BIM and Basic Challenges Associated with its Definitions, Interpretations and Expectations

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ABSTRACT

The construction industry in recent years has incorporated information technology which serves to facilitate the conceptualization and realization of construction projects. These efforts have culminated in the development of "Building Information Modeling" (BIM), a process consisting of generating and managing digital renderings of a building's functional and physical features. BIM has attracted widespread popularity recently; however, there is several challenges concerning its definitions and expectations in early phases of construction projects. Evidently different organizations and people create their own definitions of BIM, based on the specific way they work with BIM. Thus, it is evident that there are differences in the way BIM is perceived by both different individuals and organizations within the construction industry. As a result, it might be difficult to come up with a common definition of BIM for the entire construction industry. In other words, there is confusion concerning what BIM is, and what BIM is not. This can lead to misunderstandings concerning expectations from different stakeholders involved in construction projects where BIM is utilized. Therefore, by reviewing and analyzing current literature in the area of BIM, the main objective of this paper is to discuss the most common challenges of BIM's definitions and expectations which hinder the comprehensive realization of its benefits in order to increase the awareness of construction practitioners and firms. It is suggested that the definition of BIM should not be unilateral but rather encompass several key characteristics which have been attributed to it.

Keywords - BIM, BIM challenges, BIM definitions, Building Information Modeling, construction industry

I. INTRODUCTION

Traditional method of describing three dimensional objects in two dimensions (2D) was brought to construction by Gaspard Monge (1799). This method was the basis for construction drawings due to its usefulness in describing objects in detailed 2D drawings. The basis of this method has remained as the core base of professional communication in construction since eighteenth century. By developing technology and availability of professional computers that can simulate buildings, it is possible for construction practitioners to replace their drawings by simulated objects. Building Information Modeling (BIM), as a new way of technical communication in construction, refers to representation of a structure as an object by using computers to simulate buildings. Although the BIM concept was presented during 1970s due to technological constraints, its usability has remained isolated since the mid-1990s. However, technology constraints are removed right now and foster use of BIM worldwide.

By using BIM, the objects are in their 3D (3 Dimensional) formats. Objects are defined as parameters and not isolated creatures so changes in one object result in changes in other related objects automatically. Therefore, there is no need for many drawings to describe construction objects – in buildings and/or infrastructures projects. In addition, making changes in the design phase is eased and there is no need to redesign parts of structures due to small changes in other parts. Another advantage of using BIM is its transparency. Using BIM assists all stakeholders to monitor the project status in different phases since transparency increases by using BIM because of availability of data for all stakeholders and project construction and design team members. Another advantage of BIM which has caught attention recently is its capability for improving sustainability by modeling energy usage of buildings. Through use of geometric and parametric data using computational flow dynamics, BIM can be used as main source for modeling energy usage of buildings. This is a great leap in constructing sustainable buildings.

Although, numerous advantages have been suggested for use of BIM, there are some minor weaknesses and challenges in using it [1, 2, 3, 4, 5]. This paper, presents a brief overview of the most common challenges in using BIM in order to stimulate the debate and increase the awareness among construction practitioners and firms. The paper seeks to make both theoretical and practical contributions in the area of BIM regarding better realization of its benefits and challenges as well as more effective use of it in construction projects.

By conducting a comprehensive literature review, the authors figure out that there are some challenges in the early phases of BIM implementation in construction projects. These challenges are associated with different definitions, expectations and interpretations of BIM among various involved individuals, organizations and stakeholders. Therefore, it is tried to discuss what are the challenges and differences in definitions, interpretations and expectations in literature and their influence on construction firms

II. METHOD

This paper is based on the two well-known frameworks about BIM and CIC. A framework which is developed by Jung and Gibson [6] is presented to show the bases of CIC; since the second framework, which was developed by Jung and Joo [7] is based on the first framework. It is worth noting that these frameworks share several similarities.

So, firstly, around 100 recent publications concerning BIM are searched. Then, by reviewing them, the authors chose about 25 most relevant and useful articles. Given the aim of the paper, it was tried to utilize the relevant primary and secondary sources relating to BIM. The authors analyze the paper in order to distinguish what has been learned and accomplished in the area of BIM and what still needs to be learned and get more attention. In order to find articles the following words have been searched in scientific databases:

1. BIM
2. BIM challenges
3. BIM definitions
4. CIC
5. BIM framework

III. LITERATURE REVIEW

This paper aims to discuss early challenges relating to BIM. In order to do this, it would be beneficial to refer to the bases of CIC (Computer Integrated Construction) - since BIM by its definitions is a new use of technology in construction – and find and study the possible challenges related to using BIM in construction. Therefore, authors try to explore bases of CIC which was developed by Jung and Gibson [6] and a framework for implementing BIM that was developed by Jung and Joo [7].

Reference [6] developed a framework for CIC as shown in Fig 1. Their framework consists of three variables as project life cycle, business functions and IS concern. These variables consisted of six phases for project life cycle, fourteen business functions and four IS concerns. This framework has been developed by conducting a massive literature review, using a case study and guidance form researchers [6] and considered as a reliable framework for CIC. As mentioned previously, Jung and Gibson [6] divided project life cycle to six different phases as Planning, Design, Procurement, Construction, M & O and Disposal. They enumerate fourteen business functions in their framework (Fig. 1).

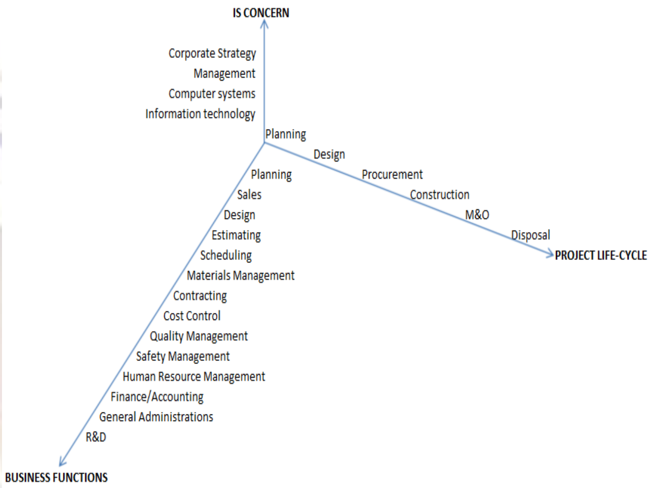

Fig. 1. Framework of CIC by Jung and Gibson [6]

The framework of Jung and Gibson [6] is considered as one of the most reliable frameworks for CIC and is popular among researchers; however, the authors believe that it may be restricted by a lack of knowledge that was not accessible at the time of publishing (1999). Moreover, the existence of BIM and its popularity started to increase after 2000, following publishing Jung and Gibson [6] paper. Thus, we try to investigate other frameworks for both CIC and BIM in order to assess any element that can restrict potential uses of BIM. A later paper applies the framework of Jung and Gibson but relates it to BIM [7]. It is worth noting that Jung and Joo [7] made their paper on the bases of Jung and Gibson [6] CIC framework and use it to link BIM and CIC and develop a practical framework. Jung and Joo [7] developed a 3-dimensional BIM framework (Fig. 2). It consisted of BIM Technology which is further divided to Utilization, Standards, Relation and Property; BIM Perspective, which is divided to Project, Organization and Industry; and Construction Business Functions that is defined by Jung and Gibson [6] earlier.

In the following parts, we discuss the challenges connected to BIM briefly and then use the CIC and BIM frameworks to explore the possible linkage between these challenges and CIC and BIM practical frameworks.

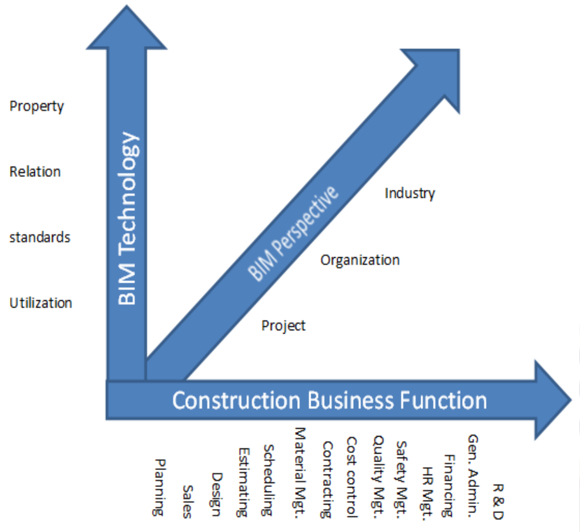

Fig. 2. A framework for BIM developed by Jung and Joo [7]

IV. Different Definitions and Benefits

Many scholars have discussed BIM issues recently; everyone in project teams elaborates new outcomes of using BIM. But what BIM means in the mind of project team members? In a project team, in order to establish future safe communication, members should agree upon using specific technical terms, software and sometimes even procedures. What is really the definition of BIM? Is there any unique definition for BIM so that project team members can refer to it? Does everyone refer to a specific method of drawing when talking about BIM? Does everybody pointing to specific dominant software when they refer to BIM? Different definitions of BIM would be a challenging issue in projects if its importance remains quarantined.

There are several inconsistencies and misinterpretations in definitions of BIM [8]. The definitions could vary depending on the user's point of view, type of organization and their particular work. For example, from a design perspective, BIM is defined as the digital representation of the physical and functional characteristics of a project [9], which refers to the process and technologies used to create a BIM model. From the construction point of view, BIM is considered as the development and use of a computer software model to simulate the construction and operation of a faculty [10]. However, for facility managers, BIM may be a powerful new tool to enhance a building's performance and manage operations more efficiently throughout a building's life. It is worth noting that the latest use of BIM in facility management is a new approach in using BIM which calls for further researches. But how BIM is defined by different organizations and/or institutes?

The National Institute of Building Sciences (NIBS) defines BIM as the following [11]:

"Building Information Model or BIM utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and it is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility."

Another definition of BIM is proposed by Van Nederveen [12] as:

"A model of information about a building that comprises complete and sufficient information to support all lifecycle processes and which can be interpreted directly by computer applications. It comprises information about the building itself as well as its components, and comprises information about properties such as function, shape, material and processes for the building life cycle".

With these features, most of BIM users aimed at achieving cost savings and try to include integrated cost modelling, construction sequencing and facilities management (FM) capabilities. However, there are many possibilities for different interpretations of BIM as a result of various distinct definitions of BIM. For example, some may argue that BIM should be regarded as the entire process exchanging, reusing and controlling project information being generated during the lifecycle of buildings while others consider it as just a simple information modeling. Some even can just describe it as a 3D digital representation of the physical building while another group may discuss the idea of creating a single repository of information about the building which can be of use throughout its lifecycle and, finally, some focus on the collaborative aspects of BIM (see Table. 1). Moreover, some users consider BIM as an advanced Computer Aided Design (CAD), while others take it into account as a series of models for distinct elements of a project. The most obvious difference of BIM in comparison with CAD is that CAD depicts construction elements with lines that define a structure's geometry; however, BIM creates each element of the structure as an 'intelligent' object containing a broad array of information in addition to its physical dimensions. Each element in the BIM model well relates to other objects and to the design in general [13].

BIM is being used in a number of different levels of maturity. As the first level, it is used as unmanaged CAD, in 2D, with paper or electronic paper data exchange. In the next level it may utilized as managed CAD in 2D or 3D format with a collaborative tool providing a common data environment with a standardized approach to data structure and format. In this case, commercial data will be managed by standalone finance and cost management packages with no integration. The next stage BIM is used as a managed 3D environment held in separate discipline "BIM" tools with data attached. Commercial data will be managed by enterprise resource planning software and integrated by proprietary interfaces or bespoke middleware. This level of BIM may utilise 4D construction sequencing and/or 5D cost information. And in the highest level, it is considered as fully integrated and collaborative processes enabled by "web services" and compliant with emerging Industry Foundation Class (IFC) standards. This level of BIM will utilize 4D construction sequencing, 5D cost information and 6D project lifecycle management information.

Table 1. Examples of different definitions of BIM.

Scholar/Organization	Definition
Van Nederveen [12]	Comprises complete and sufficient information to support all lifecycle processes and which can be interpreted directly by computer applications. It comprises information about the building itself as well as its components, and comprises information about properties such as function, shape, material and processes for the building life cycle
NIBS [11]	Provide parametric based model to reflect insertion, extraction, updating or altering physical, functional characteristics of building at each steps as needed throughout the processes to support cooperation among related parties
Cheol and Shik [14]	Comprehensively manage and use information on all steps from planning to expiry through exchanging and sharing information according to projects, processes focusing on interoperation of information through the entire lifecycle of construction
GSA [15]	Refers to the entire processes of exchanging, reusing, controlling information generated during the lifecycle of building through object oriented artificial intelligent information model
Gang [16]	Comprehensively control all information and organization, duties and processes needed from the stage of planning for construction to its cycle of design, construction, maintenance and demolition

It will take years before the majority of construction firms make such full use of BIM systems. In the meantime, professional team members, contractors, and sub-contractors with design responsibility will find themselves at various stages of BIM preparedness. There will be a small gap between some and a huge gap between others. Different stages of BIM development will require different approaches; there will be no "one size fitting all" during the transition to fully integrated BIM.

Considering these definitions between different project organizations, participants and stakeholders; having unique approach, understanding and interpretation to BIM benefits may seem impossible. There is a wide range of possible uses of BIM in construction projects. At one extreme, architects and engineers can utilize BIM basically to produce better quality design documents without providing the digital model to any other party. Similarly, contractors can separately create models for estimating, fabricating or simulating construction without sharing the models. Used in such limited ways, BIM may not reach to its full potential. At the other end of the spectrum, BIM can provide a collaborative framework among all project parties, allowing a better way of data sharing concerning what is being designed and how it will be constructed [1, 2, 3, 4, 5].

According to Eastman et al. [17], effective use of BIM may bring several remarkable impacts on a project outcome through improved design, improved constructability, and quicker project completion, saving time and money both for the owner and for the project team. BIM is also emerging as the solution to reduce waste and inefficiency in building design and construction. Eastman et al. [17] argue that there are different uses of BIM in construction. These include 3D, 4D, 5D and 6D BIM which can be described as the followings:

3D – Model:

1. **Model walkthroughs**. These provide a great visualization tool enabling designers and contractors to work together to identify and resolve problems with the help of the model before walking on-site.
2. **Clash detection**. In the traditional way, most clashes are identified when the contractor receives the design drawings and everyone is on-site and working. With clashes being detected so late, delay is caused and decisions need to be made very quickly in order to provide a solution. BIM enables potential problems to be identified early in the design phase and resolved before construction begins.
3. **Project visualization**. Simple schedule simulation can show the owner what the building will look like as construction progresses. This provides a very useful and successful marketing tool for all those involved in a project.
4. **Virtual mock-up models**. Often on large projects the owner will request physical mock-up models so they can visualize, better understand and make decisions about the aesthetics and the functionality of part of the project. BIM modelling enables virtual mock-ups to be made and tested for a fraction of the cost.
5. **Prefabrication**. The level of construction information in a BIM model means that prefabrication can be utilized with greater assurance that prefabricated components will fit once on-site. As a result, more construction work can be performed offsite, cost efficiently, in controlled factory conditions and then efficiently installed.

4D – Time

1. **Construction planning and management**. BIM models provide a means of verifying site logistics by including tools to visually depict the space utilization of the job site throughout a project's construction. Tools can further be used to enhance the planning and monitoring of health and safety precautions needed on-site as the project progresses.
2. **Schedule visualization**. By watching the schedule visualization, project members will be able to make decisions based upon multiple sources of accurate real-time information. Within the BIM model a chart can be used to show the critical path and visually show the dependency of some sequences on others. As the design is changed, advanced BIM models will be able to automatically identify those changes that will affect the critical path and indicate the corresponding impact on the overall delivery of the project.

5D – Cost

1. **Quantity Take-offs**. The model produced by BIM includes information that allows a contractor to accurately and rapidly generate an array of essential estimating information, such as materials' quantities and costs, size and area estimates. As changes are made, estimating information automatically adjusts, allowing greater contractor productivity.
2. **'Real Time' cost estimating**. In a BIM model cost data can be added to each object enabling the model to automatically calculate a rough estimate of material costs. This provides a valuable tool for designers, enabling them to conduct value engineering. However, it should be noted that overall project pricing would still require the expertise of a cost estimator.

6D – Facilities Management (FM)

1. **Lifecycle management**. Where a model is created by the designer and updated throughout the construction phase, it will have the capacity to become an 'as built' model, which also can be delivered to the owner.
2. **Data Capture**. Sensors can feed back and record data relevant to the operation phase of a building, enabling BIM to be used to model and evaluate energy efficiency, monitor a building's life cycle costs and optimize its cost efficiency. It also enables the owner to evaluate the cost-effectiveness of any proposed upgrades.

V. HOW BIM CAN BE RESTRICTED BY DIFFERENT EXPECTATIONS?

By having a comprehensive view on empirical studies that have been conducted about BIM, it is clear that not only our perceptions from BIM defers greatly from each other, but also our expectations from BIM defers due to many reasons; having different definitions or unfamiliarity with all BIM's potential uses may be a result of having different expectations. These different expectations may hinder the full use of BIM abilities; therefore, BIM's potential abilities hide under the users' expectations and only some parts of it may be used. This phenomenon was named as *"BIM Consideration"* [6].

VI. RESTRICTING BIM BY PROJECT UNITS

BIM became a widespread tool for communication recently, but what are the common communicating challenges while different stakeholders and project team members use BIM? The very first challenge arises when project owner make first decision in using BIM in different phases of project and establish ways of communication between project team members'. It is arguable that the role of establishing first contacts and making decisions on ways of communication are not always dedicated to the owner, though it is argued that usually owner, a party which is pointed by owner or a party which is made prior agreements with owner in order to participate in project - for instance, as an investor - will make these decisions later. In this paper by using the term *"owner"* authors point the party which is responsible for making a project teams and ways of communication between team members [18].

Failing in establishing first agreements on communication procedures, ways and methods have been known as one of the most common causes of challenges between team members. It has also been known as a famous communication barrier in project teams that hardens communication and acts as a communication barrier in project teams [18, 19]. If a project team fails to decide on the communication procedures, which is a common pitfall in communication between project teams, another problem arise in project teams which may not be related to different definitions of BIM but may be linked to the use-level of BIM and eagerness of different contractors – or stakeholder – to release information to other parties. Although a number of causes have been discovered for the hiding information phenomenon, which is a widespread phenomenon especially in lump-sum contracts; in this paper another aspect of this phenomena will arise, that has a completely different cause, and is connected with the use-level and lack of first agreement in communication ways.

It is observed that in some projects contractors– usually design team contractors – use BIM to win the jobs. In this case, BIM is used as a professional tool only in design phase. Other uses of BIM are ignored in this use. *Hollywood BIM* is the best term to introduce this situation in a project [20, 21]. Although there should be a number of reasons for this kind of minimization that may result in limiting the other uses of BIM, we argue that lack of fixed standards in project documents and/or inappropriate observation – control – from the owner – or any other party which is responsible for supervising the work could be the main reason for this *Hollywoodian* use. However, this is only a proposed reason and need further investigations by scholars.

Hollywoodian BIM is not the only case that BIM may be restricted by different project organization units; *lonely BIM* is noted as another misuse of BIM which is related to the isolating BIM and its information to only one organization or party in the project. Vardaro et al.[20] explained this shortcoming as a situation in which BIM is just practiced inside only one organization and BIM uses which are related to the information sharing are ignored. This situation may happen, for instance, when consultancy that is responsible for design uses BIM as a tool for design but share design drawings and details in 2D drawings with other stakeholders [20, 21].

In contrast to the lonely and Hollywoodian BIMs, *"Social BIM"* and *"Intimate BIM"* are considered as two other – and more successful – uses of BIM. Social BIM is referred to a more collaborative approach to BIM and its useful advantages. Social BIM refers to a manner in which information used by one party – stakeholder – is shared among other stakeholders openly. A flourishing advantage of social BIM is transparency which eases communication between different stakeholders. Intimate BIM, as another approach to application of BIM in projects, is distinguished when all main parties of a project share risks and rewards in projects. This situation is likely to happen when gain sharing approach is used as procurement method for pointing main contractor and other project organizations; Hergunsel [21] argues that this may be possible through BIM-integrated project delivery. Intimate BIM and social BIM results in better collaboration in producing drawings and other project documents; hence reduce time and cost of the project.

VII. DISCUSSION

Having a thorough review on empirical studies that have been undertaken in the area of BIM, it is evident that not only our perceptions from BIM defer greatly from one person to another, but also our expected outcomes of using BIM defers due to many reasons; having different definitions or unfamiliarity with all BIM's potential uses may be a result of having different expectations. These different expectations may hinder full use of BIM abilities; therefore, BIM's potential abilities hide under the users' expectations; therefore, only some parts of BIM's potential may be used. Some Authors named this phenomenon as *"BIM Consideration"* [6]. Authors believe that this shortcoming can be referred to IS Concerns of Jung and Gibson [6] and/or BIM Technology of Jung and Joo [7]. In this phenomenon, construction managers may not be able to understand full potentials of BIM so its uses could be isolated due to misunderstanding of its meanings and uses by top managers.

There are various stakeholders that interact when BIM is utilized. Evidently different organizations and people create their own definitions of BIM, based on the specific way they work with BIM. Thus, it is evident that there are differences in the way BIM is perceived by both different individuals and organizations within the construction industry. As a result, it might be difficult to come up with a common definition of BIM for the entire construction industry. In other words, as Jongeling [13] emphasizes, there is confusion concerning what BIM is, and what BIM is not. This can lead to misunderstandings concerning expectations from different stakeholders involved in construction projects where BIM is utilized. The result is the problem in lack of comprehensive realization of BIM benefits. The authors propose that this may result in limited use of BIM. In this manner, according to Jung and Joo [7] and Jung and Gibson [6] Business Functions uses of BIM may be quarantined only in Safety Management and/R&D

or any other single project units since project organizations are not believe in BIM‘s potentials.
The last shortcoming which was identified in the literature reviewed and explored by the authors refers to differences of BIM's expectations among construction people. According to Jung and Joo [7] and/or Jung and Gibson [6], discussing this issue may be beneficial. The authors believe that BIM's abilities may be hindered by construction managers due to having divergent attitudes and expectations about BIM. For instance, some may consider BIM only as a design tool while others use BIM as a main source of communication between project stakeholders.

VIII. CONCLUSION

The literature fails to present a unique and comprehensive definition of BIM. A relevant and accepted calculation methodology and baseline to properly evaluate BIM's benefits have not been established yet. There are mixed perspectives and opinions of the benefits of BIM, creating a general misunderstanding of the expected outcomes. The frequency and variety of the definitions of BIM illustrate the confusion in defining and quantifying BIM and considering its potential benefits. This deficiency not only prohibits the collaborate process between stakeholders, but it also makes the measurement of BIM's effectiveness too general and qualitative. Hence, BIM is a very wide concept with divergent characteristics.

It is; therefore, important to be precise when discussing BIM, for instance when specifying requirements regarding BIM in the tender request documents. This is important for avoiding misunderstandings and ensuring that stakeholders can deliver what has been requested concerning BIM. Moreover, this paper proposes that the definition of BIM should not be unilateral but instead encompass several key characteristics which have been attributed to it. The study further asserts that there is a risk in offering a narrow definition of BIM as this primarily makes it more problematic to establish a baseline for comparisons. Subsequently, a narrow definition makes it difficult, if not impossible, to improve BIM uses by means of benchmarking.

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