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Building Information Modeling in Project Management: Necessities, Challenges and Outcomes

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Abstract

Building Information Modeling (BIM) is becoming a comprehensive collaborative process in the construction industry. Despite its short history, BIM has had an increasing growth during the last decade. This is happening mainly due to its capabilities on construction projects. BIM can create a common language between all parties and system divisions in a project and make them an integrated team. The approach of BIM strongly matches with integrated project delivery systems. The role of BIM as a coordinator of project system is quite similar to the duties of a project manager. BIM integrates different disciplines by effective communication, analyzes the project systems for constructability, estimates the cost and time of projects at any time using quantity takeoffs, draws a big picture of projects using visualization and builds collaborative teams. All these are what a project manager does in a different scale during a project life cycle.

This paper aims to show the correspondence of BIM and project managers' roles on construction projects. It emphasizes the importance of having proper BIM knowledge and experience for project managers to succeed. This paper also discusses the requirements of BIM knowledge and experience enrichment of project managers.

Keywords: Building Information Modelling, Project Management, Construction

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1. Introduction

1-1. History

Building Information Modeling (BIM) can be defined as a reliable, digital, three dimensional, virtual representation of the project to be built for use in design decision-making, construction scheduling and planning, cost estimates and maintenance of construction projects (Words & Images, 2009).The BIM Handbook (2008) defined BIM as a computer-aided modeling technology for the purpose of managing the information of a construction project

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focusing on production, communication and analysis of building information models. The National Building Information Model Standard Project Committee defined the BIM as following:

> "A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward."

The concept of BIM theoretically emerged and was developed at Georgia Institute of Technology in the late 1970s and grew rapidly after that. The growth happened because of the increasing attention paid to construction teams and firms that found merits in using BIM in order to integrate the process of the construction projects and managing them. The term Building Information Modeling was first used in 2002 to describe virtual design, construction and facilities management (Harris, 2010).

Graphisoft in 1986 introduced its new software as a solution for virtual building. This software, Archicad, was really a drastic improvement in CAD programs of that time since Archicad allowed the creation of three dimensional (3D) models of projects (Dey, 2010). The terms Building Information Modeling and Building Information Model and the acronym of BIM were widespread when Autodesk released the "Building Information Modeling" (Autodesk, 2003).

1-2. Construction Project Management

Construction projects constitute the main part of all disciplines projects due to their amount, variety and cost. The U.S. Census Bureau News (2013) estimated that the construction industry would spend more than $874 billion in 2013. These projects range from small residential or retail projects to mega multifunction projects. Needless to say, with any scale of a construction project, there is a necessity for managing it. The management of construction projects requires knowledge of modern management as well as an understanding of all construction processes. Along with the change in technology, organizational arrangement or procedures and new features and methods, the management of construction projects differs (Hendrickson, 2000). Construction project management is a series of activities for determining how, when and by whom the work, including all life cycle activities, will be performed.

Similar to the Project Management Body of Knowledge (PMBOK) definitions, the construction project manager handles project management planning, cost management, time management, quality management, contract administration, safety management and risk management. The project manager is also in charge of communication between all stakeholders on the project including owner, designers, engineers, professional crew and administrative staffs. Generally, construction project management shares the common and overall characteristics of general projects, therefore, the rules and methods required for general project management can be applied to this type of projects.

2. Building Information Modeling Aspects

2-1. Integrated Project Delivery System

Integrated project delivery (IPD) is a growing approach for delivering projects that unifies different disciplines' efforts and integrates all parties including project managers, designers, engineers, systems and practices into a collaborative process. IPD optimizes the value of a project by improving efficiency through all phases. IPD recruits all

parties involved in the project and makes them a coherent team. With IPD all parties are encouraged to concentrate on project general outcomes rather than individual objectives. In order to have a more effective approach, BIM tools enable the whole team to communicate, visualize and analyze great deals of complex project information in a holistic and cohesive way. Combining and unifying detail information from all parties into an integrated model will improve the productivity of a project team and facilitate its management.

A BIM-based IPD approach results in many advantages during the construction project lifecycle. With an integrated collaboration approach, the project team can effectively track, assess and review the project, make decisions when necessary, resolve conflict and discrepancies and execute the project successfully. IPD is an integrating approach for project management, and BIM is the technological interface that facilitates this process.

2-2. Unique Language

Having an identical usage and comprehension of vocabularies is a key factor for success in project management (Project Manager Education and Opinion, 2012). Therefore, managers tend to be well educated and improve their verbal skills to be involved in various projects, understand what people are saying, and perhaps more importantly, be understood by others (Ward, 2008). For this purpose, some efforts have been implemented during the last decade, for instance, buildingSMART, formerly the International Alliance for Interoperability (IAI), is an international organization which has the mission to enhance the informative communication between various construction software

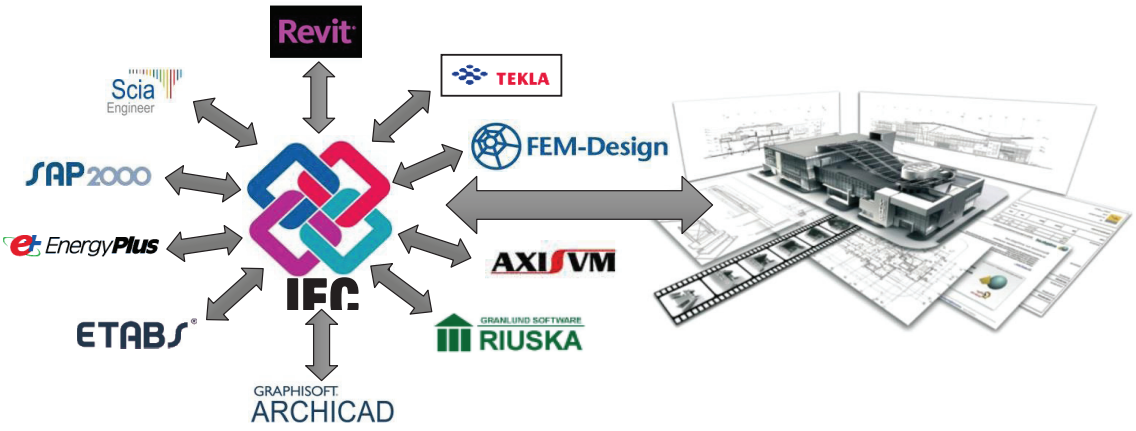

Fig 1. Mutual relationship between IFC and Some BIM applications

applications. BuildingSMART has developed Industry Foundation Classes (IFCs) as a neutral specification for Building Information Models (Words & Images, 2009). The Industry Foundation Classes were developed to build a vast set of consistent data representations of building information for exchange between different softwares in the construction industry (Figure 1). This is a holistic approach which considers all phases of a construction project life cycle. As an object of the buildingSMART alliance, data interoperability is a main factor for obtaining the BIM efficiency. Thus, it tries to develop a common data schema that facilitates the data exchange between various BIM applications. This data schema comprises interdisciplinary building information as used throughout the project phases from feasibility to operation and maintenance.

2-3. Technical Aspects of BIM

BIM has some specific features that can effectively be used in project management. These features, which are increasingly developed, can be summarized as follows (Lahdou & Zetterman, 2011):

- Clash Detection

  One of the common problems of different disciplines' plans for a construction project is the geometrical design inconsistencies. This issue happens when there is an overlap between the plans of different disciplines. Using BIM, it would be possible to bring the plans together and detect the clashes. Modifying the aesthetic problems is another possibility of this visual checking.

- Constructability

  Using BIM, it would be possible for teammates in a project to review and handle constructability issues and (if needed) promote issues into RFIs. In addition, visual information can be provided from a vantage point to show the problems. This visual information accompanying markup allows further investigation for finding solutions and, thus, mitigates the risks.

- Analysis

  Helping the project managers, designers and engineers in doing more analyses and enabling better decision making is another aspect of BIM. By linking the building information models to appropriate tools, it would be possible to analyze the energy consumption of a construction project and then find better solutions such as changing materials and orientation, mass and space, etc. Moreover, light, mechanical and acoustics analyses are also available to be performed by BIM.

- Time & Cost Estimation (4D & 5D)

  Time and cost estimation are other features of BIM which enable project managers to visualize the construction project at any point in time and have a clear understanding of project phases. Time and cost estimation, which are generally called 4D and 5D, can be properly utilized in the first stages of a project and facilitate the decision making process with minimum cost and time needed. Furthermore, BIM has the capability to simulate the various alternatives for a construction project and hence helps project managers and executives to reliably predict the consequences of their decisions.

- Integration

  The project team can deal and interact with a unified model when a composite model is built from an amalgam of various disciplines' models. Having this capability, and through the different phases of a construction project, BIM can coordinate the design, analysis, and construction activities on a project and, therefore, results in integrity of projects.

- Quantity Take-off

  Quantity takeoffs in a BIM model can be very helpful for the project teams and managers to analyze their decision and have a clear and reliable insight to various alternatives in the design phase or even throughout the project lifecycle. Since there is a possibility of integration between the BIM model and a database

containing cost estimation, an accurate estimation can be obtained faster. Moreover, these takeoff items can be used easily in procurement procedure.

- Element Based Models

  Since the BIM models generally are composed of objects –and not geometries, such as line, surface, etc. – the whole model can be divided into a specific number of smaller objects. This breakdown makes it possible to have a defined and clear scope of projects. The distinction between the elements will result in a better management design, estimation and construction.

- Collaboration and Team Building

  Collaboration and team building is another key factor for BIM success on construction projects. All efforts made by various specialties on a project are unified and applied to one model. This results in direct correspondence and team building. All disciplines have to work on a unified model as a team and have an effective collaboration during a project using the BIM concept.

- Communication

  The Nature of a unified model to input, modify and analyze the data in BIM models will improve communication and collaboration between all parties involved on the construction project including project managers, architects, engineers, and contractors. These unique building models facilitate the communication throughout the project and lessen the disputes between different parties.

3. Role of BIM in Project Management

3-1. BIM vs. PMBOK Knowledge Areas

Capabilities of BIM on construction projects correspond to the PMBOK knowledge areas, since the nature and role of each item are alike. Therefore, BIM can be considered as an effective and powerful tool in project management in the construction industry.

Integration management is the first area of PMBOK, which has the same function as the BIM. BIM integrates the documents, plans and efforts of all parties involved on a project. BIM is also an object-based environment that can categorize different elements of a building and break it down into different groups, like what occurs in project scope management. Another characteristic of BIM is its capability in managing time and cost or what is allegedly called 4D and 5D. This is similar to project cost and time management areas in PMBOK standard. Although the constructability does not illustrate all risks associated with a construction project, it is a powerful tool in building a project and mitigates the construction risks. Clash detection in BIM acts as a quality process which visually recognizes, modifies and analyzes the soft and hard clashes. Collaboration and team building in BIM is what human resource management considers as a project management area. Communication is a main feature of BIM which facilitate the professional relationship between all parties including project managers, designers and engineers on a construction project by creating effective and direct communication channels. Finally, procurement management would be possible by quantity takeoffs which are produced by BIM. In addition, changes in any item can be easily reflected in cost and time

and work needed for its procurement. In spite of the extensive framework of project management, BIM can be presented as a main and effective concept corresponding to project management knowledge areas. Figure 2 shows a model of PMBOK knowledge areas considering BIM on construction projects.

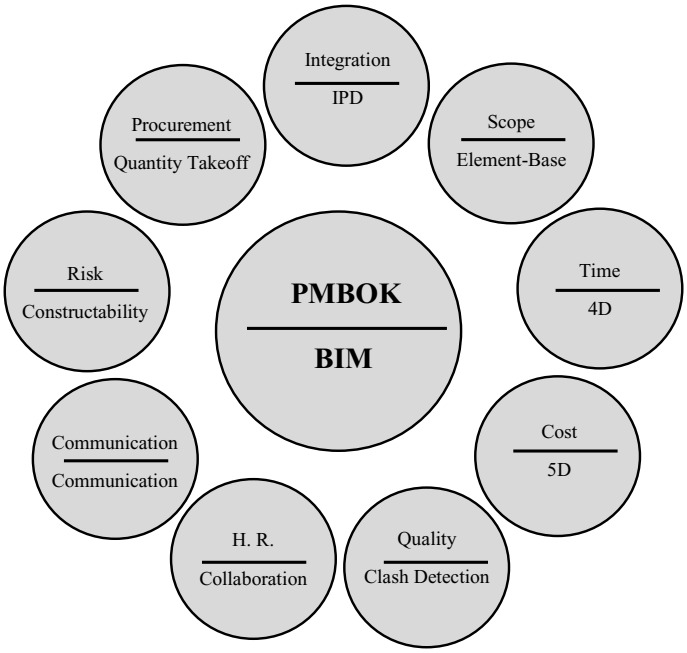

Fig 2: PMBOK knowledge areas versus BIM roles in construction project management

3-2. BIM Benefits and Advantages

Different sources of construction project management identify key advantages of using BIM as follows (Qian, 2012):

- "Enhanced project collaboration and control among stakeholders
- Improved productivity (less re-work, conflicts and changes)
- Better project quality and performance
- Faster project delivery
- Reduced wastages
- Reduced construction costs
- New revenue and business opportunities"

BIM as a centralized repository allows everyone involved on construction projects to access the same version of data which mitigates the risk of poor communication for project managers (Alagarsamy, 2000). Eastman et. al. (2008) believe that concept, feasibility and design analysis, which result in increased building performance and quality, is the

main advantage of BIM in the pre-construction phase. More accurate visualizations of a design, automatic low-level corrections when changes are necessary, 2D drawings generation, earlier collaboration of multiple design parties, cost estimates extraction during the design stage and energy efficiency and sustainability improvement are advantages in the design phase of a construction project. BIM also synchronizes design and construction planning, detects design errors and omissions, utilizes design models as the basis for fabricated components, and implements lean construction techniques in the construction phase. In addition, using BIM would enable better facilities operation and management in the post construction phase.

3-3. Challenges

One of the most rigorous discussions in implementing the BIM comes from personal beliefs toward this concept. In a recent survey, Lahdou and Zetterman (2011) show that if the project team members do not really believe in the importance of BIM and its advantages on a construction project, the outcome will not be satisfactory. In another survey, Qian (2012) shows that top rated areas of BIM for investment includes software and hardware, developing internal collaborative BIM workflow and procedures, and BIM education. Brewer et. al. (2012) state that the challenges for using BIM on construction projects can be grouped and presented as 1) technical challenges, which are generally conflicts and issues regarding data sharing among team parties and BIM softwares' problems; 2) skills and training challenges, which are mainly about the training project team members and improving their skills; 3) legal and procedural challenges which refer to the lack of a standard and legal definition for BIM professional responsibilities; and 4) cost challenges, which sometimes hinder the construction firms from changing and upgrading their current systems to a BIM oriented system.

4. Discussion

4-1. Project Managers' Knowledge

Since mutual relationships are a main feature of BIM, characteristics of users influence the effectiveness of BIM. BIM users include all parties and professionals involved; hence, attitudes of teams members should be considered as an effective factor, specifically, project managers as the core of communication channels. Experience level of project managers has a direct relationship with the success of BIM on a construction project. Qian (2012) believes that the BIM merits and advantages are directly proportionate to the experience level of the users.

Hardin (2009) asserted that having an experienced BIM project manager on the project team is a key factor of construction project success. BIM knowledge of project manager enhances the capabilities of BIM from a software application to a holistic notion which integrates and coordinates all parties and systems on the project. Thus, considering the BIM knowledge as an excessive capability for construction project managers should be withdrawn; instead, having appropriate experience and knowledge in BIM should be set as a criterion for admission of a construction project manager.

4-2. Education

Education is a basis for professional development in industry. Education of project management has inconsistencies among different colleges and programs (Rokooei & Miralami, 2010; Rokooei, Azizi & Miralami,

2010). Like any other practical concept, BIM education is first introduced as a theoretical notion. Particularly, alongside the growing use of BIM in industry during the last decade, different universities in the world have paid more attention to BIM education and put it in their curricula. The U.S. universities as pioneer educators have the main role in this regard. The BIM-related courses are offered mainly in construction engineering and management programs. Within these courses, the concept of BIM and the related software trainings are being taught. O'Brien et al. (2003) designed a collaborative design course, which utilized available software. As a goal for this course, the integrity of the design process was highlighted. Peterson et al. (2010I) believed that instructors at various universities have tried to offer innovative courses that focus on preparing students for professional collaboration and training construction management concepts with the last technological achievement in BIM. They also showed that the introduction of BIM-based project management tools is a helpful method to develop more realistic project-based class assignments. This method enables students to utilize different formal project management methods in real-world project management problems. Ghosh and Chasey (2013) used BIM as a concept in relevant construction management contents and applied it as a new experience for Project Management in a capstone course. Despite the efforts for BIM education in construction management programs, it seems that there is still a gap between education of BIM and project management. Merging these two concepts together in order to present BIM-oriented project management contents can found a concrete basis for future project managers to promote their theoretical knowledge as well as practical capabilities.

5. Conclusion

This paper shows the main aspects of BIM including clash detection, constructability, analysis, time and cost estimation (4D and 5D), integration, quantity take-off, element-based models, collaboration and team building, and communication on construction projects. These capabilities have empowered BIM to play a significant role in project management as a new tool. Obviously, BIM, like any other tool in a system, should be utilized by a user, and one of the best persons for filling this role is the project manager. There are close similarities between the performance of BIM in the construction process and the project manager as the heart of decision making. Therefore, BIM can be considered as a managerial tool rather than a technical one on construction projects. This viewpoint is the result of a comprehensive definition of BIM. What BIM really does is different from what a set of software does. Similarities between the role of project manager and BIM on construction projects necessitate some more considerations such as having clear understanding of the BIM concept and enough knowledge and experience in BIM. For this purpose, construction curricula should have an effective combination of BIM and project management contents offered for the students who pursue project management positions in their future professional lives.

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