At the organisational level, change management factor stands out to be the most recognised common factor. This is perhaps because adoption of BIM and lean construction in the construction context has been identified as an innovative process (Hosseini et al., 2016, Kim and Park, 2006) which calls for change for better. Successful implementation is heavily reliant on leadership and employees who are willing to make and accept the change, i.e. embrace the new technology and/or new process. At the supply chain category, government support tops the list of common factors. Such consensus indicated governments have a big role to play in promoting and supporting the adoption of BIM and Lean Construction practices in the construction industry. In other words, developing proper infrastructure and preparing relevant standard and regulations by the governments is a key step to the wide adoption of BIM and lean construction. At the project level, both BIM and lean construction literature highlighted that lack of client's involvements, their knowledge and demand for adoption are a hurdle to the adoption of BIM and lean construction. Moreover, there are unique BIM factors and lean construction factors spread throughout the three major factors including project nature, return on investment and work culture that need to be considered along with all the common factors in any BIM and lean construction implementation in the industry.

The conceptual model presented in the study provides the researcher such a context for the analysis and formulation of future research efforts into BIM and lean construction. The model supports awareness and consideration of the interrelated nature of factors and barriers to BIM and lean construction adoption. Moreover, the model introduces theories to be tested in future research on the topic.

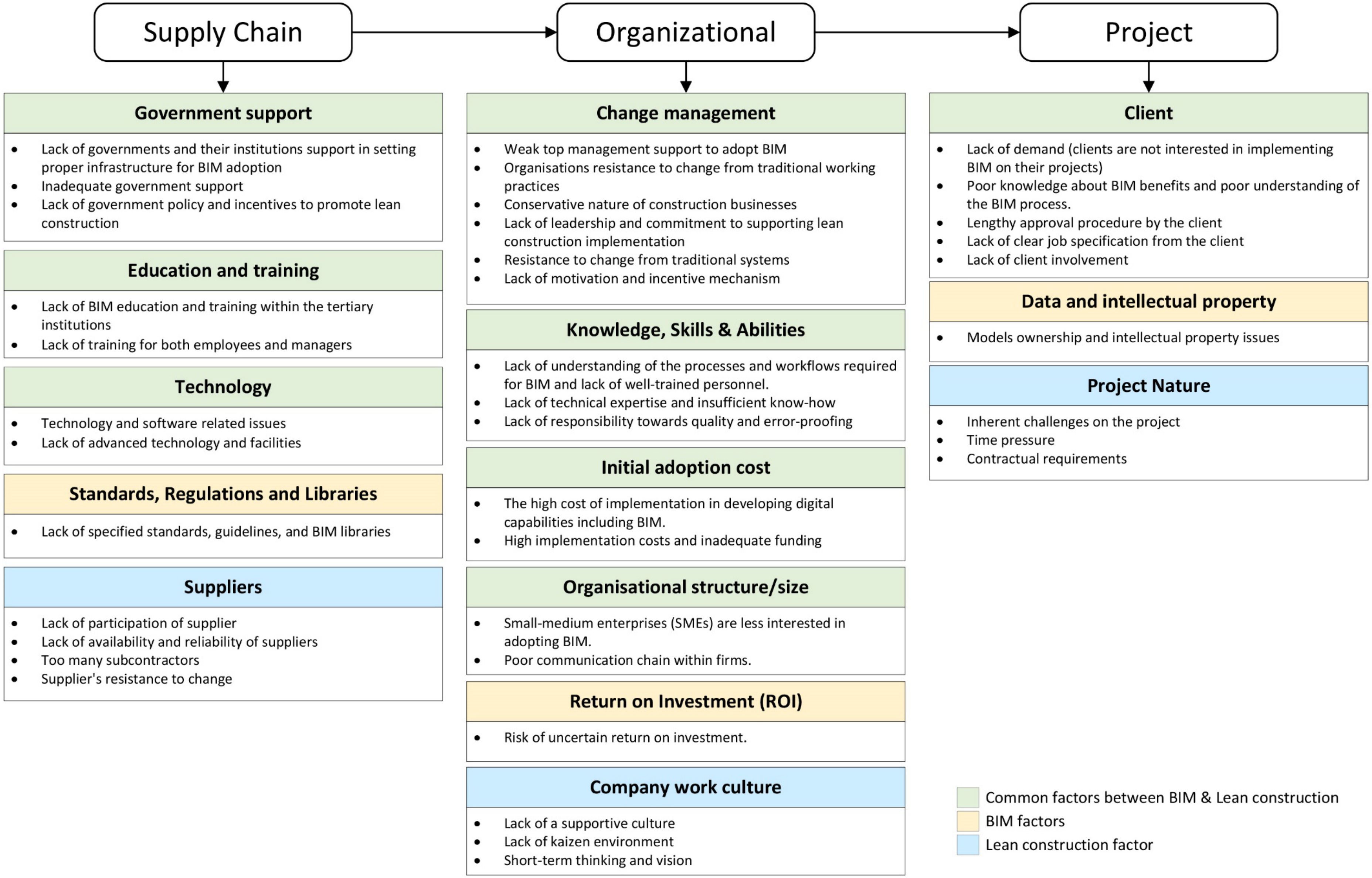

Figure 6: Integrated model of factors and barriers influencing BIM and Lean construction adoption

6. Conclusion

This paper reviewed published research into the barriers/issues of BIM and Lean construction adoption and proposed an integrated framework including the influential factors for the adoption of BIM and LC in the construction industry. This study concluded that the influential factors and barriers to LC adoption overlap with barriers of BIM adoption across three categories, including supply chain (industry and institutional), organisational and project. Interestingly, the most common barriers are found to be associated with supply chain and organisational factors. From the practical point of view, this allows the industry, organisation, and project to see where the common barriers to both practices lie and what the exclusive barrier(s) are. As there are growing numbers of research outputs in BIM or LC's domain, this study synergised the two innovative practices by uncovering the common factors and barriers in an integrated framework. In terms of future research, a validation exercise for the proposed integrated framework is desirable. Last, the study is limited in that the literature search only used Scopus and excluded conference papers. Another steam of future studies might consider expanding the work covering other scholarly works and databases (ie. IGLC conference database, which represents certified knowledge about LC).

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