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RESEARCH ARTICLE

Making Sense of Multi-Actor Social Collaboration in Building Information Modelling Level 2 Projects: A Case in Malaysia

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Abstract

Despite the diversity of thinking among the scholars on building information modelling (BIM) collaboration, there is a paucity of studies that capture the dimension of social collaboration in BIM projects. This study attempts to develop a comprehensive understanding on the key attributes of multi-actor social collaboration in BIM projects through the experience of practitioners in BIM-Level 2 construction project. The success of multi-actor social collaboration has been investigated through structured interviews with 22 BIM practitioners in a BIM-Level 2 project based on an established theoretical framework of social collaboration. The findings indicted that relationship-oriented attributes; relational contracts BIM execution plan; guideline, standard and work process manual approaches; employer information requirement (EIR); understanding roles and leadership; commitment from top management; resources; training, team building workshop and awareness program; coordination; and understanding on the theoretical knowledge of BIM are of importance towards multi-actor social BIM collaboration. This study acknowledges that the success of multi-actor social collaboration was influenced

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by the consolidation of many attributes, and it extends the dominant relationship between related attributes for multi-actor social collaboration based on the "best practice approach", which includes dominant-centric attributes (i.e., behaviour formation, procurement model and support principles). This research contributes to the body of BIM knowledge in the construction domain by focusing on what it takes to achieve greater social collaboration in BIM Level 2 projects.

Keywords

BIM, Key Attributes; Multi-Actor; Social Collaboration; Malaysia

Introduction

In recent decades, most studies have found that the construction industry underperforms (Hossain and Nadeem, 2019), putting additional pressure on the industry to improve project delivery efficiency (Elmualim and Gilder, 2014). The fragmentation process, adversarial culture, complexity of the decentralized for coordination and interoperability, ineffective communication and planning are some of the major factors that have contributed to the declining efficiency in project delivery (Alreshidi, Mourshed and Rezgui 2017). The aforementioned issues further hinder the effective collaboration (Merschbrock et al., 2018), resulting in multidisciplinary actors being unable to collaborate effectively to deliver projects (Blay, Tuuli, and France-Mensah, 2019). Several scholars (e.g., Mignone et al., 2016; Liu, Van Nederveen and Hertogh, 2017) acknowledge that inconsistent standardisation of work practises, intricate contractual and strategy can lead to collaboration failure, particularly on a social dimension, and thus exacerbate project planning problems, delays, and cost overruns. The complexities of multi-actor behaviour (e.g., entrenched silos, inability of interaction among actors, complexities of culture) also contributes to the failure of collaboration for social-centric initiatives (Blay, Tuuli, and France-Mensah, 2019; Cross and Carboni, 2021). To address existing issues and concerns surrounding the social collaborative practice, Building Information Modelling (BIM) has been introduced as a predominantly capitalised technology that can facilitate more positive cooperative and collaborative behaviour among BIM actors in multidisciplinary teams (Merschbrock et al., 2018; Babalola et al., 2021).

It is widely acknowledged that BIM has the potential to promote social collaboration (Blay, Tuuli, and France-Mensah, 2019) through building information activities such as, creating an open knowledge-sharing space within multidisciplinary team, detecting clashes early in the during design and construction stages, and reducing the request for information (RFI) as well as cost of projects (Zhang et al., 2017; Merchbrock et al., 2018). The success of multi-actor social collaboration has been influenced by the several factors such as project strategy plan implementation, actor behaviour characteristics and the consistency of working process, which should be emphasized as a backbone for organizational structure to foster fully collaboration in BIM project context (Mignone et al., 2016). Specifically, the adoption of the dominant function of socio-centric of BIM collaboration has revolutionised change management in particular through the BIM-Level 2 projects. The BIM-Level 2 can be defined as managed 3D environment held in separate discipline BIM tools through collaborative working (e.g., sharing information, data, etc) (BSI, 2016). The collaborative platform in BIM-Level 2 project has revolutionised the processes of change identification, analysis, and monitoring. With the new adaption of dynamic template approach, minimises the impact of change by capturing feedback processes caused by the change and thus makes the generic processes more effective (Lee and Pena-Mora, 2007). The BIM-Level 2 mandate was driven by the UK Government's 2011 Construction Strategy to ensure efficiency, collaboration, innovation, and value across all areas in the industry. To date, BIM-Level 2 is the highest compulsory level being achieved on government projects in the UK following the passing of the BIM mandate in April 2016 (Blay, Tuuli, and France-Mensah, 2019).

Despite the fact that most developed countries are aware of BIM's capability as a collaborative platform on BIM-Level 2 projects (Akdag and Maqsood, 2019), the context of BIM social collaboration remains an underperforming area (Oraee, Hosseini and Edwards, 2021). In addition, emerging economies such as Malaysia face such limitations, with multi-disciplinary organisations' inability to perform social-centric collaboration in BIM activities eventually leading to design clashes, errors, and omissions (Blay, Tuuli, and France-Mensah, 2019; Oraee, Hosseini and Edwards, 2021). Furthermore, the complexity of behaviour (i.e., interaction between practitioners and entrenched silos), slow adaptation to culture changes and new processes involved in working practices also contributed to the poor project performance (Blay, Tuuli, and France-Mensah, 2019). Recent studies in Malaysia context (e.g., Ya'acob, Rahim and Zainon, 2018; Al-Ashmori et al., 2020) revealed that the subject of practitioners in shifting common practices and adopting new wave of interaction (also known as socio-centric) to foster collaborative working environment among BIM actors in projects still exists and remains stagnant. To address these issues, the Malaysian government through Construction Industry Development Board (CIDB) introduced the Construction 4.0 Strategy Plan (2021-2025) as a framework that will boost the construction industry's capabilities within the 4.0 Industry revolution landscape by maximizing the application of BIM (as one of the 12 recognised disruptive technologies) (Ibrahim, Esa and Rahman, 2021). BIM implementation is specifically recognised as a short-term implementation (to be implemented within one year after the introduction of the plan) in the context of facilitating the use of technology in simulation and modelling activities in the construction supply chain.

Despite the fact that most previous studies (e.g., Blay, Tuuli, and France-Mensah, 2019; Oraee, Hosseini and Edwards, 2021) have successfully captured the general context of BIM collaboration, such as collaboration theories, benefits and challenges, the in-depth information on what constitutes the success of social BIM collaboration has not been widely explored. As a result, the purpose of this study is to assess the key attributes (KAs) influencing social collaboration in a Malaysian BIM level 2 infrastructure project, with the goal of encouraging construction practitioners to gain a better understanding and knowledge, in order to achieve a high level of social collaboration among multi-actors throughout the BIM project life cycle. The findings from this study would provide a foundation to further addressing the capability of organisations (i.e., social collaboration) in wider dimensions of social collaboration in ensuring the success of BIM implementation (e.g., exchange and sharing of project information, professional knowledge, etc.) Furthermore, a focus on socio-centric collaboration would bring a specific and clear change in the management process, working practices, behaviours in project management as well as to improve continous communication in person and virtually amongst parties from design to the construction stages (Ghaffarianhoseini et al., 2017).

Building Information Modeling (BIM) is a relatively new disruptive innovation for the construction industry that has been used to improve the productivity of collaborative working environments among multi-disciplinary teams (Blay, Tuuli, and France-Mensah, 2019; Oraee, Hosseini and Edwards, 2021). Several related standards have been developed to address this new collaborative environment in order to streamline the method of working among all multidisciplinary teams that use BIM (BSI, 2016). Initially, the UK Government introduced BS 1192:2007 in 2011, which focuses on the collaborative production of architectural, engineering, and construction information-codes of practise (BSI, 2013). Following the passage of the BIM mandate in April 2016 by the UK government's 2011 Construction Strategy, BIM-level 2 is currently the highest mandatory level being achieved on government projects in the UK, and it is distinguished by a collaborative working environment and requires coordinated information exchange between systems and parties in the projects (Blay, Tuuli, and France-Mensah, 2019). As a result, specific guidance for the information management requirements associated with projects delivered using BIM was introduced in 2016 via PAS1992-2:2013 in order to achieve BIM-level 2 (BSI, 2013). In fact, the use of these BIM standards in BIM-level 2 has transformed the processes of change identification, analysis, monitoring, and control, resulting in a more effective collaborative working environment (Blay, Tuuli, and France-Mensah, 2019).

Previous studies (e.g., Alreshidi, Mourshed and Rezgui, 2016; Blay, Tuuli, and France-Mensah, 2019) emphasised that engagement in more collaborative ways in terms of social context in the BIM projects through the selection of project implementation strategy (i.e. relational contract such as Integrated Project Delivery (IPD), partnership and etc; ownerships and intellectual property rights (IPRs); standard guideline and work manual process) are able to assist and governs the different team working approaches in project delivery. Furthermore, the need for a clear understanding of roles and responsibilities, trust and respect are important influences for social collaboration during the coordination, communication and working process across various disciplines in the projects (Liu, Van Nederveen and Hertogh, 2017). It is worth noting that the extent of construction literature on collaboration practices tend to focus more on the concept, benefits and barriers rather than specific social collaboration practice. Although there is a diversity of current thinking on various ways to improve BIM implementation in projects, information on the influencing attributes that contribute to successful multi-actor social collaboration remains elusive.

Key Attributes (KAs) of multi-actor social collaboration in BIM projects

In this paper, the term of key attributes (KAs) of social collaboration refers to the consolidation of definition suggested by the previous studies (i.e., Kouch, Illikainena and Perala, 2018; Blay, Tuuli, and France-Mensah, 2019), which defined as critical determining factors that have potentiality contributed to the social collaboration among BIM actors, and hence could directly indicated the current state of success of BIM project implementation. Initially, a systematic literature review (SLR) approach was used to review the available literature in order to identify KAs of successful social collaboration among multi-actors in BIM projects. The review identified a set of 40 candidate KAs influencing social collaboration (see Figure 1) based on the categorization in Noor, Che Ibrahim and Belayutham (2021)'s conceptual lens, which can form the basis for influencing social collaboration within the various multi-disciplinary teams in the projects.

Overall, the findings suggest that organisations that prioritise 'team and individual interaction and behaviour' have a direct influence on the relationship between multi-actors. Understanding roles and leadership, as well as commitment from top management have been identified as the main behavioural categories influencing the establishment of multi-actor social collaboration practise. Despite this, the literature indicates that a 'process in BIM,' 'management support,' 'assessment arrangement,' and 'foundational platform' are critical in influencing team and individual behaviours among team members to ensure the effectiveness of the collaborative process in the project (Mignone et al., 2016; Merschbrock et al., 2018). Although actor interaction and behaviours are important factors influencing social collaboration, the process attributes (i.e., coordination, standardisation of work practises, centralised communication, sharing of information and experience) are viewed as a complementary element to demonstrate the workflow during project execution (Liu, Van Nederveen and Hertogh, 2017; Mignone et al., 2016). It goes without saying that project teams must be equipped with 'management support' attributes such as training, software, and hardware in order to strengthen existing skills and become acquainted with culture change (Merschbrock et al., 2018). Furthermore, continuous assessment and digital technology (e.g., common data environment (CDE), augmented reality (AR), etc.) are recognised as supportive tools for integrating multi-actor collaboration to improve project performance (Mignone et al., 2016).

It is also clear that the entire element of the organisation is governed by the 'management strategy,' such as contractual, policy, and strategy attributes, which enhance proactive interaction within project teams and ensure the smooth operation of the BIM process to achieve the desired project goals (Alreshidi, Mourshed and Rezgui, 2016). Previous research (Liu, Van Nederveen and Hertogh, 2017; Merschbrock et al., 2018)

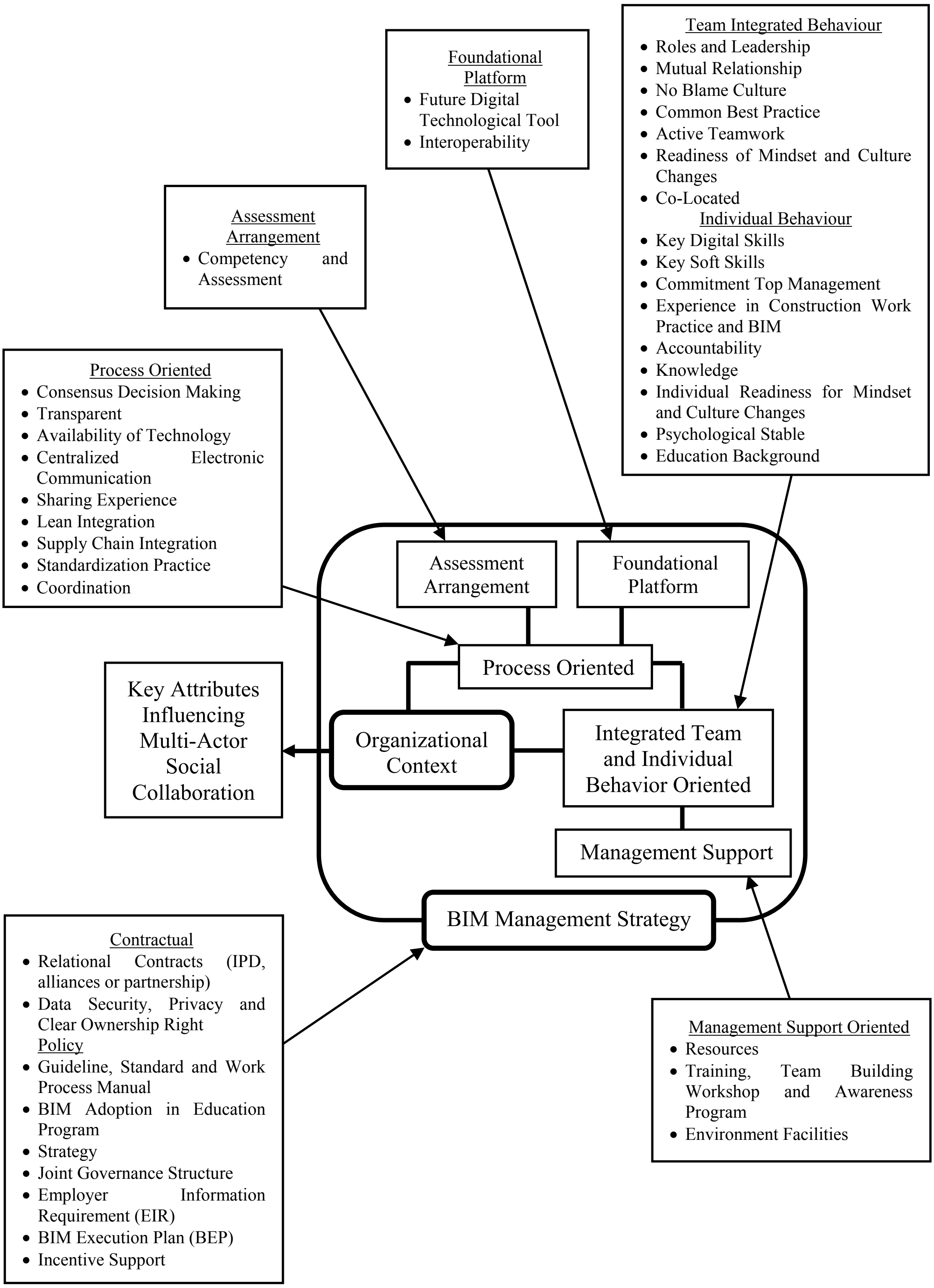

Figure 1. Summary of 40 Attributes Identified from Existing Literature (Adapted from Noor, Che Ibrahim and Belayutham, 2021)

indicates that the selection of necessary contracts (i.e., IPD, DB, and so on) is a critical component to ensuring the success of social collaboration, where early involvement of actors could facilitate decision making, leading to effective communication and the reduction of residual performance risk. However, the standardisation of guidelines and manual work processes under 'policy' should be adaptive in order to deal with the BIM scope and the roles of multi-actors in initiating collaborative working practises in projects (Merschbrock et al., 2018). On the other hand, strategy arrangement (e.g., EIR and BEP) is the most important approach to providing a better joint governance structure within project organisation, where able to align the multi-actor behaviour with the centralised and standardised work practise, values, and coordination mechanism thus, governing and controlling the organization's interaction towards the project goals (Kouch, Illikainena and Perala, 2018). Noor, Che Ibrahim and Belayutham (2021) provide a detailed discussion and evaluation of these characteristics.

RESEARCH METHODOLOGY

A case study was conducted on the Malaysia's largest infrastructure urban railway project. The case was chosen because it is a leading example of advanced BIM-based design practise in Asia that achieves BIM-Level 2. The project was recognised as the first infrastructure developer in Asia to achieve Level 2 accreditation in the use of BIM in accordance with international standards by Lloyd's Register, a leading international classification association providing professional services in engineering and transportation (Azman, 2018). The project includes an approved rail alignment of 52.2 km in length, 13.5 km of which is underground. A total of 37 stations will be built, 11 of which will be underground (MRT, 2019). The BIM workflow was successfully established and implemented in the project execution, where the use of BIM workflow was mandated throughout the project's design, construction, and operational stages to fully exploit the potential for significant cost savings (MRT, 2019). The project was carried out with the collaboration of 20 disciplines and over 1000 professionals from various parties (i.e., contractor and consultant) (MRT, 2019). As a result, this project, which prioritised BIM and collaborative design at BIM-Level 2, provides a compelling context for the study.

The fact that being the only BIM level 2 project in the country (due to its uniqueness), it was thought to be extremely useful to draw on the project members' experience, knowledge, and expertise as valuable input towards the success of multi-actor social collaboration in BIM project (Adam et al., 2021). Furthermore, the case as chosen based on convenience sampling, which includes ease of access (researcher networking and connections), proximity (due to the current movement control order due to the COVID 19 pandemic), and the ability to meet the research study's requirements (i.e., BIM social collaboration).

Sampling Size

In terms of sample size, a total of 30 potential experts were identified and contacted using the snowballing technique. All potential experts received invitation e-mails, phone calls, and messages outlining the scope of the research study. Finally, 22 experts from a pool of 30 potential experts agreed to participate in this research study. The number of experts who participated in this study is deemed appropriate due to the number of experts identified using the snowballing technique ranges between five and twenty respondents. Furthermore, there is no limit to the number of respondents required for the snow balling technique, which allows the researcher to end the process when the information has reached a saturation point for the study's outcome (Kumar, 2005).

Research Method

This study used a concurrent nested mixed research method with questionnaires surveys (as the predominant or primary method) and an integrated qualitative approach with in-depth interviews to validate the research findings through the description and best captures of thoughts, feelings, and lived experiences for several individuals in order to gain a broader, rich perspective of the topic (i.e. social collaboration) and for studying different features (e.g. diverse professionals backgrounds) within a single study (Zhang and Creswell (2013). The survey and face-to-face interviews were conducted in January 2020, when the project was nearly 70% completed.

Prior to main data collection, a pilot study was conducted through face-to-face interviews with 10 respondents (i.e., 7 experts with BIM experience ranging from 7 to 10 years and 3 academics with 5 years of BIM experience) who were responsible for reviewing the contents and structured questions (part of content validity) in the survey forms. Following a thorough discussion with the group of experts and academics in this pilot study, a set of 40 attributes was selected from the 50 origin attributes, with some of the attributes were consolidated based on the similarity of the concepts of the attributes. Following the concurrent nested mixed approach, the main data were collected first through a questionnaire survey, in which the 40 attributes KAs of multi-actor social collaboration were consolidated and assembled into a questionnaire. The questionnaire comprised both closed-ended and open-ended questions and was divided into two parts, which are as follows;

Part 1: This section sought background information on each participant's level of experience, how many years they have been in the industry and BIM projects, education background, involvement as professional practitioners, participation in any construction industry or BIM programme, conference and publication; types of work sector involved and type of contracting that they have been involved in over the years.

Part 2: The second part focused on the assessment of the KAs in terms of their importance of ranked and details on the top ten KAs in relation to their important influenced to the success of multi-actor social collaboration in BIM projects.

A survey was conducted via face-to-face interview with 22 selected BIM experts (i.e., engineering consultants, contractors, clients etc.) who were directly involved in a BIM level 2 project, with the session lasting approximately two and a half hours for each respondent who was assisted by the researcher. First, the researcher explained the purpose of the study as well as the set of questions included in the questionnaire survey. The researcher then works with each expert one-on-one on the attributes highlighted in the questionnaire survey. At the same time, the following questions were posed: Please provide a scale rating for each attribute based on your experience and involvement in this BIM project and previous related projects, and then provide the ten most important attributes, as well as your thoughts on the following key attributes; Do you think the top ten key attributes are important in facilitating social collaboration and the success of BIM-level 2 collaborative working practises? Please provide the reasoning for it.

Following that, all 22 interviews' discussions were voice recorded (with verbal consent from respondents) and notes were taken throughout the session. Data were systematically analysed using manual qualitative data analysis, and transcribed, coded, and summarised into the (i.e., top ten ranked) attributes to reflect commonalities between responses. Next, all assigned quotations were reviewed for coding and themes, as well as duplications, to ensure that they represented the shared meaning underpinned by the concept of social collaboration in BIM level 2 projects. Finally, for each of the top ten ranked attributes, the relevant quotation was consolidated (i.e., voice recorded and notes), cross referenced, and interlinked with the relevant fundamental principles outlined in the Publicly Available Specification (PAS) 1992-2: 2013 standards for performing collaborative working practise and information management for BIM-level 2 projects.

Profile of respondents

Overall, a total of 22 respondents worked in consultant organisations, with 96% holding upper and medium level management positions in their organisations (see Table 1). It is clear that half of the respondents are from senior and top management and are involved in decision-making, with the remainder mainly responsible as operational drivers to ensure project completion. For example, project manager from Gamuda, senior manager from MRT Sdn Bhd and engineering consultant from Arup. Sixty-one percent of the respondents have an average of ten years of construction industry experience, while 22.7 percent have an average of five years' experience. The majority of respondents had five to ten years of experience working on BIM projects on average, with 18.1 percent having more than 11 years of experience.

In terms of the respondents' involvement in wider BIM related learning activities, the majority of respondents have professional qualifications and actively participate in the construction industry, BIM programmes, and conferences. Meanwhile, 22.7 percent have experience in sharing industry knowledge and experience through publication. This demonstrates that all 22 of the selected respondents that involved in this BIM level 2 project have extensive and diverse career experiences.

Table 1. Summary of respondents

	Respondent characteristics	No. of respondents (total = 22)	(%)
Types of Organization	Developer	2	9.1
	Consultant	14	63.6
	Contractor	6	27.3
Designation	Managing director	2	9.1
	Senior manager	2	9.1
	Project manager	2	9.1
	BIM manager	5	22.7
	Architect	1	4.5
	Civil and structure (C&S) engineer	4	18.2
	BIM coordinator	4	18.2
	Others	1	4.5
Education background	Master degree	7	31.8
	Bachelor degree	11	50.0
	Diploma	3	13.6
	Others	1	4.5
Involvement's experience	Professional practitioners	10	45.5
	Involvement in any construction industry or BIM program	11	50.0
	Participation in conference	14	63.6
	Publication record	5	22.7
Respondent's experience in terms of types of delivery methods	Traditional	3	13.6
	Design and Build	19	86.4

In addition to professional experience, all respondents are registered and certified members of various professional bodies (e.g., Board of Engineers of Malaysia, Board of Architect of Malaysia, etc). Furthermore, some of the respondents have been actively involved in construction and BIM programmes at the local and international levels as chair of committee and committee member (e.g., BIM Institute of Malaysia, National BIM Committee of Malaysia, European Chamber of Commerce, Building Construction Authority of Singapore). The majority of the respondents had worked on building projects, and nearly 73 percent of them had worked on infrastructure projects, particularly rail projects. Furthermore, 27 percent were involved in road projects, while 23 percent and 9 percent involved in airport and port projects, respectively. Almost 86.4 percent of respondents have had experience with project delivery methods such as design and build throughout their careers, while 13.6 percent have had more experience with traditional methods of project delivery. This is supported by the fact that Design and build (DB) and traditional systems are the two most commonly used procurement methods in Malaysia (Suratkon, Yunus and Deraman, 2020).

RESULTS AND FINDINGS

Assessing and ranking of multi-actor social collaboration attributes

The questionnaire was designed to solicit the respondent's assessment on the degree if importance of the 40 attributes for determining the success of multi-actor social collaboration in BIM projects using a five-point Likert scale (1: not important to 5: very important). The mean rating and standard deviation (SD) of key attributes influencing multi-actor social collaboration are shown in Table 2.

Overall, the most important attributes under the *Contractual* categories associated with the main categories of BIM management strategy were "relational contract related to IPD, alliances or partnership" (mean = 4.455), followed by "data security, privacy, and clear ownership right" (mean = 4.182). In terms of *Policy*, the majority of respondents indicated that "guideline, standard, and work process manual approaches" (mean = 4.591) was the most important attributes that needed to be emphasised in the project organisation to influence the success of social collaboration. Following that, the "preparation of BIM adoption in education programme" received a mean rating of 4.182. The multi-actor social collaboration attributes "BIM execution Plan" and "employer information requirement" received the highest mean ratings under *Strategy* categories, with a mean rating of 4.818 and 4.727, respectively. Meanwhile, the attribute with the lowest mean score was "incentive support" (mean = 3.682).

For the Organisational platform main categories are comprised of six categories, each of which includes several key attributes capable of influencing multi-actor social collaboration in BIM projects. The attribute of "understanding roles and leadership" (mean = 4.636) was the highest attribute influencing social collaboration among multi- actors in the *Integrated team* category, whereas the lowest attribute influencing social collaboration among multi-actors in the Integrated team category was "no blame culture (mean = 3.591). Under the *Individual* category, the most important attribute influencing multi-actor social collaboration was "Commitment from Top Management" (mean = 4.591). Meanwhile, "individual education background" (mean = 3.136) was the lowest attribute on the list due to the adaption of BIM knowledge and skills could be enhanced through experience and training courses offered through workshops or specialize courses. The attributes "training, team building workshop, and awareness programme" and "resources" were identified as top attributes that contribute to enhancing social collaboration among BIM actors in the *management support-oriented* category, with a mean rating of 4.500 and 4.318, respectively. Meanwhile, the most important attributes specified under the *Process* category were "coordination" (mean = 4.636) and "standardisation practise" (mean = 4.545). In contrast, the lowest attribute associated with process category was identified as "consensus decision making" (mean = 3.727), followed by "lean integration" (mean = 3.591). The mean rating for "competence and performance arrangement" in the *Continuous arrangement assessment* category was 4.045. Meanwhile, the most influential attribute influencing social collaboration associated

Table 2. Mean rating and standard deviation of KAs influencing the multi-actor social collaboration

Main Categories	Categories	Code	Attributes	Mean rating	SD
BIM management strategy	Contractual	KA1	Relational contracts (IPD, alliances or partnership)	4.455	0.739
		KA2	Data security, privacy and clear ownership right	4.182	0.664
	Policy	KA3	Guideline, Standard and Work Process Manual Approaches	4.591	0.666
		KA4	Preparation of BIM Adoption in Education Program	4.182	0.795
	Strategy	KA5	Joint Governance Structure	3.909	1.109
		KA6	EIR	4.727	0.631
		KA7	BEP	4.818	0.395
		KA8	Incentive Support	3.682	0.995
Organisational Platform	Integrated Team	KA9	Understanding Roles and Leadership	4.636	0.531
		KA10	Mutual Relationship or Interdependency Contribute Great Decision Making	3.955	0.950
		KA11	No Blame Culture	3.591	1.098
		KA12	Focus Towards Achieving the Common Best Practice for Project	4.182	0.501
		KA13	Trust and Respect	4.000	1.024
		KA14	Active Teamwork Based on Continuous Spirit and Motivation	4.091	0.750
		KA15	Readiness and Awareness of Mind Set and Culture to Change and Share Among the Top Management and Multi Actor	4.273	0.631
		KA16	Co-Located Structure of Team Through Virtual Platform and Physically Meeting Approach	4.500	0.598
	Individual	KA17	Key Digital Skills	4.182	0.853
		KA18	Key Soft Skills Through Virtual Platform	4.273	0.631
		KA19	Commitment from Top Management	4.591	0.590

Table 2. continued

Main Categories	Categories	Code	Attributes	Mean rating	SD
		KA20	Experience in utilization of BIM and Construction Work Management Practice	3.727	1.120
		KA21	Accountability	4.227	0.752
		KA22	Understanding on the Theoretical Knowledge of BIM	4.045	0.999
		KA23	Individual Readiness for Changes of Culture and Personal Attitude Through Virtual Digitization Practice	4.545	0.510
		KA24	Psychological Stable and Well Being	3.364	1.329
		KA25	Individual Education Background	3.136	1.246
	Management support oriented	KA26	Resources	4.318	0.780
		KA27	Training, Team Building Workshop and Awareness Program	4.500	0.512
		KA28	Environment Facilities	3.182	0.907
	Process oriented	KA29	Consensus Decision Making	3.727	0.985
		KA30	Transparent	3.909	0.811
		KA31	Availability of Technology for Exchange and Sharing the Information Through Virtual Platform	4.409	0.590
		KA32	Centralised Electronic Communication	4.227	0.869
		KA33	Sharing Experience Through Virtual Process	3.818	0.795
		KA34	Lean Integration	3.591	0.908
		KA35	Supply Chain Integration	4.045	0.844
		KA36	Standardization Practice	4.545	0.596
		KA37	Coordination	4.636	0.658
	Continuous Assessment Arrangement	KA38	Competency and Performance Assessment	4.045	1.046
	Foundational Platform	KA39	Integration of Future Digital Technology Tool	4.045	1.090
		KA40	Interoperability	4.455	0.596

with the *Foundational platform* category was "interoperability" (mean = 4.455), implying that interoperability in terms of standardisation of software and tools during the working process was one of the important features that could contribute to the effectiveness of social collaboration among multi-actors involved in BIM projects.

The interclass correlation coefficient (ICC(k)) method (combination of interrater agreement (IRA)+interrater reliability (IRR)) was used to determine the consistency and consensus of the experts' ratings on the attributes influencing multi-actor social collaboration. Previous research (Che Ibrahim, Castello and Wilkinson, 2015) found that the interrater reliability (IRR) coefficient indicates the consistency of the pattern of ratings by two or more raters, while the interrater agreement (IRA) coefficient shows the degree of similarity in the level or magnitude of ratings by two or more raters. The values 0.898 (IRR) and 0.976 (IRA) were calculated in this study, both of which exceeded the 0.70 threshold (LeBreton and Senter, 2008). As a result of the findings, the high IRR and IRA value indicates a high level of consistency and consensus among experts in assessing the KAs influencing multi-actor social collaboration.

Upon further examination, the survey results confirm that 92.5 percent of the KAs addressed, received average responses ranging from towards "important" to "very important," and 7.5% of the attributes indicate "fairly important," which are also considered important rating criteria, are required to foster the multi-actor social collaboration practise. Despite the fact that quantitative ratings (see Table 2) can be extremely useful in identifying areas of relative strength and weakness, it is believed that attention to open-ended ranking questions is important in presenting a clear picture of the primary contributors influencing the success of social collaboration practise among BIMs actors. Following that, each respondent was asked to identify and rank the top ten KAs (see Table 3). Specifically, each respondent was required to choose 10 significant attributes from a list of 40 and rank them from 1 to 10 in order to determine the most significant attributes that influence social collaboration among multi-actors in a BIM project.

The ranking order for the top ten KAs was determined using the plurality voting method (as adopted by Lin et al., 2002), with the most first-preference votes being selected based on the highest cumulative percentage compared to the other attributes. The KAs were ranked based on the highest cumulative percentage received for each rank. For example, the attribute KA1 received the highest percentage (22.7%) when compared to other attributes, resulting in KA1 being ranked first. However, attribute KA7 was chosen for rank No. 2 because it has the highest cumulative total percentage, which is the percentage ranked first (9.1%) plus the percentage ranked second (27.3%), totaling 36.4 percent. The attribute KA3 was chosen for rank No. 3 because it received the highest cumulative total percentage, that is the percentage ranked No. 2 (27.3%) plus the percentage ranked as No. 3 (18.2%), totalling 45.5 percent. For rank No. 4, attribute KA6 was selected as it has highest cumulative total percentage, where the percentage ranked as No. 3 (36.4%) plus with the percentage ranked as No. 4 (13.6%), totalling 50.0 per cent. KA9, KA19, KA26, KA27, KA37, and KA22 were ranked similarly as No. 3, No. 4, No. 5, No. 6, No. 7, No. 8, No. 9, and No. 10, respectively (see Table 4).

DISCUSSION

In the survey's open-ended question, respondents were asked to explain their reasoning for the key attributes provided for the top ten in ranking order that have the greatest potential to influence multi-actor social collaboration practise in BIM projects. The results revealed that there is a difference of opinion among respondents about ensuring the success of social collaboration based on respondents' diverse backgrounds, types of projects involved, and contract procurement. The following sections discuss the related comments in relation to the top ten attributes identified above.

Table 3. Ranking of attributes based on percentage

KAs	Rankings/%																			
	No.1		No.2		No.3		No.4		No.5		No.6		No.7		No.8		No.9		No.10	
	1	Σ1	2	Σ2	3	Σ3	4	Σ4	5	Σ5	6	Σ6	7	Σ7	8	Σ8	9	Σ9	10	Σ10
KA1	22.7	22.7	4.5		-		4.5		-		-		-		-		9.1		-	
KA2	-	-	13.6	13.6	-	13.6	-	13.6	-	13.6	-	13.6	4.5	18.2	-	18.2	-	18.2	4.5	22.7
KA3	18.2	18.2	9.1	27.3	18.2	45.5	-		-		4.5		-		4.5		-		-	
KA4	-	-	4.5	4.5	4.5	9.1	4.5	13.6	-	13.6	9.1	22.7	-	22.7	-	22.7	-	22.7	-	22.7
KA5	-	-	4.5	4.5	-	4.5	4.5	9.1	13.6	22.7	-	22.7	-	22.7	-	22.7	-	22.7	4.5	27.3
KA6	13.6	13.6	13.6	27.3	9.1	36.4	13.6	50.0	4.5		4.5		4.5		-		4.5		-	
KA7	9.1	9.1	27.3	36.4	18.2		18.2		4.5		-		4.5		-		-		-	
KA8	-	-	-	-	-	-	4.5	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5
KA9	4.5	4.5	-	4.5	18.2	22.7	4.5	27.3	-	27.3	-		9.1		9.1		4.5		-	
KA10	-	-	-	-	-	-	4.5	4.5	-	4.5	9.1	13.6	-	13.6	-	13.6	-	13.6	4.5	18.2
KA11	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5
KA12	-	-	-	-	4.5	4.5	9.1	13.6	-	13.6	-	13.6	9.1	22.7	4.5	27.3	-	27.3	-	27.3
KA13	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5
KA14	-	-	-	-	-	-	4.5	4.5	-	4.5	-	4.5	4.5	9.1	9.1	18.2	4.5	22.7	4.5	27.3
KA15	-	-	-	-	-	-	4.5	4.5	4.5	9.1	-	9.1	-	9.1	9.1	18.2	4.5	22.7	-	22.7
KA16	-	-	-	-	-	-	4.5	4.5	22.7	27.3	4.5	31.8	-	31.8	-	31.8	-	31.8	-	31.8
KA17	-	-	-	-	-	-	4.5	4.5	4.5	9.1	-	9.1	-	9.1	-	9.1	13.6	22.7	-	22.7
KA18	-	-	-	-	-	-	--	-	4.5	4.5	9.1	13.6	-	13.6	4.5	18.2	-	18.2	-	18.2
KA19	-	-	-	-	4.5	4.5	-	4.5	4.5	9.1	22.7	31.8	4.5		-		-		-	
KA20	-	-	-	-	-	-	-	-	4.5	4.5	4.5	9.1	22.7	31.8	-	31.8	-	31.8	-	31.8
KA21	-	-	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5	9.1	13.6	-	13.6	-	13.6
KA22	4.5	4.5	4.5	9.1	0.0	9.1	-	9.1	4.5	13.6	4.5	18.2	-	18.2	9.1	27.3	-	27.3	9.1	36.4
KA23	-	-	-	-	-	-	-	-	4.5	4.5	4.5	9.1	-	9.1	-	9.1	4.5	13.6	-	13.6
KA24	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5
KA25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KA26	13.6	13.6	4.5	18.2	4.5	22.7	-	22.7	-	22.7	4.5	27.3	9.1	36.4	-		-		4.5	
KA27	4.5	4.5	9.1	13.6	-	13.6	4.5	18.2	-	18.2	9.1	27.3	-	27.3	4.5	31.8	9.1		-	
KA28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KA29	-	-	-	-	-	-	-	-	-	-	-	-	9.1	9.1	-	9.1	-	9.1	-	9.1
KA30	-	-	-	-	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5	4.5	9.1	-	9.1
KA31	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5	9.1	13.6	13.6	27.3	4.5	31.8	-	31.8
KA32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.1	9.1	4.5	13.6	4.5	18.2
KA33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KA34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. continued

KAs	Rankings/%																			
	No.1		No.2		No.3		No.4		No.5		No.6		No.7		No.8		No.9		No.10	
	1	∑1	2	∑2	3	∑3	4	∑4	5	∑5	6	∑6	7	∑7	8	∑8	9	∑9	10	∑10
KA35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	4.5	9.1	13.6	-	13.6
KA36	-	-	-	-	9.1	9.1	-	9.1	-	9.1	-	9.1	4.5	13.6	-	13.6	-	13.6	9.1	22.7
KA37	4.5	4.5	-	4.5	9.1	13.6	9.1	22.7	-	22.7	-	22.7	-	22.7	9.1	31.8	13.6	45.5	18.2	
KA38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	4.5	-	4.5
KA39	-	-	4.5	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	4.5	9.1
KA40	4.5	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	-	4.5	4.5	9.1	18.2	27.3

Notes: “-“denotes as no response in ranking the attribute.”∑” is calculated based on ∑n-1 +n

Table 4. The top ten key attributes of multi-actor social collaboration

Rank	Code	KAs
1	KA1	Relational contractual (IPD, alliances or partnership)
2	KA7	BIM execution plan (BEP)
3	KA3	Guideline, standard and work process manual
4	KA6	Employer information requirement (EIR)
5	KA9	Understanding roles and leadership
6	KA19	Commitment from top management
7	KA26	Resources
8	KA27	Training, team building workshop and awareness program
9	KA37	Coordination
10	KA22	Understanding theoretical and knowledge of BIM

Relational contractual (IPD, alliances or partnership)

The most important attribute influencing multi-actor social collaboration practise in BIM projects is relational contractual (i.e., IPD, alliances, and partnerships). Previous researchers (e.g., Merschbrock et al., 2018) proposed that the relational contracts, could form a way of bringing the various actors together through partnering-oriented relationships, where the early involvement of multi-actors in the project could facilitate decision-making towards greater collaboration. Senior Manager 1 argued that: “The implementation of IPD contract is very beneficial because it provides positive impact for projects to integrate all project teams through the proper arrangement method addressed in the contract, sharing of benefits and risk to execute the project”.

Furthermore, the IPD-related contract could impose a contractual obligation on all parties involved to collaborate. For example, BIM Manager 3 argued: “.... in my experience managing projects that use conventional contracts, it completely fails to form collaboration among all of the project team, resulting in a disorganised and unmanageable situation.” Towards achieving BIM-level 2, the application of IPD contract (through multiparty agreement, shared risk and reward) is one of the imperative and necessary initiative that can create collaborative environment. The BIM Manager 4 emphasised that: "The adaptation of the IPD contract incorporates all parties' commitment in their working practises, to give their best, and it is only appropriate and necessary that this commitment extend to sharing failure risk and reward for performance."

BIM execution plan (BEP)

BEP's proper arrangement, understanding of contents, and updating over time among each multidisciplinary discipline could integrate them to collaborate more and further ensure its effectiveness and functionality as a moderator to govern the organization's interaction in BIM projects (Kouch, Illikainena and Perala, 2018). Senior Manager 2 stated that: "As a live documentation, the better preparation of BEP such as clear statement for roles, type of software and the deliverables process that specifically describe the project execution could push the team to integrate together".

Most of respondents believed that this "live document" enables all parties to engage in collaborative working practises because it must be updated on a regular basis from the start of the project to the end of the project. For example, BIM coordinator emphasized that: "This document elaborates how they execute the project to meet the EIR needs, as well as facilitate the other parties in any decision making and share information."

Guideline, standard and work process manual

As part of a project's BIM policy, it should be adaptable to the BIM scope and roles played by multidisciplinary teams, and it should be usable on a variety of computing platforms in both public and private projects (Wong et al., 2010). Senior Manager 1 added that: "Putting in placed the guideline, standard and work process manual in the any project is crucial to nurture collaboration practice among actors."

Given the significance of this attribute, experts believed that having and adopting a uniform standard would be a critical requirement that must be followed in order to form collaborative work practises between diverse organisations in projects in order to standardise the BIM workflow (Lin and Yang, 2018). For example, the BIM coordinator stated, "in our project, we have BSI standard and ISO standard that are very useful to form the proper workflow of process for projects that contribute to the success of collaborative working practises between disciplines."

Employer information requirement (EIR)

As EIR is a pretender documentation that is required for BIM project delivery, it is critical for the multidisciplinary team involved to have such an understanding as part of their collaborative strategy in order for them to communicate, collaborate, and comply with the client requirements and deliverables (Hafeez et al.,2016). Managing Director 1 offered the following insight: "Organising of organisation structure to form collaboration is reflect by the client requirement in the initiating stage of project". Project Manager 2 argued that: "Having a clear requirement in EIR, is crucial since it could act as collaborative platform to integrate parties performing the BIM work process".

The EIR (as one of the fundamental principles for achieving BIM level 2) aims to ensure that users' information needs are clearly defined at the start of the BIM process, and it provides a mechanism for collaboration that allows project parties to communicate, manage, and deliver client requirements (Ashworth, Tacker and Druhmann, 2017).

Understanding roles and leadership

Project participants must understand the set of BIM specific roles in order to facilitate multidisciplinary collaboration practise and minimise interdependencies among actors (Badi and Diamantidou, 2017). Furthermore, the recognition of the new roles would encourage them to centralise virtual communication among all actors who have a significant influence on the social collaboration environment. BIM Manager 1 argued that "In the hierarchy structure, they must have a clear picture of each of the roles played for project members (e.g., BIM manager, BIM coordinator, and BIM modeller), because the BEP explains these roles in detail, which indirectly influences them to build up the leadership spirit to organise the project well." This was supported by Managing Director 1 who emphasised: "Roles of understanding and leadership is crucial for parties performing teamwork for them collaborate to accomplish the work process". The expertise of various disciplines (i.e., architects, contractors, engineers, project managers and software technicians) must have include tacit knowledge and experience to enhance their required understanding related to the task that has been entrusted for them to generate the active collaborative working environments (Oraee, Hosseini and Edwards, 2021).

Commitment from top management

A high level of commitment could transform working methods to BIM-based processes, thus offsetting the limitations related to experiences that can stymie team member collaboration (Al-Hattab and Hamzeh, 2018). Managing Director 1 argued that: "It is difficult for all of those things to happen without the highest commitment from top management in project, where they need to have the mutual understand on BIM to gain this spirit".

Having top management's commitment is critical for team members to motivate themselves in order to strengthen their relationships and form collaborative working practises to complete tasks. BIM Manager 5 in particular emphasised: "It's difficult for project teams to commit to their task, but higher commitment shown by top management could boost their staff motivation to focus more, learn more consistently, and collaborate well to complete work task." This is consistent with the findings of Oraee, Hosseini and Edwards (2021), who discovered that top management must play effective roles (conducting social activities) as a form of appreciation to ensure the consistency of self-motivation for them to focus on their work.

Resources

Several scholars have stated that an adequate resource (i.e., financial and subsidies) provided by top management for training, software, team working workshop, and facilities is an important driver in integrating team members to form a social collaboration environment (Al-Hattab and Hamzeh, 2018). This is consistent with Gu and London (2010), who stated that it is critical for the team environment to be supported with appropriate resources in order for them to improve their productivity of working practise. BIM Manager 2 argued: "The initial of top-down approach to invest in training, hardware and software is also important to enhance project team understanding and competency which able to influence them to collaborate together to fulfil the common goals for project".

The shortcomings of BIM tools (i.e., common data environment) continue to impact collaborative practises, with the main issues being interoperability across the project life cycle, particularly between various tools (Oraee, Hosseini and Edwards, 2021; Babalola et al., 2021). Even though there are a few interoperable formats available, such as IFC, this format is not widely accepted by all BIM tools, necessitating vendors to improve their software and standards to be updated.

Training, team building workshop and awareness program

Despite the fact that the actors have prior work experience, training, team building workshops, and awareness programmes are essential in preparing them for team effectiveness (Gu and London 2010). BIM knowledge, soft skills, and technical skills are the most important requirements because they will communicate with advanced digital tools that are appropriate for each actor's level of understanding and capability. BIM Executive stated that: "For newcomers, and even now, our company has arranged for continuous internal training for all departments to improve their BIM knowledge and keep their technical skills up to date on a regular basis".

Besides, the empowerment of skills competency and knowledge understanding need to be prioritized, which can be achieved through professional development, in particular to older generations of staff, who are more resistant to change (Oraee, Hosseini and Edwards, 2021). This is supported by BIM Manager 2: "If they have BIM knowledge, skills, and experience, training may increase their productivity and also allowing them to centralise their understanding and collaborate more effectively."

Coordination

Coordination has been linked to the overall effectiveness of organisational collaboration (Al-Hattab and Hamzeh, 2018). With increased commitment, leadership, and open communication within the multidisciplinary team, they will be able to collaborate more effectively through the coordination process using the specific platforms (e.g., common data environment (CDE), BIM 360), to achieve the common goal (Zanni, Soetanto and Ruikar, 2017). Senior Manager 1 argued that: "Coordination during the design and modelling process, in particular, would help them understand where they need to have mutual understanding, practise open culture, and cooperation when making any decision in the project".

The majority of respondents believed that coordination is important because of its ability to drive collaborative work practises in order to improve project performance. BIM Manager 2 stated, for example, that "...such as BIM manager and BIM coordinator in project requires BIM knowledge, experience, and effective communication, but they also need coordination skills to effectively identify clashes and reduce error during coordination meeting." This is consistent with Lin and Yang (2018), who stated that BIM professional knowledge, trust, and experience could influence the diverse project team to collaborate effectively during the design phase to execute coordination for BIM model.

Understanding theoretical and knowledge of BIM

It has been suggested that it is critical for all actors to have a theoretical understanding and knowledge of BIM, as this will allow them to collaborate and work together more effectively (Van Gassel, Láscaris-Comneno and Maas, 2014). The incorporation of BIM knowledge and experience would hasten the learning process among actors (Al-Hattab and Hamzeh, 2018). BIM Manager 3 argued that: "It is essential for all actors to comprehend the BIM knowledge that encourage their involvement and collaboration".

In order to embrace collaboration in a social context, each project team and individual must engage in continuous learning regarding BIM knowledge because BIM evolution occurs on a regular basis (Oraee, Hosseini and Edwards, 2021). BIM Manager 2 specifically stated: "...it's important to have theoretical knowledge because for BIM, there will be a new thing that they need to learn from time to time. For example, while we previously focused on modelling, we are now concentrating on information and asset management".

Fundamental Principles for Influencing Multi-actor Social Collaboration in BIM-level 2 Project Delivery

It is worth noting that the transition from BIM-level 1 to BIM-level 2 is a necessary benchmark for determining the maturity level and success of a collaborative working environment. According to Bew et al. (2008), BIM level 1 is associated with the implementation of intelligence on basic CAD usage as the entry point into the BIM maturity level. BIM level 1 features include visualisations and the development of building models, and it is often referred to as 'lonesome BIM' because the models generated cannot be shared among construction project stakeholders. Furthermore, at this level, there is no or little collaboration among the various disciplines because everyone creates and manages their own data information in order to complete their assigned project. However, in order to fully implement BIM in the project, a transformation shift from BIM-level 1 to BIM-level 2 is required, because this level promotes collaborative working by providing each discipline with its own 3D CAD model. Collaborative working at this level necessitates streamlined project-related information exchange and seamless coordination between all systems and diverse disciplines (Babatunde and Ekundayo, 2019).

Drawing from the analysis through survey and depth interview, the top ten attributes have been clustered into three dominant-centric approaches based on the similarity of nature features of KAs capable of influencing social collaboration among multi-actors as best practice approach towards performing success of collaborative working practise (See Figure 2); these include: *behaviour formation*, *procurement model* and *support principles*. Based on the empowerment of 'behaviour formation' domain, there are three internal attributes need to be highlighted in built the individual and team characteristics in the project (i.e., understanding theories and knowledge of BIM, commitment from top management and understanding roles and leadership). This socio-centric approach is the best option in providing the higher level of collaborative working practice, which multi-actors in diverse discipline able to change the way of working with higher level of awareness and responsible feel in managing well for project (Awwad, Shibani and Gostin, 2020). Nonetheless, 'procurement model' domain is considered crucial to form the strong bonding between multi disciplines in the project, this would comprise (such as, relational contract, guideline, standard and manual procedure, EIR and BEP). According to Alreshidi, Mourshed and Rezgui (2016) and Mignone et al. (2016), the extensive procurement model has led to the introduction of more collaborative-based procurement in delivering projects. Towards providing an integrated team in handling project for BIM level - 2, the advance 'support principles' (i.e., resources, coordination, training, team building and awareness program) are necessity to embedded together for progressive collaborative working practice.

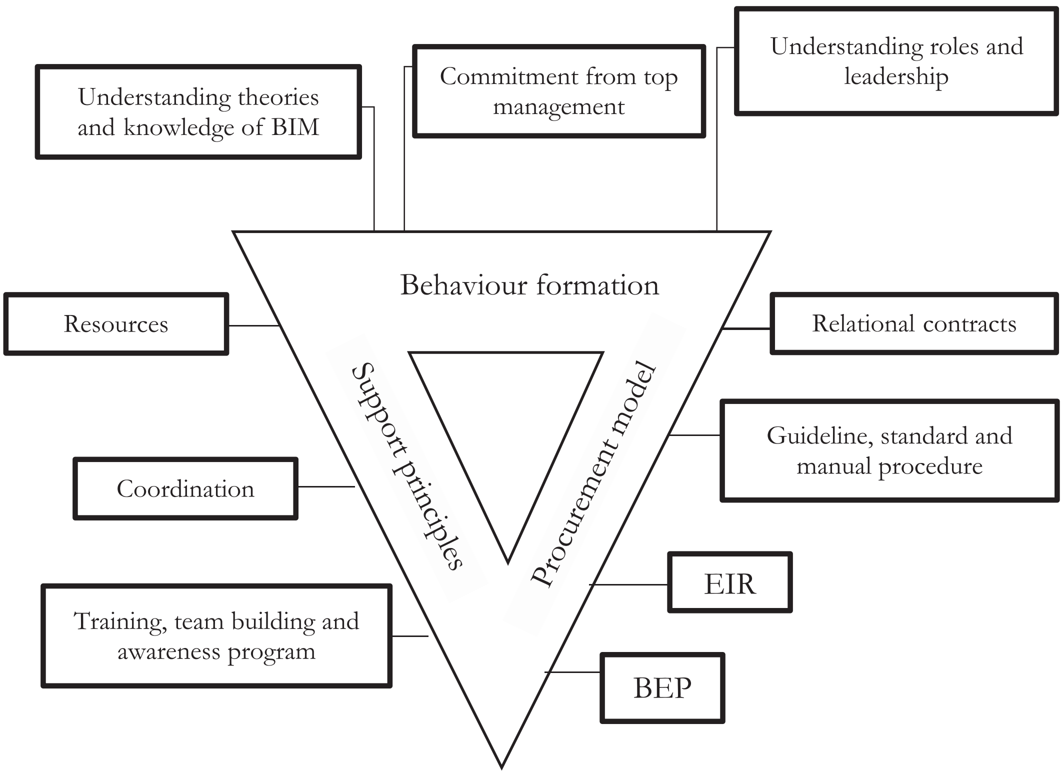

Figure 2. Best practice approach influencing social collaboration among multi-actors in BIM Level-2 projects

Based on Publicly Available Specification (PAS) 1992-2: 2013, seven fundamental principles for performing collaborative working practise for BIM-level 2 project delivery were considered as a reference to the three main domains in order to shift from lower collaboration (BIM level-1) to higher collaborative working (BIM level-2) in the project. The relationships of the three main domains (i.e., behaviour formation, contractual model, and support principle) and the seven fundamental principles are discussed in turn.

FUNDAMENTAL PRINCIPLE 1: ORIGINATORS PRODUCE DEFINITION INFORMATION IN MODELS

The importance of producing information in models cannot be overstated when performing a project into BIM level 2, whereby the project team was assigned as the originator responsible for controlling the sourcing of information from other models where required via reference, federation, or direct information exchange (BSI, 2013). Furthermore, this current BIM level 2 practice differs from BIM level 1 practice in terms of collaboration, where previously all multi-actors in the diverse disciplines created and managed their own data sources of information using separately of 2D and 3D CAD drawing, with low level of collaboration in view of all actors still practicing physically collaboration. This is in contrast to BIM level 2, where all actors are assigned as originators and are fully responsible for collaborating using federated models and information shared in the CDE platform, as well as being involved in decision making to provide the best for the project. Specifically, project teams that react as originators to creating information in models need to focus on understanding the roles, responsibilities, and commitments, as well as consistently building relationships and leaderships among teams in order to manage essential construction project information in digital format throughout the project life cycle.

Furthermore, the standardisation level of understanding and commitment expressed by team members on the interpretation of standard requirements must be clear and transparent enough to avoid issues related to information in models and the collaboration process in steering BIM level 2 project. The collaboration process necessitates transparent standards and regulations capable of encouraging all project participants to collaborate effectively (Oraee, Hosseini and Edwards, 2021). It is acknowledged that all teams should refer to the requirements stated in the EIR and BEP as live documentation as for guidance for the right action and alleviated conflicts during the working process. This current practise creates comprehensive collaboration among multi-actors involved, which differs from BIM level 1 collaboration practise, because diverse disciplines are capable of updating federated models and information through CDE, in line with EIR and BEP, which also need to be updated from time to time in the early stages until the end of projects and influence a project's effectiveness.

It is important to note that shared understanding and experience, as well as adhering to standard requirements, are critical for diverse teams to negotiate each other's in developing information in models. Despite the fact that there are a few interoperable formats available on the market, such as IFC, these formats are not widely accepted by all BIM tools and require standards to be updated and vendors to improve their software (Oraee, Hosseini and Edwards, 2021). Also, the integration of expertise that crosses functional boundaries is critical in BIM Level 2 in order to reactive the effective coordination after all models have been integrated in one federated model. Consistent commitment and well-interaction from various organisations are an important gesture to focus attention and communicate solutions to issues during coordination meetings (Kubicki et al., 2019).

FUNDAMENTAL PRINCIPLE 2: PROVISION OF A CLEAR DEFINITION OF EIR AND KEY DECISION POINT

Based on the findings, there is a need for organisational teams to have a sense of accountability and shared values toward task and goal setting in order to strengthen the circle of interaction in producing specific and realistic EIR. This study discovered that a very positive and consistent commitment among top management is critical to motivating teamwork to collaborate in comprehending the EIR requirement for them to produce the comprehensive BEP. Having trust from the top down would create a sense of respect in both parties, increasing the level of relationships and allowing them to communicate in order to achieve the main goal of the project (Oraee, Hosseini and Edwards, 2021). Furthermore, it would assist diverse teams in achieving standardised levels of understanding in order for them to commit to responding in the BEP to optimise performance of working practises beginning in the early stages until handover (Mei et al., 2017). With this approach, the transition from BIM level-1 to higher-level collaboration (BIM level-2) could be accomplished effectively through unity and common understanding, continuous commitment, and trustful practise among multi-actors (Awwad, Shibani and Gostin, 2020) from various disciplines to fulfil their responsible task in the project.

The adoption of collaborative arrangement e.g., IPD in BIM was the best-fit approach for contracts because it was capable of displaying smart digital data sharing among all project players, primarily due to the elimination of legality (Oraee et al., 2019). The use of collaborative arrangement could also increase the value to the client, particularly in common understanding of BIM standards, early engagement to produce realistic, achievable, and specific EIR for team members, which improves collaboration, coordination, and communication in decision making (Eynon, 2016). An appropriate training, awareness, and team building workshop are critical means of increasing efficiency, cooperation, and a positive mindset among team members in order to facilitate organisational collaboration (Piroozfar et al., 2019). This approach promotes better routine and behaviour, allowing multi-actors from various disciplines to transition from BIM-level 1 to BIM-level 2 collaborative working practise.

FUNDAMENTAL PRINCIPAL 3: EVALUATION OF THE PROPOSED APPROACH, CAPABILITY AND CAPACITY TO DELIVER REQUIRED INFORMATION PRIOR TO CONTRACT AWARD

The ability to create a team leadership environment through a collective of expertise from various disciplines and senior groups could initiate active leadership, allowing them to consistently communicate in order to understand the requirements and produce a perfect solution to any problems (Oraee, Hosseini and Edwards, 2021). With this mutual understanding and synergistic leadership, a common understanding and harmonised environment among multi-disciplines would be created, easing the transition from BIM level-1 to BIM level-2 collaborative working practices in manging project.

The importance of top management involvement in supporting and nurturing team project integration practise cannot be overstated, as they acknowledged all requirements stated in EIR and BEP to motivate all teams to consistently collaborate and exchange information in producing the best outcomes. The content of the BEP is critical for the project owner to identify and assess the project team's capability, capacity, and competence in making contract award decisions (BSI, 2013). Furthermore, all teams must have a shared understanding of knowledge (e.g., standard, EIR, collaboration processes, contractual arrangements, and roles) and be committed to describing the details content of BEP (e.g., software and method use in collaboration process, information sharing, etc.), in order to orchestrate the collection action. Previously, in BIM level-1 practise, a lack of performing common understanding could impede diverse disciplines from effectively collaborating; however, a consistent spirit and supporting motivation could boost them to optimise their collaborative working practise in managing BIM level-2 projects.

FUNDAMENTAL PRINCIPAL 4: BIM EXECUTION PLAN (BEP)

The BEP is treated as a core agreement in BIM-enabled projects that delineates how the BIM project is to be delivered (Oraee, Hosseini and Edwards, 2021). The findings indicate that cross-disciplinary understanding of roles is critical for them to discuss, negotiate, hold each other accountable, and make collective decisions in preparing the contents of the post-contract award BEP, which must include everything stated in the EIR. Such understanding could encourage discovery, creativity, and empower the team to have team leadership to resolve specific tasks (Eynon, 2016). Furthermore, clarity of roles, responsibilities, and authority is an essential aspect of effective information management, which should be incorporated into contracts (BSI, 2013).

Top management commitment is widely regarded as a necessary ingredient in cultivating responsibilities and collaborative working environments. The project team recognised the importance of compliance with standards and EIR as a reference to produce specific details of BEP when bringing the collaborative working practise (Eynon, 2016). The practical application of IT solutions for resources (i.e., software, exchange formats, process and data management systems) and the identification of appropriate training should be detailed explained in BEP and MIDP and should be understood by all teams involved in facilitating project delivery management. Thus, these efforts would shift current practise (BIM level-1) into BIM level-2 practise, with a centralization of understanding and action for multi-actors in diverse disciplines, to exhibit specific, achievable, and comprehensive BEP and EIR, which are realistic to execute in order to achieve their project's common goal.

FUNDAMENTAL PRINCIPAL 5: PROVISION OF A SINGLE ENVIRONMENT TO STORE SHARED ASSET DATA AND INFORMATION

The project information model (PIM) graphical and non-graphical data documents must be well managed through CDE, which provides a collaborative environment for sharing work and can be implemented in a variety of ways. The findings revealed that the project team must understand their own roles as well as those of others in order to stimulate team integration and collaboration during information sharing, coordination, and validation in the CDE process. Continuous motivation and support from upper management, as well as centralised shared learning efforts that exhibit among diverse disciplines teams, could also ensure the consistency of PIM operation.

In order to maximise the function of CDE and integrate expertise in diverse teams, integrative teams would be formed during the professional design stage in WIP, information exchange in the shared area, and the coordination process. According to Zanni, Soetanto and Ruikar (2017), experience, effective communication, and detailed discussion encourage teams to make collective decisions, which contribute to the effectiveness of constructability by minimising clashes during coordination. With this best practise approach, the centralised shared learning and knowledge, embedded with strong spirit cultivate capable of shifting lower collaborative into progressive collaborative working environment to shared data and information comprehensively through CDE, which indirectly influences multi-actors to abandon BIM level-1 practise towards project completion.

FUNDAMENTAL PRINCIPLE 6: APPLICATION OF PROCESSES AND PROCEDURES OUTLINED IN THE DOCUMENT AND STANDARDS

Developing consistent knowledge sharing and application of standards requirements during the working process is critical for teams to make unanimous decisions and achieve productive results. In the spirit of collaboration, social engagement within teams should be prioritised, with members focusing on the collective effort rather than individuals (Cross and Carboni, 2021).

The ability of teams to use the appropriate resources and skills, in reaching the target, especially in exchanging information and completing the challenges of the coordination process, is influenced by the ability of teams to use the appropriate resources provided (i.e., software, hardware, and etc). Continuous learning and experience from experts through continuous workshops would allow all teams to greatly accelerate and improve collaborative, as well as raise the reliability of relationships and cultivate their shared commitment to drive their working process and adhere to standards. According to Pauna et al. (2021), one of the criteria for selecting actors is the ability to work collaboratively and developing the ability to work efficiently together is important. As a result of this positive wave cultivation, it is possible to transform the actors' (BIM level-1) practise to progressive changes in workflow (BIM level-2), ensuring the application of processes and procedures outlined in documents and standards can be successfully executed.

FUNDAMENTAL PRINCIPAL 7: DEVELOP MODELS INFORMATION USING SELECTED TOOLS

Interactions between project teams in information management can only be supported by BIM approach interoperability, i.e., the interoperability of various models created by different models interoperability). However, in order to achieve successful interoperability, social empowerment in the form of team bonding interaction, understanding of roles and knowledge, a culture of trust and mutual expectation, and a culture of trust and mutual expectation must be prioritised. A synergy of teamwork among teams that collaborate in federated models may generate mutual conversation and communication, which further encourages mutual understanding and respect, influencing the seamless interoperability of models to exchange information, coordinated model to resolve issues (e.g., clash detection), and facilitate to visualise constructability. The use of BIM as a central repository for building project management is promising and has the potential to revolutionise information management for a project and throughout the project life cycle. Thus, top-down cooperation and collaboration are required in order to determine heterogeneous software tools that are interoperable with each other, which must be clearly indicated in BEP as a part of contractual agreement in the early stages of projects, allowing for a minimise of disparity of software tools and vendors to co-exist and making collaboration practise more efficient. Furthermore, continuous training (internal and external) based on updated software is required to consistently upgrade skills and competency in an accelerated collaborative working environment among project teams working towards the set goal. Consequently, the dramatic transition from BIM level-1 to BIM level-2 practise was accomplished successfully, easing the launch of the BIM level-2 implementation process toward expanding the construction industry revolution 4.0 strategies.

Conclusions

This study provides an overview of the KAs influencing multi-actor social collaboration in BIM projects from the perspective of Malaysian practitioners. This study assessed the importance of the KAs in nurturing the social collaboration practise based on the SLR, questionnaire survey, and in-depth interview with established of 22 BIM experts of BIM-Level 2 projects. The findings suggest that all of attributes are important in determining the success of social collaboration in BIM projects. Moreover, this study recognises importance of identifying not only the relevant KAs but also the dominant attributes in detail. The top ten ranked attributes that contribute to the success of multi-actor social collaboration are as follows: contractual; BEP; guideline, standard and manual work process; EIR; understanding roles and leadership; commitment from top management; resources; training; coordination and understanding theoretical of BIM knowledge.

These findings led to the development of a best practise approach consisting of three dominant-centric factors (i.e., behaviour formation, procurement model, and support principles) that have an implicit and explicit influence on social collaboration among actors. Following that, the proposed best practise was used to address the collaborative working practise outlined in the BIM-level 2 project delivery basic principles. The incorporation of these best practises into the ecosystem of digitalize construction industries will assist industry organisations and academics in responding to the needs and preparing a project team to achieve successful BIM-level 2 by bringing social collaboration practise among multi-disciplinary teams as a primary concern to drive the success of collaborative environments and acts as a catalyst for collaborative environments.

This study is of benefits of construction industry players (i.e., owners, designers, and contractors) in cultivating a collaborative culture among project teams in order to successfully manage information management for BIM project delivery. As a result, additional research is recommended to validate the proposed 'best practise approach' to real-world working practise referring to the fundamental principles for level 2 information modelling among experts with experience in managing BIM-level 2 projects.

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