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Building Information Modeling (BIM)-Based Information Management Platform in the Construction industry

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Abstract

Of late, Building Information Modeling (BIM) is being widely used in managing construction information. As it comprises a 3D object-oriented system with geometric and non-geometric information, BIM allows a comprehensive digital representation of a built facility with great information depth for the construction stakeholders (i.e., architects, engineers, contractors, and subcontractors). Despite BIM being widely used in managing construction information, the components of BIM-based information management are limited studied. Hence, the objective of this paper is to review the components of BIM-based information management through an extensive literature review. Two main databases (i.e., Scopus and Web of Science) are used to obtain the information. The findings indicated that BIM-based information management facilitates construction stakeholders (i.e., architects, engineers, contractors, and subcontractors) to collaborate and integrate information into single sources and hence improves the construction documentation performance (i.e., cost, time, quality, and safety). The paper also concludes discussions that indicate the knowledge gap in current research to be investigated for further research.

Keywords: BIM-Based Information Management, Platform, Literature Review, Digital Representation

Introduction

Recently, Malaysia is facing a series of economic crises which has caused the Malaysian Construction Industry sector to perform inconsistently over the last four decades (Ministry of Finance Malaysia, 2022). According to Riazi et al (2020), the Malaysian Construction Industry has been categorised as inefficient and adversarial and needs to be structurally and culturally reformed. One of the reasons is the construction industry is facing fragmentation among the stakeholders which has caused additional costs due to rework, disputes among the stakeholders, an increase in the building cost and construction times, and a lack of innovation of automation during the project execution. As highlighted by Nawi et al (2014), fragmentation can be defined as the various organisations (i.e.; Architecture, engineering, and construction organisations) involved in various processes of the construction project. The differentiation and specialization needs of these organisations have resulted in the construction industry becoming more complex. They further added that fragmentation in the construction industry can be divided into two (2) folds; internal fragmentation and external fragmentation as cited by (Abadi, 2005). Internal fragmentation involves the issues of the integration and coordination between different alliance organisations (i.e., client and, consultant), while external fragmentation refers to the problem involved in non-alliance organisations (i.e., local authority) at different phases of the design process.

In the previous traditional approach, all the design and construction processes were conducted in separate entities or described as work over the wall syndrome as shown in Figure 1, and is a sequential manner that is carried out throughout the project lifecycle (Nawi et al., 2014; Nawi et al., 2014). As a result, the quality of information transmitted will be reduced as misunderstandings and misinterpretations may occur among the stakeholders. When low-quality information is obtained from the contractor, design clashes between the architectural, structural, and MEP designs will happen. This is due to a lack of design coordination and monitoring after the design changes which then results in risk situations for the contractors during the construction phase of the project (Akintan & Morledge, 2013). The effect of low design constructability will cause construction problems such as a decrease in construction productivity, low project quality, construction cost overrun, and disputes among construction players (Alshwal, 2013; Riazi et al., 2020).

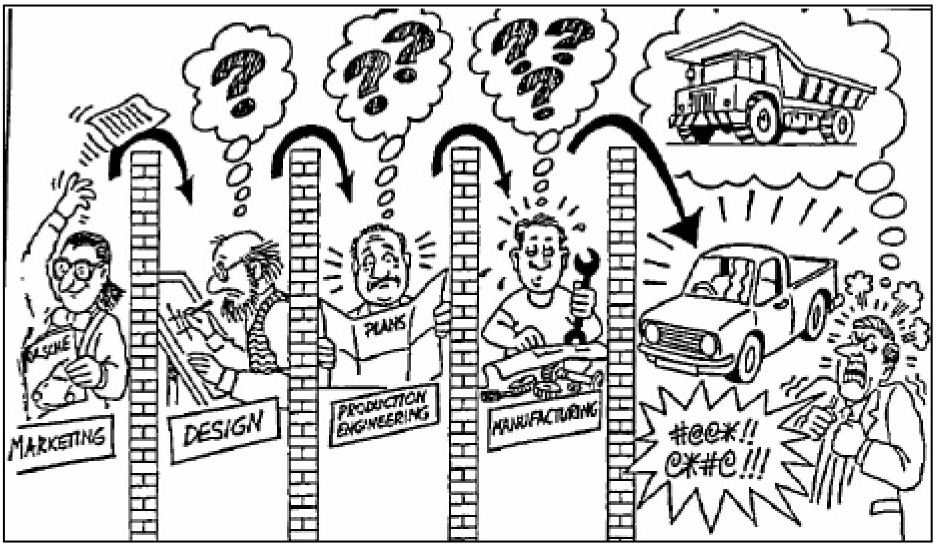

Figure 1: Over-the-wall syndrome
(Sources : Mohd Nawi et al., 2014)

Hence, as technology becomes the main driver of transformation, the digitalisation tool is provided to boost a higher efficiency of construction productivity by the adoption of BIM. BIM is the development and use of a computer software model to simulate the construction and operation of a facility. BIM is a data-rich, object-printed intelligent, and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to decide and improve the process of delivering the facility (Erntrom et al., 2006: Azhar et al., 2012). In addition, BIM is one of the vital technologies that provides a collaborative platform for sharing information among construction stakeholders throughout the construction lifecycle (CIOB, 2019). Despite numerous studies that have recognised the capability of BIM in managing construction information, research related to the components related to BIM-based information management is required to be explored. Therefore, this paper aims to explore the components related to BIM-based information management through a comprehensive literature review.

Literature Review

History of BIM

Figure 2 shows a timeline of BIM history. In the 1950s, the application of Computer Aided Machine Technology (CAM) was first introduced. Then, followed Computer-Aided Design Technology (CAD) in 1963 by Ivan Sutherland. In the 1970s, Professor Charles Eastman introduced the concept of BIM and later, developed the Building Description System (BDS) which is a database that develops models which allow the design of construction drawings. The ability of BDS enables the construction of complicated physical models consisting of specified elements. Nevertheless, BDS is not widely used due to the limited design stage, which is a single individual library.

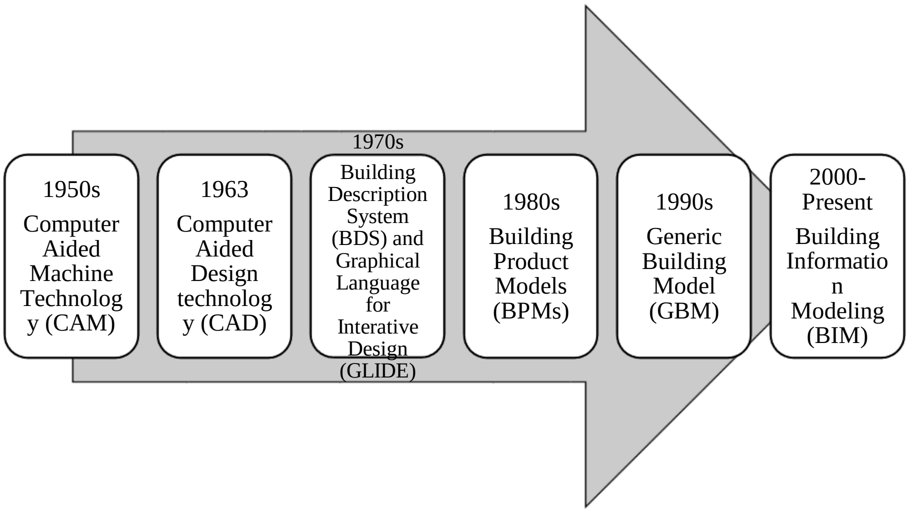

Figure 2: Timeline of BIM History

As a result, Graphical Language for Interactive Design (GLIDE) was introduced in 1977 that incorporated the BDS elements. GLIDE became the basis of the BIM platform, which consists of certain building elements. It is also used to examine the accuracy of cost estimations and evaluates the structural design at the design stage (Latiffi et al., 2014). Then, from 1990 until 1989, Building Product Model (BPM) was developed which covered the design applications, estimations, and construction processes across its lifecycle. Nevertheless, BPM produced formation products rather than managing information (Cherkaoui, 2017). Later in the 1990s to 1995, Generic Building Model (GBM) was introduced to expand the information to the project teams within the construction activities (Cherkaoui, 2017). Subsequently, in the 2000s and onwards, BIM was introduced for managing information using 3D modeling from the planning until the completion stage in a real-time construction simulation.

Level of Development and Level of Details

Level of Development and Level of Detail refers to the levels of development of a BIM model for a built asset (Boton et al., 2015). The quality of a model is determined by the LOD of the project. LOD can designate two different concepts, which can coincide in some situations: the level of development and the level of detail. The level of development of a BIM model relates to the amount of information that is relevant to the concrete development of the project and is necessary to produce tangible decisions. It consists of the graphical content of models, while the level of detail designates the entire amount of information (i.e., non-graphical content) that the BIM element contains. If all this information is relevant to the setting-up of the construction project, the two concepts coincide (Abualdenien & Borrmann, 2022). Figure 3 presents the level of development of the projects. While Table 1 shows the description of each Level of Development.

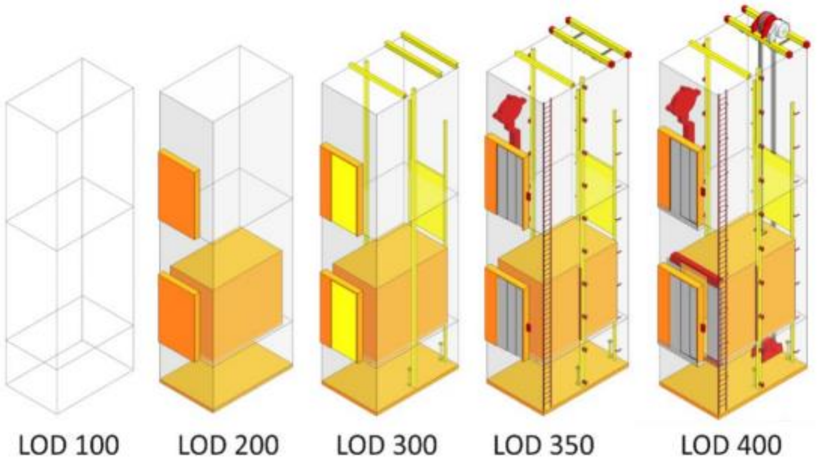

Figure 3: Level of development of the projects
(Sources : Abualdenien & Borrmann, 2022)

Table 1
Level of Development Descriptions

Level of Development	**Description**
LOD 100- Concept Design	The 3D model is developed to represent the information on a basic level. Thereby, conceptual model creation is possible in this stage. Parameters like area, height, volume, location, and orientation are defined
LOD 200- Schematic Design	The 3D model elements are modeled with approximate quantities, sizes, shapes, locations, and orientations. The attach non- geometric information for the model elements is attached.
LOD 300- Detailed Design	Accurate modeling and shop drawings where elements are defined with specific assemblies, precise quantity, size, shape, location, and orientation. The non-geometric information on the model elements is also attached.
LOD 350- Construction Documentation	It includes model details and elements that represent how building elements interface with various systems and other building elements with graphics and written descriptions.
LOD 400 - Fabrication & Assembly	Model elements are modeled as specific assemblies, with complete fabrication, assembly, and detailed information in addition to precise quantity, size, shape, location, and orientation. Non-geometric information to the model elements can also be attached
LOD 500 - As-Built	Elements are modeled as constructed assemblies for Maintenance and Operations. In addition to actual and accurate size, shape, location, quantity, and orientation, non-geometric information is attached to modeled elements.

(Adapted from Latiffi et al., 2015: Abualdenien & Borrmann, 2022)

According to Barnes & Davies (2015), the level of development and level of details of the BIM models increase as the project proceeds based on the agreement by the construction stakeholders. As such, a different aspect of the model will be developed at different levels and originate with different members of the project team (i.e., from employers to consultants, to the contractor and suppliers, and finally back to the employers). As a result, the employers are required to define the level of development and level of detail that will develop the project through the BIM protocol. This is to ensure that the model will be developed in sufficient detail, and ensures the information embedded in the models is useful to the construction stakeholders. The level of development and level of details is also defined as 'data drops' (i.e., information exchanges) that allow the employer to verify whether the project information is consistent with their requirements and enables them to decide whether to proceed to the next stage. Nevertheless, at present, there is no standardized definition of the timing of the data drops for each level of development and level of detail which must be aligned with the employer's decision points and must be consistent across all the appointments (i.e., with the construction stakeholders).

BIM Dimensions

BIM dimensions are referred to as how various data are linked to an information model. By adding additional dimensions of data, a fuller understanding of the construction project (i.e., how it will be delivered, what it will cost, and how it should be maintained) is obtained (Wildenauer, 2020). These dimensions (i.e., 3D, 4D, 5D, 6D, and 7D BIM) (as shown in Table 2) can all attainably (but not necessarily) occur within a BIM Level 2 workflow.

Knowing which dimensions are to be delivered and converted to be extracted and presented to the client, allows the construction stakeholders particularly the project team to define the information required. Furthermore, BIM provides an opportunity to optimize, simulate, visualize building design and deliver high-quality construction documentation (Najjar et al., 2019). These BIM dimensions will be easier to use if the RIBA Plan of Work, BS EN ISO 19650, and a series of standards are referred to in order to understand the types of information that are required for the projects. Furthermore, these RIBA Plan of Work and BS EN ISO 19650 provide a guide in examining the need of the project, the information needed, who is needed and their responsibility, and when it is required (Centre for Digital Built Britain, 2020). Nevertheless, these BIM dimensions will increase until up to nD, if the information embedded in the BIM model also increases.

Table 2
BIM Dimensions descriptions

BIM Dimension	**Description**
3D (The Shared Information Model)	3D BIM is the model that consists of three (3) main disciplines (i.e., architecture, engineering, and M&E) that are combined. The 3D model is the basis of the BIM model which consists of the process of creating graphical and non-graphical information and sharing this information in a Common Data Environment (CDE).
4D (Construction sequencing)	4D BIM adds a dimension of information to the project information model in the form of programming/ scheduling data. Time-related information emphasizes specifically the related information on the lead time, the time needed to become cured/hardened/operational, how long to install/construct, the flow and sequence of the elements to be installed and the time clashed on other areas of the projects.
5D (Cost)	5D BIM is related to 4D BIM plus the cost information. In this case, the BIM model can extract accurate cost information (i.e., cost of purchasing and installing a component, cost of renewal/replacement elements, and running costs). The cost information is derived from basic data (i.e., 3D +4D BIM) and associated information that is linked to the specific elements within the graphical model.
6D BIM (Project Lifecycle Information; Sustainability)	6D BIM involves information related to cost and sustainability that purposes to support facility management and operational stage to obtain a better outcome. The information is related to energy performance, operational performance, and decommissioning data derived/configured and integrated from the information of components details (i.e., manufacturer particular, installation date, and maintenance requirement)
7D (Operations and Facilities Management)	7D BIM refers to information related to facility management. These include the information for preventive maintenance scheduling, sustainability analysis, asset management, disaster & emergency planning, and space utilization management.

(Adapted from Najjar et al., 2019 : Wildenauer, 2020)

Common Data Environment (CDE)

Common Data Environment (CDE) is a single source of information used to collect, manage, and disseminate documentation, graphic information, and non-graphical information among multidisciplinary teams for the whole project (Barnes & Davies, 2015; Radl & Kaiser, 2019). The CDE can be implemented via a file-based retrieval system, server, and extranet. According to Barnes & Davies (2015), there are four (4) main areas of information embedded into the CDE. As such, (i) work in progress - unapproved information for each team; (ii) shared area- the information has been checked, reviewed, and approved for sharing with other teams; (iii) published- the information has been signed off by the client or their representative (i.e., lead designer) and (iv) archive – used to record the progress of each project milestone, documentation, and record for further audit and use.

CDE provides a collaborative working environment among the project team and helps avoid duplication and mistakes. During the process of coordinating the data, the BIM Information Manager is the important person in managing the information. He or she becomes the gatekeeper, policing the CDE and ensuring it follows the agreed protocol and that data are secure (Barnes & Davies, 2015). As a result, the ownership of data within the CDE remains with the originator, and the model produced by the different team members does not interact and remains authorship and separate. The author further explained that, during the construction and design stage, the CDE is formed in the basic Project Information Model (PIM), and when handed to the employers/ occupier, the CDE is in the form of the Assets Information Model (AIM). The richness of data is developed during PIM where the designer and construction teams store the information of the project in the CDE and PIM will be changed to AIM as the data are continually used during the post-completion and operation and maintenance stage.

BIM Interoperability

According to the European Interoperability Framework, Interoperability has been defined as the ability of information and communication technology (ICT) systems and the business processes they support to exchange data and enable the sharing of information and knowledge (Shehzad et al., 2021). Rafael et al (2018) highlighted that interoperability identifies the need to pass data between two or more application software to jointly contribute to their works. These definitions are applied to BIM as the BIM software tools work together and have the ability to transfer information among themselves. Simply put, the information sent from one BIM software tool must be understood by other BIM software tools. As a result, the semantic language of interoperability is required for both/multiple BIM software tools to transfer/exchange information (Shehzad et al., 2021).

The Industry Foundation Classes (IFC) is the industry standard for exchanging the Building Information Models which was introduced in 1994 by the International Association for Interoperability (IAI) (Porsani et al., 2021). Currently, the IFC specifications are administered by the buildingSMART alliance. IFC applies the ISO 10303 suite of specifications for data modeling and exchange that requires a set of protocols, and rules to define the data describing the building and to create a common international 'object library repository' (Temel et al., 2020). The standard was developed to facilitate the consistency of transferring the data among these multiple BIM software tools. During the transferring/exchanging of the information, all the information is required to be codified according to these IFC formats. As such; (i).ifc: default file format based on the ISO-STEP standard; (ii).ifcxml: encoding based on XML file structure and (3).ifczip: a compressed archive of one of these previous formats also contains additional material, such as PDFs or images (Temel et al., 2020). The advantages of the IFC format allow the collaboration between various technical roles in the construction process which allow the BIM software tools to exchange information through the standard format. As a result, the reduction of cost, errors, and time saved may lead to a higher quality of data consistency/flow from the design phase to the operational and maintenance stage.

Discussion

BIM-based information management becomes a platform where information is stored, shared, transferred, retrieved, or has accessibility and redundancy. These can be achieved by using CDE. For instance, the CDE provides correct, the latest information that manages information with a document-based system. Transparency in data storage greatly improves information visibility and reduces redundancy in information flow, and the amount of time spent retrieving the information. The efficient way of working to achieve high-quality information conveys many advantages to the construction industry. As such it improves understanding and communication, leading to greater productivity, cost, and quality, and avoids fragmentation in the construction industry. Nevertheless, in creating a collaborative workflow, several issues (i.e., process (resources, tool, training); actors (context, culture, organization, environment), teams (relationship, roles, composition), and tasks (demand, structure) need to be tackled (Oraee et al., 2019).

Conclusion

This study contributes to the knowledge of the highlighted components of BIM-based information management platforms in the construction industry. It is useful for those parties (i.e., architects, engineers, contractors, and subcontractors) who are interested in promoting BIM and may find these ideas helpful in guiding their efforts. BIM is highlighted as an alternative solution towards fragmentation issues in the construction industry which emphasises on the use of digital models across the construction lifecycle. In the form of a 3D model-based, BIM comprises a 3D geometric with semantic information and parametric relations between the objects. These levels of geometric details or levels of information provided by the model are shown by producing the Level of Development and Level of Details. Furthermore, the actual BIM model also depends on the project's deliverables (i.e., for visualizing using a 3D model, project scheduling-4D model, costing and estimating-5D model, sustainability -6D Model, and facility management- 7D model).

The sharing source of information known as CDE is also introduced to promote a collaborative platform to the construction stakeholders. Apart from the process of transferring and exchanging the information of the BIM software tool, BIM interoperability was also discussed. By using a standardised data format (i.e., IFC), both or multiple BIM software tools can work together. Hence, further studies will also provide the opportunity to build on the current study by delving into the nature of each BIM-based information management component (i.e., Level of development and level of detail, BIM dimensions, CDE, and BIM interoperability). The challenges and remedial solutions for these components are also another fertile ground for research found in this study.

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