Exploratory Investigation of Scope Management for a BIM-enabled Construction Project

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ABSTRACT

Despite the recommendation of the international BIM standard ISO 19650, the current scope management process and practice for a BIM-enabled project need to be improved for the full benefits of the BIM adoption. Due to a lack of clarity in BIM-enabled project scope definition and roles and responsibilities for project key participants, unnecessary reworks and various change orders are occurred in the project execution phase. To minimise reworks and *improve productivity, it is essential to understand the status of BIM-enabled project scope management practice. However, the current practice of scope management in a BIM-enabled project environment has been rarely studied. Thus, the research aims to identify the current scope management practice for BIM-enabled construction projects via interviews. It is revealed that the current scope definition process fails to provide clear roles and responsibilities for a BIM manager and a project manager separately. Additionally, the disconnection between the PIM and AIM causes ineffectiveness of utilising lessons learned for scope definition. The research findings will contribute to providing insights to improve the current scope management practice more suitable for a BIM-enabled project.*

Keywords: BIM, BIM Standard, ISO 19650, BIM Project Scope, Scope Management

INTRODUCTION

2D paper-based collaboration in the design and construction industry has shown limitations in increasing productivity compared to other industries as it is complicated and difficult to cope with various design and scope changes throughout a project lifecycle. Furthermore, recent clients' requirements for atypical and unique designs as well as sustainable attributes of a building add complexity to improve productivity. To improve productivity and handle changes efficiently, the construction industry has increasingly adopted Building Information Modelling (BIM) as it is a digital information management platform to productively manage construction projects from the planning to the operation and maintenance stage based on effective decision-making and efficient collaboration among key project participants. Consequently, the construction industry has adopted BIM for various construction projects in various countries including the US, UK, Singapore and South Korea where mandates BIM use for public construction projects (Kim, Freda and Nguyen, 2020).

While enabling capabilities of BIM such as early design collaboration and design regulation checking, informed cost planning and sustainable built asset management (Kim et al., 2021, Xing, Kim and Ness, 2020; Kim et al., 2016) improve productivity, it adds new complexities to project scope management related to digital information exchange and coordination among key project participants in a BIM environment. ISO 19650 (2018) recommends identifying a high level of project requirements and scope before determining a digital information exchange platform for BIM at the project planning stage. Researchers supported the importance of scope identification and management plan at the project planning stage for the success of a BIM-enabled construction project as it is 'Start on the Right Foot' as a colloquial terminology. Indeed, the Royal Institute of Chartered Suveyors explicitly emphasised the importance of integrated scope identification to connect traditional project management and BIM-enabled project management processes (RICS, 2017). Researchers emphasise the importance of a systems approach to managing the complexities of BIM-enabled construction projects effectively without hampering the well-established traditional workflow and overwhelming project stakeholders by requesting a plethora of extra digitalised design and technical information (Kiridena and Sense 2016).

Consequently, the AIA Digital Documents Guide (2022) indicate the project deliverable identification as well as roles and responsibilities for the delivery of work packages must be identified and developed based on iterative collaboration among all levels of project team individually and collectively from the outset of a project. It is evident that the current scope management process and practice need to be improved to achieve full benefits from the BIM adoption. However, the current practice of scope management in a BIM-enabled project environment has been rarely studied and identified. Thus, the research aims to identify the current scope management practice for BIM-enabled construction projects as well as the common problems in scope management. The research will shed light on how to improve the current scope management process.

BIM-enabled PROJECT SCOPE DEFINITION IN ISO 19650

For BIM to serve as a fundamental solution to productivity and efficient collaboration, it is essential for the Architecture, Engineering, and Construction (AEC) sectors to achieve BIM maturity across the supply chain. BIM maturity level is defined as the technological progress achieved in the AEC sectors according to the degree of collaboration and information sharing between the different stakeholders involved in a project (B/555, 2014). The international BIM standard ISO 19650 emphasises that the selection of an appropriate digital platform for collaboration and coordination of project information is instrumental for seamless information sharing and BIM maturity improvement. Although the International Organization for Standardisation released BIM-enabled projects specific standards ISO 19650 series in 2018 and 2020 to provide a framework for information management throughout the whole life cycle of any built asset, it primarily focuses on developing and managing project information named the Common Data Environment (CDE) in a BIM system.

Figure 1. Connection between ISO 21500 and ISO 19650 (ISO, 2018)

More importantly, ISO 19650 explicitly indicates that the BIM standard belongs to ISO 21500 Project Management standard, and recommends to be applied based on the project management process as shown in Figure 1. However, researchers (Boje et al., 2020) criticised the current practice of managing the BIM project scope of works since the complexities of managing project scope and client requirements in a BIM-enabled project environment is overlooked. Khudhair et al. (2021) supported the arguments by pointing out that a partial understanding of information requirements and scope management processes causes additional reworks and change orders in the execution stage. Furthermore, an ad-hoc approach to applying BIM for construction projects without a holistic comprehension of a BIM-enabled project environment is currently prevalent in the AEC industry. Consequently, a BIM-enabled project has been considered time-consuming and prone to generating more change orders during the construction stage since seamless integration of the scope of works for design and construction information from diverse project key participants is not captured from the outset of a project (Shayan et al., 2019; Kim et al. 2016).

Indeed, there are six core information packages comprised of four requirements and two deliverables to establish and develop the CDE in the international BIM standard as shown in Figure 2. The four requirements are further divided into visual and non-visual information document packages – Organisational Information Requirements, Asset Information Requirements, Project Information Requirements, and Exchange Information Requirements. The two deliverables are BIM models, which are named Asset Information Model (AIM) and Project Information Model (PIM), that are created in a BIM tool such as Revit or

ArchiCAD based on the four requirements identified prior to the BIM model creation. The most important aspect of the diagram in Figure 2 is that all four requirements are interconnected, and the final outputs and requirements for the PIM are provided by the EIR.

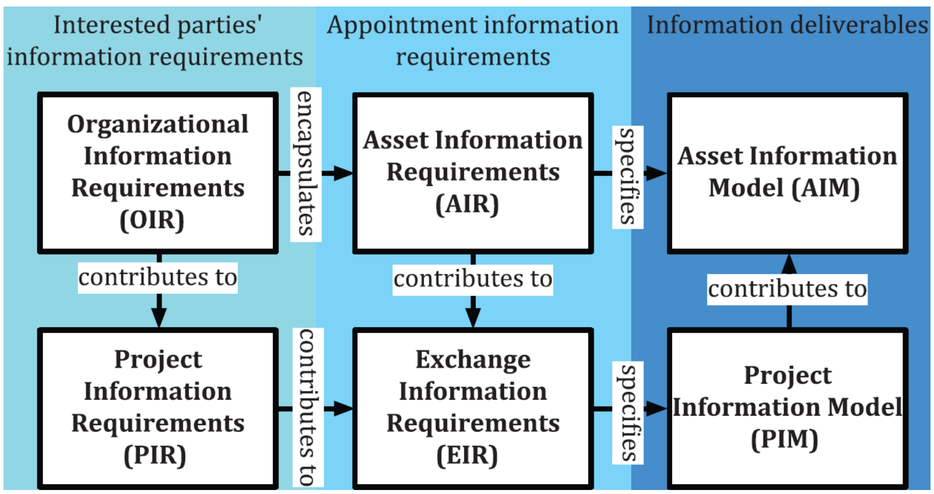

Figure 2. Relationship between Requirements and Deliverables in ISO 19650-1 (ISO, 2018)

When the PIM is fully developed, the construction project is also completed. The final output from the PIM, which is a As-built Asset BIM model, is handed over to a client for the operation and maintenance of the building at the end of the project, and the As-built Asset BIM model is the AIM. Given the information flows and BIM model development processes, clear and detailed scope identification and management is crucial to deliver high quality deliverables – Physical Building and Asset Information Model.

Especially, complete BIM-based design development and electronic file-based collaboration are the essential part of the CDE for a BIM-enabled project environment. Although the CDE enables all stakeholders to collaborate effectively and efficiently based on a single source data, the CDE environment also contains a high risk in information sharing and coordination because a 'Garbage in, Garbage out' situation can occur if there is no clear scope of work identified. In other words, design, construction, and project management information that was previously shared and collaborated in a paper-based project environment documents needs to be converted to suit the digital BIM environment, and researchers asserted that the traditional project management process fails to fully correspond with the rapid changes (Waheeb and Andersen, 2021; Chan et al., 2018). Regarding, Taylor and Bernstein (2009) highlighted the importance of management support during the transition to a digital collaboration environment with BIM as it will change the traditional project management process and add extra workload to the project team to align the BIM management aspect with the existing process.

PROJECT SCOPE MANAGEMENT FOR BIM-enabled PROJECTS

Atkinson et al. (2006) argued that project tender documents or proposals are unlikely to be successful when the project scope is vaguely identified, and assumptions are not properly understood among project team members. Although the fundamental uncertainty of a project cannot be completely removed, El-Sawalhi et al. (2007) pointed out that poor scope management leads a project to a high-risk project environment, and consequently, the contractual agreement on the project scope is destined to be modified and generate various change orders in the execution stage. Especially, the statement of work should provide sufficient technical and managerial details for developing designs and construction project management plans including schedule and cost management plans (Chen and Kamara, 2011). However, when there are insufficient details provided, the level of project risks will become high, and relevant subject matter experts such as a BIM modeller, BIM coordinator, and BIM manager are not able to create the two deliverables – PIM and AIM (AIA, 2022). Smith and Tardif (2012) emphasised the importance of the planning stage where various construction information such as design, time, cost, and quality needs to be identified and defined as detail as possible for project success. Furthermore, Beach et al. (2017) recognised that blindly adopting BIM technology will fail to enhance productivity since the essential part of the CDE including integrated information exchange and project scope management process is not fully defined. Pellerin and Perrier (2019) and Gong et al. (2019) support the importance of scope management by asserting that project planning and scheduling based on detailed work packages and deliverables are vital to achieving project success.

Despite the importance of scope definition and management, Chan et al. (2018) recognised that BIM technology has been primarily used for schedule management and cost estimation and planning. Researchers criticised that less attention is given to scope management although poor scope management is the root cause of time delay and cost overrun and project risks related to reworks and change orders (He et al. 2017). As aforementioned, the text and visual-based exchange information requirements need to be converted into 3D BIM model. To define the scope of work and detailed information included in a BIM model, design and construction professionals need to develop a BIM execution plan (ISO, 2018). The BIM execution plan should capture both design and project management information within the scope of work for the PIM creation. However, researchers recognised that the BIM execution plan is currently being developed with one side of information either design or project management information. (Ma et al., 2018, Whyte and Hartmann 2017). Consequently, 4D BIM (construction schedule visualisation) and 5D BIM (real-time quantity and cost estimation) capabilities require extra time and costs to be utilised for actual project planning and progress tracking since project requirements and scope of work are not fully identified and converted into the CDE of a BIM environment (Derbe et al., 2020). Furthermore, Cicacioglu and Yaman (2021) identified that the essential construction information is often omitted due to the insufficient level of details of individual BIM models which causes inefficiency and reworks. To minimise reworks and define information sufficiently, the AIA Digital Documents Guide G203 (2022) recommend an iterative process for scope management to identify project deliverables and project team members' roles and responsibilities as clearly as possible from the outset of a project. Thus, the research will identify the current practice and the common problems for scope definition for BIM-enabled construction projects.

RESEARCH METHOD

This research adopted a semi-structured interview to identify the current practice and the common problems for scope definition for a BIM-enabled construction project. A total number of 18 design and construction professionals responded to the interview. The participants were targeted purposefully and selected internationally from the UK, US, Spain and Australia to reveal global-wise common issues in scope management, and only invited who have hands-on experience of BIM-enabled construction projects as well as get involved in the scope management process as core project team members. The purposive sampling approach is adopted to capture high quality and in-depth information from the participants who specifically fits the purpose of this research. The interview questions were categorised into three main groups: a) Participants' demographic profile; b) Scope Management Practice in a BIM-enabled project; c) Challenges in BIM Scope Management. The questions were developed based on the literature review and comprised of semi-opened questions using Liker Scale to effectively capture the experts' opinions qualitatively and quantitatively. Due to the geographical constraint, interviews were conducted via phone and an online tool such as Zoom with the participants in the UK, US and Spain. The local participants in Australia were interviewed via face-to-face interviews.

RESULTS AND DISCUSSION

50 purposely targeted construction professionals were invited for the interviews, and 18 participants accepted the invitation (36% response rate). All participants have more than 10 years of experience, and 56% (10 participants) have more than 12 years of experience in their fields. The average experience of the participants is 12.3 years in using BIM or getting involved in a BIM-based project. The respondents' profile is as shown in Table 1.

Table 1. Profile of Interviewees

Role	MD	GC	SM	SCM	PM	SPE	QM	DE	Total
Private Sector	1	1	1	-	3	2	1	1	10
Public Sector	1	-	3	1	1	-	-	2	8

*Note: MD: Managing Director, GC: General Contractor, SM: Site Manager, SCM: Supply Chain Manager, PM: Project Manager, SPE: Senior Project Engineer, QM: Quality Manager, DE: Design Engineer

The overall balance between the public (8 participants) and private (10 participants) sectors is intentionally achieved to obtain insights from both sectors since the public sector mandates BIM use for public construction projects while the private sector does not have the mandate. The private sector is much actively adopting and utilising BIM for various construction projects to improve productivity and achieve more with less costs.

A. Current Scope Management Practice in a BIM-enabled project

A-1. Involvement of Project Manager

Interviewees were asked to indicate if a project manager is mainly involved in the contract development process from the outset of a BIM-enabled project. As shown in Figure 3, 67% of interviewees (12 persons) indicated negative responses, and only 22% (4 persons) indicated positive responses to the question.

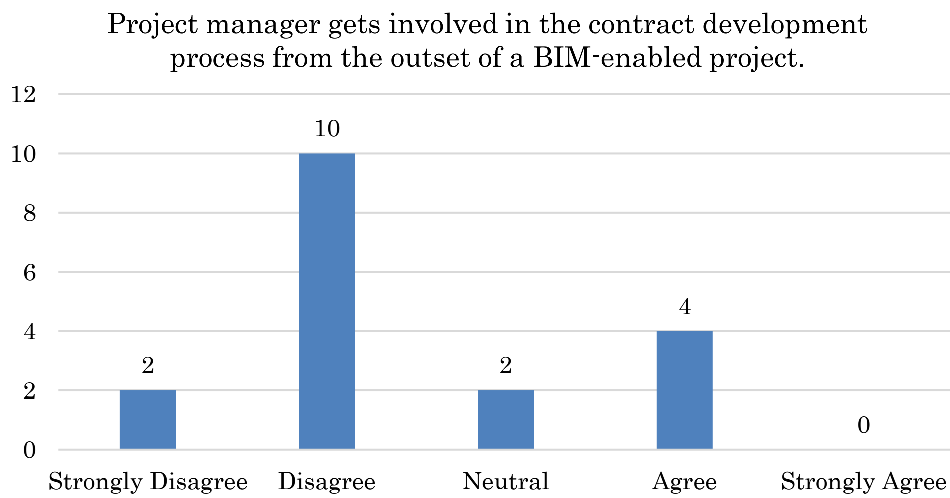

Figure 3. Level of Involvement of Project Manager for the Contract Development (Y-axis = Number of Respondents)

Based on the findings, a project manager currently does not play a core role in the contract development for a BIM-enabled project, and the 12 interviewees commonly pointed out the unclear roles and responsibilities between a project manager and a BIM manager in a real-life project. Interviewees commented that the current scope definition of a BIM project is mainly relying on a BIM manager, and a project manager gets involved in the contract development only after the scope of works for BIM model development is finalised.

Although BIM serves as a critical information exchange and collaboration platform from the design stage, the scope for BIM model development and management still belongs to the project scope. The four interviewees indicated the positive response emphasised the importance of the relationship between BIM and Project management processes because the scope of works for the entire project should provide a sub-scope of works for BIM model development and management, which is echoed with the ISO 19650 (2018).

A-2. Importance of Scope Definition for Progress Tracking

Interviewees were asked to indicate the importance of detailed scope definition for project progress tracking in a BIM-enabled project. This question is related to the first question, and intended to see the connection between scope definition and project progress checking in terms of deliverables from the end of each project stage.

As shown in Figure 4, the positive and negative responses were indicated equally. Especially, the seven persons who indicated that the detailed scope of work is not significant for progress tracking commonly commented that the progress checking in a BIM-enabled project environment is automatic, and it is easy to check the progress without complicated progress reports. Based on these comments, it can be extrapolated that there is a high risk of reworks due to a lack of clear scope definition as well as a high possibility to miss an opportunity to recognise misinterpretation of the client's requirements timely.

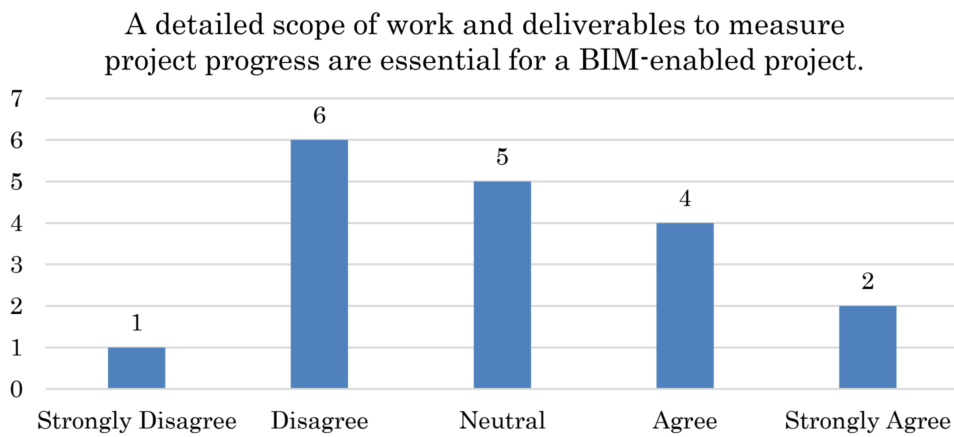

Figure 4. Importance of Scope Definition for Progress Tracking
(Y-axis = Number of Respondents)

Indeed, the six persons who showed an understanding of the importance of the clear scope definition and the five persons who indicated Neutral for this question all agreed that the automatic progress checking and design change reflections capabilities in a BIM-enabled project environment can be a "double-edged sword" since poor scope definition will eventually lead a project to poor performance and reworks. Furthermore, all interviewees agreed that the scope definition is one of the most critical tasks for project progress tracking although the six interviewees commented that the importance of scope definition can be relatively less important in a BIM-enabled project environment compared to a traditional project environment.

B. Challenges in BIM Scope Management

B-1. Project Deliverable Identification

Interviewees were asked to indicate when the project deliverables are fully identified. 78% of interviewees (14 persons) agreed that the concept design stage is where the full scope of BIM models and information exchange plans are developed as shown in Figure 5.

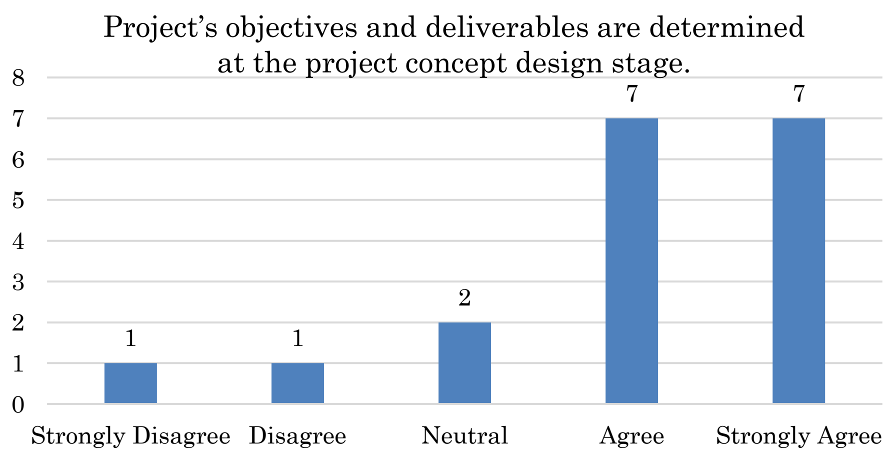

Figure 5. Project Deliverable Identification in the Concept Design Stage (Y-axis = Number of Respondents)

Figure 5. Two negative responses indicated that the project deliverables are identified at the planning stage, and further updates and fine-tuning in the project scope will be carried out at

the concept design stage when a 3D BIM model is developed for an initial design review.

However, all interviewees pointed out the benefits of BIM use for design scope definition as well as a deliverable definition since BIM enables all project key participants including a client, design team and contractors can intuitively understand design intent and project scope for cost, time and quality based on a 3D BIM model environment. Interviewees all agreed that the BIM-enabled environment is more effective and efficient to understand design intent and requirements compared to various 2D drawings and technical reports. In addition, all interviewees also asserted that a BIM-enabled construction project should go through a concept design stage as the concept design stage is the best stage to amend design intent and fulfil the client’s requirements which might be omitted or misinterpreted in the planning stage. Interviewees advised that the current BIM model developments are often intended to combine the concept and detailed design stages together, so reworks occur during the detailed design stage.

B-2. Utilisation of Lesson Learned for a BIM-enabled Project

Interviewees were asked to indicate how lessons learned from the previous BIM-enabled projects are utilised for scope definition, and about 90% of interviewees (16 persons) indicated a lack of utilisation of the lessons learned for scope definition as shown in Figure 6.

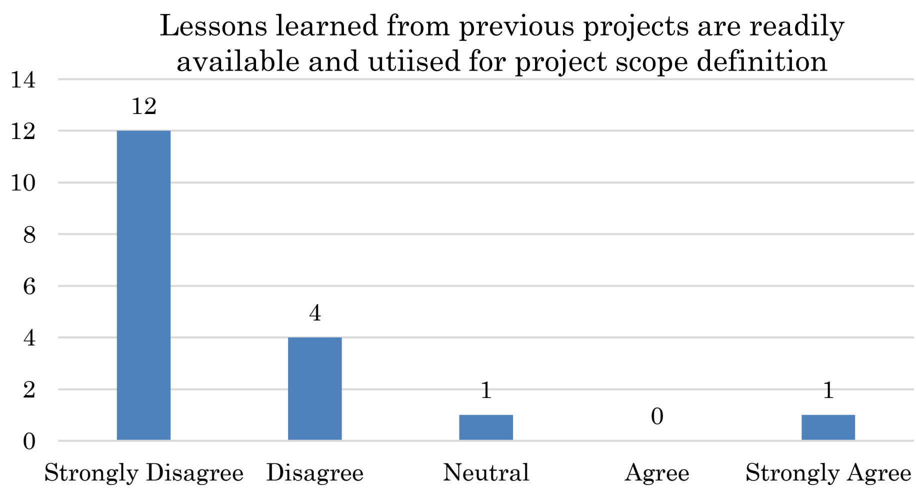

Figure 6. Utilisation of Lessons Learned (Y-axis = Number of Respondents)

Interestingly, the most of interviewees commented that there is difficulty to utilise lessons learned for a new project since essential lessons learned for scope definition are not readily available in the Asset Information Model (AIM) where the required information is supposed to be archived as recommended by ISO 19650. Interviewees pointed out that there is a disconnection between the Project Information Model (PIM) and the Asset Information Model (AIM) since the PIM is progressively developed by a general contractor and sub-contractors while The AIM is further developed from the PIM once a general contractor hands over a PIM to a client after the completion of a project. Consequently, two different parties manage different types of information about a building at different stages of a building's life cycle.

Furthermore, even if a project team attempts to utilise the AIM to obtain lessons learned, the main information from the AIM is mainly building operation and maintenance which is more relevant to business case development and strategic decision rather than a project objectives and scope definition. Two interviewees commented that project team members' workloads temporarily increase to extract the required information from the AIM which causes complications to the entire project workflow. As a result, construction professionals tend to develop a project plan and define scope without utilising lessons learned as it requires less workload and saves efforts and time. However, all interviewees agree on the importance of utilising lessons learned to avoid the same mistakes and risks as well as improve the quality of project outcomes.

CONCLUSION

Currently, the AEC industry around the world strives for digital innovation to improve productivity and achieve competitive advantage. Although the international BIM standard provides a way of managing a BIM-enabled project, the current scope management process and practice need to be improved for the full benefits of the BIM adoption. However, the current practice of scope management in a BIM-enabled project environment has been rarely studied and identified. Thus, the research interviewed global experts in BIM-enabled projects to identify the current scope management practice for BIM-enabled construction projects as well as the common problems in scope management.

It is revealed that the current scope definition process is not effective enough to achieve the full benefits of BIM adoption due to unclear roles and responsibilities between a BIM manager and a project manager. In contrast, construction professionals understand the concept of the CDE for project progress tracking. Finally, the disconnection between the PIM and AIM is identified, and this causes ineffectiveness of utilising lessons learned for scope definition. The research findings are expected to explain the current scope management practice and provide insights to improve the current scope management practice more suitable for a BIM-enabled project.

REFERENCES

AIA, 2022. Digital Documents Guide, American Institute of Architects, US.

Atkinson, R., Crawford, L., Ward, S. 2006. Fundamental uncertainties in projects and the scope of Project Management, International Journal of Project Management, 24(8), 687–698.

B/555, 2014. Design, Construction & Operational Data & Process Management for the Built Environment, British Standards Institution, UK.

Beach, T., Petri, I., Rezgui, Y., Rana, O. 2017. Management of collaborative BIM data by federating distributed BIM models. Journal of Computing in Civil Engineering, 31(4), 04017009.

Boje, C., Guerriero, A., Kubicki, S., Rezgui, Y. 2020., Towards a semantic Construction Digital Twin: Directions for future research, Automation in Construction, 114(2020), 103179.

Chan, A.P.C., Ma, H.X., Yi, W., Zhou, X., Xiong, F. 2018. Critical review of studies on building information modelling (BIM) in project management, Frontiers in Engineering Management, 5(3), 394–406.

Chen, Y., Kamara, J.M. 2011. A framework for using mobile computing for information management on construction sites, Automation in Construction, 20(7), 776-788.

Cicacioglu, S., Yaman, A.H. 2021. BIM Based Time Management Among Construction Contractors in Turkey: An Interview Study, Periodica Polytechnica Architecture, 52(2), 192–204.

Derbe, G., Li, Y., Wu, D., Zhao, Q. 2020. Scientometric review of construction schedule studies: trends, gaps, and potential research areas, Journal of Civil Engineering and Management, 26(4), 343–363.

El-Sawalhi, N., Eaton, D., Rustom, R. 2007. Contractor pre-qualification model: State-of-the-art, International Journal of Project Management, 25(5), 465-474.

Gong, P, Zeng, N., Ye, K., König, M. 2019. An Empirical Study on the Acceptance of 4D BIM in EPC Projects in China, Sustainability, 11(5), 1316

He, Q., Wang, G., Luo, L., Shi, Q., Xie, J., Meng, X. 2017. Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis. International Journal of Project Management, 35(4), 670–685.

ISO 19650-1, 2018. Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles, International Organization for Standardization.

Khudhair, A., Li, H., Ren, G., Liu, S. 2021. Towards Future BIM Technology Innovations: A Bibliometric Analysis of the Literature, Applied Sciences, 11(3), 1232.

Kim, K.P., Freda, R., Nguyen, T.H.D. 2020. Building information modelling feasibility study for building surveying, Sustainability, 12(11), 1-19.

Kim, K.P., Ma, T., Baryah, A.S., Zhang, C., Hui, K.M. 2016. Investigation of readiness for 4D and 5D BIM adoption in the Australian construction industry, Management review: an international journal, 11(2), 43-64.

Kim, K.P., Matheson, J., Newton, J., Wills, J. 2021. Improvement strategy for the level of BIM utilisation in the Australian construction industry, Management Review: An International Journal, 16(2), 86-100.

Kiridena, S., Sense, A. 2016. Profiling Project Complexity: Insights from Complexity Science and Project Management Literature. Project Management Journal, 47(6), 56-74.

Ma, X., Xiong, F., Olawumi, T.O., Dong, N., Chan, A.P.C. 2018. Conceptual Framework and Roadmap Approach for Integrating BIM into Lifecycle Project Management, Journal of Management in Engineering, 34(6), 05018011-1-10.

Pellerin, R., Perrier, N. 2019. A review of methods, techniques and tools for project planning and control, International Journal of Production Research, 57(2), 2160–2178.

RICS, 2017. Building Information Modelling for Project Managers, Royal Institute of Chatered Surveyors, UK.

Shayan, S., Kim, K.P., Ma, T., Freda, R., Liu, Z. 2019. Emerging challenges and roles for quantity surveyors in the construction industry, Management Review: An International Journal, 14(1), 82-96.

Smith. D.K., Tardif, M. 2012. Building Information Modelling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers. John Wiley & Sons, USA.

Taylor, J. E., Bernstein, P.G. 2009. Paradigm trajectories of building information modeling practice in project networks, Journal of Management in Engineering, 25(2), 69–76.

Waheeb R.A., Andersen, B.S. 2021. Causes of Problems in Post-Disaster Emergency Re-Construction Projects—Iraq as a Case Study. Public Works Management and Policy, I-31, 2021.

Whyte, J.K., Hartmann, T. 2017. How digitizing building information transforms the built environment. Building Research and Information, 45(6), 591–595.

Xing, K., Kim, K.P., Ness, D. 2020. Cloud-BIM enabled cyber-physical data and service platforms for building component reuse, Sustainability, 12(24), 10329-10351.