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A Review of Application Building Information Modeling (BIM) During Pre-Construction Stage: Retrospective and Future Directions

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Abstract. Pre-construction is one of the biggest areas of risk and uncertainty in construction project as it deals with subsurface ground conditions information. The amount of detail data needed in pre-construction especially for existing data modelling and site analysis should be sufficient enough to ensure that significant risks could not reasonably be anticipated. Current practicing method in interpreting data during this stage tasks reveal limitation. Construction industry faced many obstacles due to the depends on the traditional practice; paper-based document which missing and redundant data always happened. In recent years, there has been a shift in construction where people move to BIM application because of its potential to reduce the problem faced by infrastructure world. BIM has become a successful technology and widely popular in the construction world especially in developed countries because of its potential. Nowadays, people are moving one step ahead in BIM which is adoption of BIM during pre-construction stage. Thus, this paper review studies centered on BIM-integrated modelling during preconstruction stage. But there is lack of practical researches have been made during this stage. Although a large number of studies on BIM have been conducted in the past decade, a lack of consensus remains among researchers and practitioners regarding the applications of BIM during pre-construction stage, the availability of subsequent data integration tool for geotechnical activity. A comprehensive literature review was conducted for data collection and analysis. After in-depth review of journal articles widely cover the application of BIM, this study summarizes an overview and critical reflection of geotechnical data integration using BIM during pre-construction stage. The results are useful for the identification of research clusters and topics in the BIM community.

1. Introduction

A standard project typically has three phases; pre-construction phase, construction phase and post-construction phase [1]. Pre-construction is one the biggest areas of risk and uncertainty in construction project as it deals with subsurface ground conditions and geotechnical information. Ham et al. [2] summarized that this phase is where gathering necessary information is done in advance to set the direction of project as well as to start the construction. Tegtmeir [3] stated that any project that deals with geotechnical data consider as a complicated work as it begins with site investigation and data interpretation from public sources by sub-contractor before it can be integrated into 3D programme and simplifying it for design and construction purpose.

The building and construction industry today has been driven to use Building Information Modeling (BIM) in their project in conjunction with an idea to transform the construction industry to be highly productive, environmentally sustainable, with global competitive players while focused on safety and quality standards. Different people have different way in describing BIM [4] but they still share the same concept of and it is an important note that there is no single satisfactory meaning behind BIM. From Papadonikolaki et al. [5] perspective, BIM is an acronym to replace ‘Building Product Modelling’ (BPM) which widely used to describe the broad concept of IS in construction [6]. Surely, BIM is gradually changing the way of data being collected and analyse specifically during pre-construction phase; paper-based document to object-based modelling.

Subsurface aspect such as geology and geo-technical always being neglected and current practice do not provide sufficient data for realistic 3D modelling [4][7][8][9]. Currently less study conducted to evaluate and compare the data integration process during pre-construction phase for traditional system and BIM adoption. Such a study could help to understand the current trends of BIM adoption in geotechnical data integration and later on identify the research gaps. Therefore, this paper aims to compare the conventional and current practices of pre-construction development, to provide an analytical review of the current BIM adoption for geotechnical data integration during pre-construction stage, and identify the gaps in BIM development and adoption.

In order to address the above-mentioned research questions, this study conducts a critical review on geotechnical data integration process during pre-construction stage for construction using Building Information Modeling (BIM). The structure of this review paper is organized as follows. Chapter 2 specifically illustrates about the research methodology of this review. While, chapter 3 discussing the application of BIM during pre-construction stage.

2. Methodology

To review the geotechnical data integration during pre-construction stage using BIM, three steps were carried out. First step, a comprehensive literature review was conducted to increase the understanding of data integration process during pre-construction phase and the differences between traditional method and BIM-based method. Connecting BIM and pre-construction stage is the main concept of “geotechnical data integration” that which will be discussed in this review paper. This process involves an identification of a set of keywords before an intensive literature can be done later on. The main keywords that can represent this review are “BIM”, “Building Information Modelling, pre-construction”, “geotechnical data”, “data integration”, ‘‘safety”, ‘‘quality”,‘‘time”, ‘‘cost”, and ‘‘budget”. Once all the keywords being identified, the second step is to apply it in web search in online academic publication databases, i.e. ‘‘Web of Science”, ‘‘Sciencedirect”, ‘‘Scopus”, and ‘‘Google Scholar”. All of these web search engine is function for collecting academic and applied publications related to this topic. Only relevant reading materials such as conference papers, thesis, dissertations, journals and article can be accepted. Publication which include the keywords in the Title/Abstract/Keywords are selected to be reviewed. Most of the journal article found for this study were from leading journals of this area (e.g. Safety Science, Automation in Construction, International Journal of Project Management, Journal of Computing in Civil Engineering, Renewable & Sustainable Energy Reviews, Reliability Engineering & System Safety), publications from conference proceedings and other sources of professional associations, standard committees (e.g. HSE, ISO) and authorities. In the last step, all publications are analysed critically and being compare to identify current process, obstacles and future work to close these gaps. This strategy is also adopted by many previous studies, such as Zou et al. [10] and Li et al. [11].

3. Findings

3.1. Pre-construction Phase

The preconstruction phase of a project also known as planning and design phase [12]. Pre-construction phase is one of the important phases in construction that control the successful of project as stated in a study by Bakar et al. [13]. In response to that, many researchers have already acknowledged the significance of effective planning practices and integration of designer and contractor in the early stages of construction project life cycle [13]. Basically, the amount of detail data needed in pre-construction information especially for existing data modelling and site analysis should be sufficient enough to ensure that significant risks could not reasonably be anticipated. Gathering all information for the sake of designer and contractor really needed throughout the project before they can start work on any particular element such as design.

Kolltveita and Gronhau [14] stated that pre-construction or sometimes called as early phase is the process and activities that lead to, and immediately follow, the decision to undertake feasibility studies and to execute the main project. He continued to explain that the main tasks in this part of the early phase are feasibility studies, value analysis, formulation of project goals.

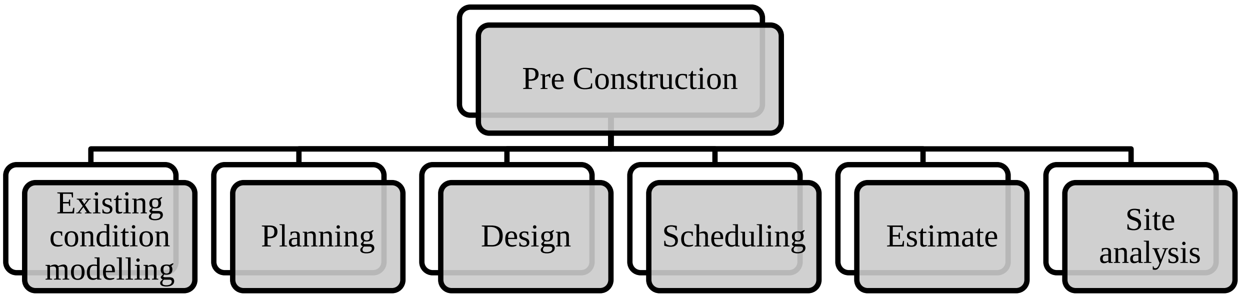

Figure 1: Activities in pre-construction phase by Latiffi et al. [1]

3.2. Workflow of Traditional Practices

Some countries still follow the traditional method of obtaining data for geotechnical information during pre-construction which is based on traditional surveying techniques such as total stations, physical measurement, and photography [15]. Then, all the data will be transferred to software before it can be used for design stage and the product of the integration is a paper-based document [14]. The method used to integrate data for geotechnical activity is via reports containing 2D site plans and log sheets and the engineer will think and visualize it in 3D [16]. Figure 1 shows the principle of geotechnical data journey laid out by Child et al [17] where the workflow is a linear waterfall process and will be ended up at national and local archive in form of paper-based document. The result data is passed to the following phase after the work in one phase is done [18].

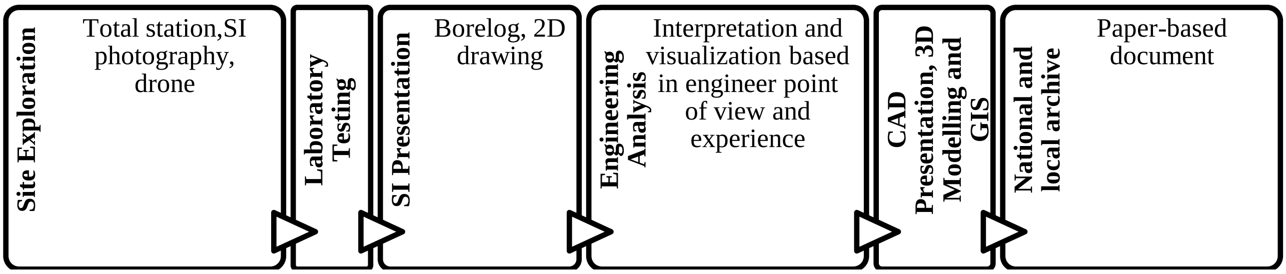

Figure 2: Traditional Approach by Child et al. [18]

3.3. Workflow of BIM Practices

3D scanning to modelling can be an impressive tool for facilities that are facing difficulties dealing with old and traditional systems like paper-based document in post-construction phase. Furthermore, particular technologies, such as the use of cloud computing [19], and 3D scanning [20] have facilitated adoption and added value to BIM. The integration of BIM through the model provided via 3D scanning ensure higher functionality [21], waste reduction, higher productivity and profit [22]. BIM provide benefit: overlap, reduce real project risks; irrelevant document eliminated; waste reduces; productivity increase; costs decrease; profit increase as improve product, improve services deliver, or expand market share [22].
Bentley [23] and Autodesk [16] are the example of a leading global provider of comprehensive software solutions that provide software to integrated data of geotechnical such as terrain, subsurface condition and etc and provide a modelling to represent surface condition and information. By that, a comprehensive project can be delivered. BIM application stops at the preconstruction phase with a limited amount of research regarding data collection of the construction process [24]. In recent years, most virtual 3D city models have been realised as purely graphical or geometrical models, neglecting semantic and topological aspects.
Previously, the data journey believed to be flat but nowadays it should be round (as in figure 3) and ingoing which available throughout the life of project and lead to the effective interpretation of ground conditions and characterization of the site [17]. Child et al. [17] continued to explained that visualizations being generated by tools and ended in the form of a digital archive.

Figure 3: The data journey transformed by Child et al. [17]

3.4. Challenges with BIM Practices
The use of BIM for pre-construction phases is not as popular as other phases of the project despite these successful applications [25]. Even, the application of BIM in pre-construction phase is more evident [1][26] than during the construction and post-construction phases because there are many activities in pre-construction but the use of BIM for pre-construction phase still not gained a wide acceptance in industry [25]. BIM became compulsory for applying to the tenders in developed countries [26] although it took some time for the government to encourage the development of modelling [17] but rarely used in developing countries such as Malaysia [27] due to the comfortableness of using the old method and cost that need to be considered to change to new method. Current software available also has lacking as tabulated in table 1.

Table 1: Software available for data integration modelling

Name	Author/ Date	Using	Primitive	Entity object	Model base	Advantage	Disadvantage
SSM	Zlatanova [28]	City visualization	Node, Planar face	Point, Line, Surface, Body	Simplex concept	Abstract primitives easily, small storage	Update dynamically and modify are complex, constructive objects are multi-values
UDM	Coors [29]	City visualization	Node, Triangle	Point, Line, Surface, Body	Triangulation	Abstract primitives easily, small storage, facial visualize	Update dynamically and modify are complex
OO3D	Shi Wenzhong, Yang bisheng [30]			Point, Line, Surface, Volume	OO modeling	Complex object, LOD, Visualization	
GTP	Wu LiXin [31]	Geological engineering	Node, Line (TIN-L, side-L), Face (TIN-F, Side-F), GTP, diagonal	Point, Line, Surface, Body	Body divide	Topology completely, 3D expression of geology, based on drill hole data	Difficult to visualization of complex geological object
TEN+Octree	Li Qingquan, Li Deren [32]	Geological engineering	Octree 、TEN		Octree express whole, TEN express part	Improve the precision of objects, reduce data storage	Difficult to build topology of spatial objects
CityGML	Tegtmeier, [3], Jayakody et al. [33]	Geotechnical extension	3D-GEM, XML-based format		Geo-information	Representative of 3D digital terrain models, buildings, vegetation, water bodies, transportation facilities or city furniture.	Less presentative to users
GIS	Hack [34]	BIM extensio			Point, edge,	3D visualization	No proper integratio

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		n		polyline, polygon, 3d Solid	system of built environment and urban system	n of the boreholes and other geological and geotechnical data.
GeoBIM	Hack [34]	BIM extension			Integration of surface and subsurface data	Not a complete set of integrated formats to handle surface and subsurface data.
Holebase SI	Morin, 2014 [35]	Autocad Civil 3D Extension			HoleBASE SI and AutoCAD Civil 3D combine to generate and maintain comprehensive 3D models of the geology that can be integrated with any other project designed data.	

4. Discussion

An important aspect of this review is to find out research gaps in current BIM-based data integration through a systematic and critical review, which is discussed as follows:

According to the reviewed paper, the data needed and the software used are the main things that need to be considered. Everyone know that BIM is the latest innovation that considered as an intelligent 3D model because of it abilities to efficiently plan, design, construct, and manage buildings and infrastructure. Latest invention is reality capture where it will use drone to capture all the points and integrate it using BIM to obtain terrain of land make the process become easier. But, the integration data process is the most critical work. The review acknowledged the fact that the optimal software-BIM not yet be found [36]. Kessler et el. [9] also shared the same fact where geology part is still absent from most BIM models but a standard software that already available in market can be used to access and visual geotechnical data. but technology together with data transfer standards. From table 2 it can be seen that all the available software has their own benefits and disadvantages. All the software stated have something lack such as soil strength parameter, the bearing capacity characteristic and soil stratigraphy not being included in the model. It will be an interesting technology if a new BIM software can produce an intelligent model that consider these three main categories [37]. The development of standardized geotechnical data format and interpretation will give a detailed insight of the underground condition that can help the whole project life cycle.

5. Conclusion

As conclusion, a further research in the field needs to be focused towards data integration modelling, on finding the new technology or tools that can be work together with BIM to provide 3D topological modelling and semantic models. In addition, the research in the area also needs to study on the conditions of such an implementation, the prototype software components (developed, verified/validated during the research) demonstrated a technical proof-of-concept for the transfer of building information and the use of BIMs in facilitating these processes. The research results demonstrated that BIMs provide the required level and amount of (geometric and semantic) information (about the building) for the seamless automation of the data management in these process, and the research also showed that although there are still barriers in the transformation process it is possible to represent a high level of geometric and semantic information acquired from BIMs in the geospatial environment. Even though the research in the area is mainly focused on the transfer of geometric information into the geospatial environment, the success of such an effort will mainly depend on the efficiency in representing the semantic information in the geospatial environment.

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