J. Basic. Appl. Sci. Res., 4(9)16-27, 2014
© 2014, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Exploiting Building Information Modeling Throughout the Whole Lifecycle of Construction Projects

Saeed Reza Mohandes[a*], Abdul Rahim Abdul Hamid[b], Haleh Sadeghi[c]

[a*]Post graduate student, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia
[b]Senior Lecturer, Department of Structures and materials, Faculty of Civil Engineering, Universiti Teknologi Malaysia
[c]Post graduate student, Faculty of architectural Engineering, University of Fars science and Research, Iran

Received: July, 12, 2014
Accepted: September 4, 2014

ABSTRACT

Over the past few years, construction industry has encountered numerous problems such as rework, design errors, accidents and building failure, time and economic losses, poor work efficiency, and low standard level of cooperation amongst team members of different sectors. As such, information communication technology (ICT) has been evolved to minimize all the aforementioned setbacks in the construction industry. In doing so, building information modeling (BIM) has been proposed to all construction members such as engineers, architects, contractors, and owners to take benefit from. Since BIM was emerged into the construction industry, it has received the attention of many researchers and practitioners. While there have been roughly numerous studies conducted on the benefits involved in the use of BIM, it is a unresolved point why there has not been a greater take up of exploiting BIM throughout the whole lifecycle of construction projects. Therefore, this paper is mainly aimed to examine the effectiveness of exploiting BIM throughout the three different phases of building's lifecycle, including preconstruction, construction, and post construction in great details regarding the previous studies conducted in this field. The authors have concluded that utilization of BIM has several benefits in different stages of construction projects, including minimizing design error, reducing rework, increasing work efficiency and cooperation amongst team members, facilitating the process of delivery and procurement, and reusing the wastages of materials.

KEYWORDS: Building Information Modeling, preconstruction, construction and post construction phase.

1. INTRODUCTION

The management of construction projects is becoming more difficult and complex [1-3]. One of the factors leading to this complexity is mutual interdependencies among various stakeholders like authorities, financing bodies, architects, contractors, lawyers, engineers, suppliers, and trades [4]. The increasing complexity and errors that may occur during projects have led the information and communication technology [ICT] to a fast-pace development [5]. During the 1990s, the most important shift in ICT for construction industry was the Building Information Modeling [BIM] proliferation that was occurred in industrial and academic contexts as a new Computer Aided Design (CAD) paradigm [6]. Presently, BIM – defined as "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" [6].Some special tools of design, engineering, and architecture professions have recently joined the basic functionalities like scheduling, structural analysis, energy analysis, progress tracking or jobsite safety [7]. BIM is mainly concentrated on design, preplanning, construction, and integrated project delivery of infrastructure and buildings; however, in recent years, researchers have shifted their focus from earlier stages of life cycle (LC) to the end-of-life considerations such as refurbishment, maintenance, deconstruction [7–13], particularly in complex structures.

1.1Definition of BIM:

The international standards refer to BIM as "shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decisions" [14]. The origination of BIM is the product models [15, 16] extensively used in the automotive, petrochemical, and shipbuilding industries [9, 17]. BIM represents real buildings virtually over the whole LC as semantically enriched, consistent, digital building models [9, 18,and 19].In realization of BIM, which is composed of parametric objects indicating building components, object-oriented software has been employed [10,15,20], in which the objects may be with non-geometric or geometric

[*]**Corresponding Author**: Saeed Reza Mohandes, Post graduate student, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia. Email Address:Reza_mohandes2011@yahoo.com

attributes associated with topologic, semantic, or functional information [9,17]. Topologic attributes make available information concerning the location of objects, perpendicularity, adjacency, and coplanarity; semantic information contains aggregation, containment, connectivity, or intersection information; and functional attributes provide the installations duration or costs.

1.2Theconcept of BIM

The BIM concept dates from the early stages of CAD in the 1980s, when it was conceptually defined by researchers [9] and employed in working software in premature CAD programs. At that time, BIM was described as three-dimensional graphical model of building that was enriched through supplementary intelligence (information accompanied with graphics). This technology is based on the Graphical Information Model [21], including the geometrical model building, the physical properties, name, and its components' functional peculiarity. The modern description of BIM dates back to the late 1990's with the appearance of several Single Building Model (SBM) that were presented by various CAD software vendors (e.g., Autodesk, Revit, Bentley, and Graphisoft) [22]. In the construction industry context, BIM has been accepted as a standard definition of information modeling technology when maximum integration between various disciplines is achieved and an intelligent parametric objects model is created. Recent years have witnessed a consistent attempt for providingconventional3-D BIM with the fourth, fifth, and even sixth dimensions, which have been developed on its base Product Lifecycle Management (PLM) analogue for the construction industry [9, 23, and 24]. This solution is known as Building Lifecycle Management (BLM) or the theoretical Unified Project Management [25]. This movement is based on the idea of further application of high-capacity information that is stored in 3-D intellectual building model.

1.3 Common Misconception about BIM

It seems that BIM is widely misunderstood concerning what it is and what it is not. The majority of people, in particular those that are unfamiliar with 3-D graphic programs like 3-D AutoCAD and Rhinoceros, make confusion between BIM and 3-D CAD. Rightly there are some similarities between them; however, BIM is significantly distinctive in AEC industry. It should be noted that 3-D CAD, while consisting of 3-D information, is merely geometry. W8x10 steel beam representation existed in 3-D CAD is just a collection of surfaces in geometry of a common rolled steel shape. For creation of a beam in the 3-D CAD, at first, a line should be defined, which is the beam's length. Then, in the geometry of the beam's cross section, a polyline is introduced and placed properly in regard with the beam's length and its orientation to its centroid, and, finally, the polyline is extruded for making a steel beam's graphic representation. In this representation, no intelligence is innate and only geometry information is generated [26].

However, in BIM, a W8x10 steel beam "knows" it is a steel beam with some relevant information like section properties, level association, length, and the columns into which it frames, and so on. It is noticeable that BIM is readily realized whenever any change is occurred in the model. Within a building information model, with the movement of one of the supporting columns of the beam, the beam's location will be attuned automatically in a way to follow the new location of its support. In 3-D CAD, the above-mentioned change is a monotonous process as follows: following the movement of one of the columns, the extrusion that is the representation of the beam should be manually deleted by the user, a new line should be created defining the beam's new location, the cross section representing the beam's shape should be then reintroduced and rotated in such a way to be rightly vertical to the new line of beam and its planned direction that is not always insignificant in 3-D, then the section should be extruded again for recreation of the beam representation.

Additionally, different from the conventional 2-D drawings, a building information model is consisted of applicable information like3-D geometric relationships, and a completely-parametric relationship among different views of model. For example, conventionally, in cases where one beam size changes, the change is required to be updated manually not only on the plan, but also on the pertinent sections, schedules and details. However, in a building information model, the beam size change can be occurred in any view, and the change is updated in all views. The whole schedule and quantity takeoff are updated also automatically. Obviously, the utilization of BIM,as the way of the future, can enhance the efficiency of AEC industry [26].

1.4 Comparing traditional workflow to implementation of BIM

The implementation of BIM is structurally different from the conventional way of workflow in the engineer's office. The workflow goes in one direction: it starts with the design of architect and continues to the structural engineer's conceptualization, analysis, and drawing production. Any change occurred by architect in the design demands the engineer to do all aforementioned steps again. In contrast to that, when BIM is implemented, there is a central building information model wherein the inputs from the whole disciplines are linked. Structural engineer is completely informed about the updates and changes performed by architect and mechanical engineer, and the structural engineer is capable of making the corresponding adjustments that are required in her/his module of BIM program that can be linked directly to a third party analysis program that is specific to the structural analysis [26].

1.5 The dominant applied BIM practicalities for existing buildings

As Rebekka Volk et al.[27] stated, the applied BIM functionalities can be classified into numerous subclasses such as; spatial program validation, Clash detection, BIM quality assessment, Cost calculation or cash flow modeling (5D), Construction progress tracking, Deconstruction, Daylight simulation, Deviation analysis, rubble management , quality control, Documentation, defect detection, Structural analysis, data management and visualization, prefabrication, carbon foot printing, Energy/thermal analysis and control, indoor navigation, Localization of building components, Subcontractor and supplier integration, Life cycle assessment (LCA), Monitoring, sustainability, performance measurement, facility management (FM), Operations and maintenance (O&M), Quantity takeoff (3D),Risk scenario planning, Retrofit/refurbishment/renovation planning and execution, jobsite safety, Safety, emergency management, Space management, and Scheduling (4D).

On the top of the whole practicalities, beyond 3-D modeling, various information is provided throughout the LC of the construction project in regard to the following areas: legal description, contract documents, change orders, shop drawings, supporting documentation for litigation, progress photographs, procurement documents, alarm diagrams, purchase requests, warranty data, organizational occupants, handicap designation, personnel lists, hazardous materials, inspection records, operating manuals, continuation of operation plans, contingency plans, disaster recovery plans, asset inventory, proper lean implementation, project closeout documentation, supply chain management, and electronic document transfer [28, 29].

1.6 BENEFITS OF USING BIM

There are many direct advantages in the use of BIM; nevertheless, its most important advantages are actually the indirect ones. Direct advantages comprise the qualities (e.g., conception, the enriched imagination, and the building information concentrated in the project). Whereas, the indirect advantages are those that are necessary for the cooperation and the achievement of the best understanding of the project and reduction of the project risk. Simulations allow a design to be checked practically prior to the construction of the real project. A model helps to visualize the project appropriately, which leads to providing a stimulation view in regard to the project requirements that can describe the project efficiently [30].

Lambert [31] believe that BIM utilization has the following advantages:

1. Materials take off is simplified
2. Complex details can be surveyed and analyzed
3. Different trade components coordination can be reviewed for potential “hits”
4. Sequence of placing a project with each other is expanded
5. The 4-D, which added time, can be merged to indicate the time during which a project can be put together
6. Site work eminences among the ultimate eminence and existing conditions can be determined
7. The best routing can be reviewed for lights, pipes, sprinklers, cables, and ductwork wires
8. The site preparations with the hoists and cranes location can be analyzed
9. Lift schedules are determined for the concrete, steel, and massive electrical and mechanical equipment placement
10. Development of the schedules and the associated argument can be extended
11. Problems associated with the potential safety are evaluated
12. Alternatives can be evaluated in more realistic terms
13. Coordination of the trade’s former for performing the real work.

Additionally, the improvement of coordination and collaboration amongst the team members [32]and the achievement of lean management’s objectives with the purpose of decreasing non-value adding waste have been also recognized as other advantages of BIM [33].Moreover, 7 pillars of BIM implementation are considered as benefits of the use of BIM through which managers can achieve improved project outputs, get rid of waste, enhance feedback, deliver fast, delay decisions to achieve consensus, give power to the team, build-in integrity, and see the whole [34]. Another study has prioritized the benefits of BIM according to their importance in their respondents’ answers [35]:

- Cost reduction or control
- Time reduction or control
- Communication improvement
- Coordination improvement
- Quality increase or control
- Negative risk reduction
- Scope clarification
- Organization improvement

2. Exploiting BIM throughout the whole life-cycle of construction

2.1Planning and pre-construction phase

Commonly, the applications of BIM are identified in the pre-construction phase of a project. This is of a great importance because information associated with the planning stage provides many benefits for the given project. This phase falls into two parts; first, the marketing and design of the project's conceptual features should be addressed; second, planning and designing the project construction [30]. Moreover, such simple conceptual models can be used for preselling processes of a project to provide a financially-safe project. Some complicated movies and images can be employed to illustrate the finalized virtual project. For these purposes, surface modeling software frequently generates schematic models. The use of a surface modeler is generally easier and the consequences are also fine assorted in such a way to be used for communication purposes.

2.2 The Model Development

Model development is the planning nature and designing phase of projects. Information feedback loop is recognized as an affiliate of the model itself, which enhances the model senses. In case of the design process transmutation, the aforementioned model is considered as the central point; additionally, the members of all project teams correspond mostly through the use of the model. Furthermore, the advanced 3-D one that provides visualization helps the designers grow in their job. The whole opinions given on the project are presented within the model. The project, in this phase, can be fairly schematic; in addition, the opinions of the project group members can be easily indicated in the model [30].

2.3 Analyzing the Constructability

Constructability is another part of the pre-construction phase, which evaluates the conditions and requirements of the construction process in order to achieve the predefined outcomes. It assesses the way systems and materials are used and analyzes the details about the construction, installation, manufacture, and assembly of the whole segments of the project. Generally, constructability consists of numerous parts such as supply deliveries accessibility, construction site layout, the job trailer place, site provisions that includes excavations and backfill operations, and so on. At this early phase of the project, value engineering can be displayed efficiently, which maximizes the design of the project and the components value. The project value can be optimized through brainstorming sessions held by all group members of the project and also through the 3-D model that provides connection among the group members [30].

2-4 The Construction Schedule

In the construction management, a critical path method (CPM)-based project schedule is commonly employed in the form of an activity-time 2-D bar chart [36]. The drawback of CPM however is being deficient in spatial context and resource components, which leads to a problem in the discrepancy of the interpretation of project schedule and the identification of mistakes of the construction plan [37]. As a solution to the problem, a collection of resource components and 3-D graphics is integrated with activity schedule, which provides a 4-D view of CPM plan. In addition, in a 4-D model, the entire changing process of both the construction site and the structure is recorded and reviewed, which helps to analyze construction conflict and the collision detection in case of movable site facilities [38].

Using the 4-D model, the construction schedule can be appropriately expanded. In cases where a primary schedule is available, a schematic construction sequel is simulated, which facilitates the visualization of construction process and concentrates the attention of other approaches onto layout of the site, sequencing, the crane location, and so on throughout the construction procedure. Furthermore, the model components can contain information about the production rates, which helps to analyze the balance schedule lines. This approach provides the fine-tuning of tasks on the basis of their placement within the project and production rates.[30].

Simulation of four dimensional (4-D) has been investigated with a concentration on the schedule management of construction and the implementation of the dynamic simulation atmosphere during procedures. Tulke et al. [39proposed a framework for the dynamic collaboration that makes instinctively a construction schedule through re-engineering approach of a business procedure and this simulates computation of expenses concerning the schedule. However, information regarding the geometry is employed only in case of visualization through simulation of four dimensional (4-D) where this is also connected to the system separate from the construction schedule. This shows that traditional techniques are not avoidable. For the meantime, Tulke et al. [40] presented a simulation system of 4D that was linked instinctively to the geometry information based on data that was stashed at a building model with schedules for a construction sequence planning. However, the system was not capable of fracturing the existing frame, which was merely an easy linking between schedule and information of geometry. Chau et al. [41] presented the functions essential for the management of geometry models of 3-D, dynamic sources and schedules on the 4-D information system platform, which was called "Graphics for Construction and Site Utilization". This platform has no suggestion concerning the consequences of developing a genuine applications or system; however, this provides conceptual meaning for the major factors that can be comprised in the 4-D simulation. These information technologies are capable of not only achieving integrated solution that includes dynamic management, process

simulation, safety analysis, and conflict analysis of constructions, but also improving the constructions' quality and efficiency. Among the all advantages, the most significant one is the reduction of construction accidents.

2.5 Construction Safety

BIM provides a powerful and new base for the purpose of expanding and implementing the methods and tools for Design for Safety (DfS) concept in order to make easy the safety considerations in designing and constructing stages of the projects. Using DfS Tools, designers are capable of identifying risks removing them properly (Gambatese, 2008). 3-D/4-D computer-aided design (CAD) software is known as the latest type of the DfS tools. Simulation and information sharing through BIM help designers recognize the potentially hazardous situations during various stages of a project.

According to the results of the survey conducted [42], 53 % of respondents stated that, visualization tools could positively more affect the improvement of construction safety compared to the currently existing tools. Furthermore, the authors concluded that buildings can be simulated at different stages by means of Virtual Design and Construction (VDC), which helps to detect the potential safety hazards. Virtual visualization instead of mere imagination of the construction sequences significantly extends the understanding of the construction procedure.

Suermann et al. [43] conducted a study on the impact of BIM on key performance indicators of project, in which 46% of respondents believed that BIM has capacity to decrease fatalities and damages respect to any construction project and, consequently, enhance the safety of worker.

Another survey was carried out by Kasirossafar et al. [44] on the influence of BIM on the construction safety and revealed that75%of respondents believed that fatalities and accidents in those projects that used BIM tools were predictable and avoidable in design phase. In addition, the most avoidable accidents were identified in this order: falls from height, cuts or blows from objects and tools, and electrical shocks or thermal contacts.

Using analysis provided in Expert Choice Software, Kasirossafar and Shahbodaghlou [45] prioritized the ways BIM can be used for the improvement of construction safety as follow:

- Incorporating and developing different levels of detail in BIM, relating to construction material, equipment, and labor at design phase (49%);
- Integrating the hazard potentials and avoidance strategies with the 3-D BIM model (22%);
- Having a better communication amongst various team members (16%); and
- Developing methods for identification of hazards among designers (13%).

2.6 Cost of Projects

Using BIM, the cost of project can be predicted in the whole stages of the project planning. In the early phases of project, establishing the budget areas is a useful strategy, which is shown in the form of square footage expenses within a model. A schematic 5-D model provides schematic quantities and produces outlines of expenses estimation. Following the expenses of project estimation and budget through the usage of the model in the design stage is referred to as an objective of value design. When the models are developed, the cost tracking can be refined through enlarging the model detail levels; in addition, the expense implications for design alternatives can be estimated at any phase of design development. Several cost analyses are based on the link between the model's components and an external database that consists of real cost information. Within the model, the quantities are integrated with the connected cost data and, according to which estimations made for the project cost. Users are able to edit and customize the databases. Numerous firms can estimate their expenses based on historical data and they are able to use previously-known data of a private database. In addition, cost data are commercially accessible and can be applied [30].

2.7 Construction supply chain management (CSCM):

To provide a complete visualization of resource flow status and support decision making in the CSCM process, an IT-based model was developed. Using BIM as an IT–based tool, visibility of the supply-network and accurate information relating to the material status at various stages can be improved [46]. Consequently, managers are able to gain access to a BIM model associated with required material information [47]. This model employs BIM capacity to provide accurately a takeoff with all details in an early phase of procurement process, and it uses GIS for supporting the spatial analysis performed in the logistics perspective (transportation and warehousing) of CSCM. A parametric model that consists of accurate BIM components makes easy the definition of distinct quantifiable elements in order to demonstrate the detailed material and component properties [48]. These quantities, which are provided by BIM tools, can be exported to a spreadsheet or an external database, and must include the material to be procured, both temporary and permanent [49]. Once the building model lacks an element (e.g., scaffolding) or a required quantity cannot be computed on the basis of the component properties, some issues may arise. Those quantities that the building information model does not directly provide would require to be entered by user. Additionally, this model uses the BIM visualization capacity for generating alerts and reports graphically. As a result, the time needed to prepare a list of the whole materials is significantly reduced and, as an alternative to employing statistics reports, it displays the 3-D visualization of the material status at any given time through making a comparison between the

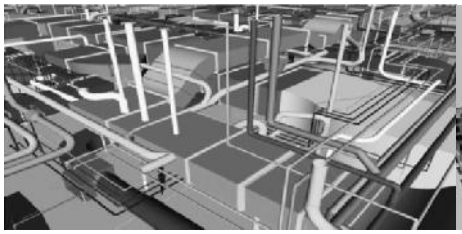
planned quantity and the incoming quantity. Furthermore, the current software tools employed in managing supply chain depend on histograms and bar charts to represent the data, which requires more consideration to decide on the materials' location within building or through the supply chain. The use of BIM that can overcome the graphical representation of the material status leads to a significant improvement. Several BIM tools make available scheduling functionality and help to link the construction schedule to the 3-D model, which provide the user with visualization of the building's sequential construction [9]. In cases where material status cannot be seen easily on a construction site because of some physical obstacles, the computer-aided visualization is required to make ease reporting of the process status. BIM produces visual report in a way to show clearly the accessibility of and final locations of materials. This feature facilitates monitoring and appropriately provides process transparency [50].

3. CONSTRUCTION PHASE

Using BIM, in the construction phase, the management of both process and project team ("people-related") can be applied. In addition, BIM helps to plan the purposes that carry over at the construction stage.

The use of BIM for construction management is starting to get popularity. Currently, main applications of BIM to the construction phase are: identifying and resolution of coordination subjects, connecting, construction sequencing plan, and the substitution of the fabrication shop drawings with a detailed 3-D model as shown in Figures 1-5. All these usages require details in the model components; furthermore, they are performed frequently with models previously generated by a sub-contractor for these causes [30].

In the construction phase, providing a schedule generated at the beginning of a project by a member of the construction management team is the most significant task. Using BIM causes the flaws of the aforementioned schedule to be reduced because of two issues. First, more time is available for construction managers to coordinate other tasks. Second, due to the improved visualization linked the schedule to the construction, lots of schedule misinterpretations reduced. Therefore, a powerful tool should be used by the construction managers, which allows a design team to combine, share, review and correct a BIM model. Although Nawiswork is not modeling software, to this end, it can be completely helpful. Nawiswork can compile and link modules to a schedule to make a schedule animation [51].



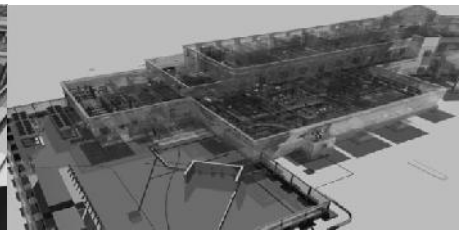
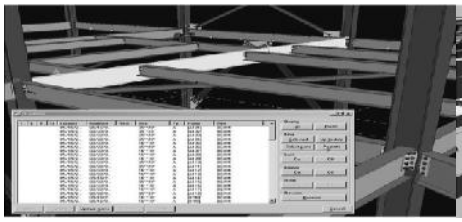


Fig 1. MEP Coordination adapted from [30] Fig 2. Courtesy of construction adapted from [30]



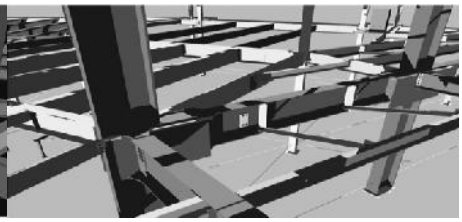


Fig 3.Structural design model adapted from [30]Fig 4.Structural design model adapted from [8]

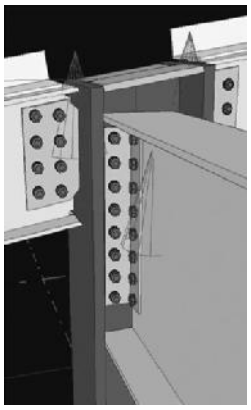


Fig 5.Fabrication model adapted from [30]

3.1 Managing the Project Team

Managing the project team is applied to interplay between the contributors of project for designing and constructing procedures. It should be noted that the project groups work for the possessor and they are required to bear objectives of the possessor in mind at the time they implement the construction management parameters in the project. The BIM plan of the project should provide the pre-defined objectives in a comprehensive way. In this sense, the main issue is the connection and coordination among the project team members.

To provide the coordination among the project team members is a particularly valuable BIM characteristic. Therefore, a detailed 3-D diagram for a project simply and rapidly shows numerous project features that are not easily imaginable in conventional 2-D drawing. In addition, there are a number of model views that support interplay among the individuals responsible to resolve the arisen conflicts. Conversation between the design adviser and sub-contractors based on 3-D formats helps the communication of visualization and intention of the designer of a particular construction prior to getting placed in given field. Therefore, BIM can be considered as a key factor that relates and communicates among the construction team members. The model is capable of accommodating for visualization of the orderly construction schedule update as well as the look-ahead thoughts that are practiced at Lean Construction [30].

3.2 Management of Construction Process

Managing the construction process is the management of procedures required for building construction projects, which are related to issues such as the construction mobilization, scheduling and sequencing, expense control and analyzing the cash flow, purchasing, material ordering and handling, the fabrication and installation of components, elimination of misusing the time, resources, and materials, and the addition of desirable techniques and materials [30].

3.3 BIM and Construction Administration

In a CAD project, the construction procedure gets started after turning over the whole construction documentation and addendum revision information to the contractor. The analysis and overlaying CAD files and sheet drawings take too much time, lack visibility, and are prone to missing information and errors. In fact, construction management is not often able to joggle managing the documentation of the project, the field management, the trades, and the management team. Particularly, in a less integrated approach(e.g., design-bid-build), the architects and engineers often seem to be less interested in documenting the project in a standard way; as a result, the project documentation turns into a jumble collection of CAD files, scans, faxes, and PDFs[51].

Since, in BIM, everything is modeled and the files are compiled into a composite model, the previous models can be compared easily to the new ones. The changes occurred in design can be tested more efficiently in comparison with other trades for clash detection, sequencing, or deviation reporting. Since BIM deals with completed models, coordination issues among many incongruous files are eliminated.

3.4 Site Coordination

Site coordination is referred to as the organization of the site, equipment, materials, site security, and safety. The site logistics plan is an important factor in the creation of a better communication and a project with higher level of safety. The plan is often housed in the job trailer and it is posted on the wall to be referred by others, which assures that the whole team members have a visual understanding of site accessibility, the material lay-down areas, and the building and parking access. The site logistics plan is a static image of the site; however, there may be various plans due to scheduling, sequencing, and different phases of project. This is why it is not unusual to see more than one logistics plan during the procedure of a project [51].

The use of site logistics plan is particularly critical in cases where materials delivered on a job site are numerous or large. Depending on the project size, combined with a tight site such as what exists in an urban setting, material lay-down coordination may be a full-time job. For this complex site coordination, a BIM solution can be a sequencing animation or a series of site logistics plans.

4. POST-CONSTRUCTION PHASE

The popularity of Models of Building information is considerably increasing with the tasks of facilities management (FM). Since BIM consists of vast quantities of visual information, it attracts a great deal of interest from units of facilities managers, maintenance and operations. Visually management of the tasks can be noticeably simpler using the 3-D model for purposes such as viewing the definite characteristics of management and helping one to visualize oneself and connecting it to others. [30].

4.1 Operations control

Operations control takes into account the capability of management of, for example, project maintenance. The BIM components show that there are many different types of maintenance-related information, for example

scheduling the maintenance, replacing the parts ordering, installation and maintenance instructions, and past records of maintenance. Other data in control definition may include energy usage data, furniture inventories, allocating the space, schedules of space utilization, locations of personnel, and so on [30].

4.2 Process controls

Process controls deals with the model employed to control the cooling and heating systems and security system, as well as the models for consumed energy analysis, access analysis, and the project's functional applications [30].

4.3 BIM AND SUSTAINABILITY

The past decade has witnessed a shift in design and construction, which has changed the way we utilize natural materials and generate products for building construction. The use of new technologies such as BIM, GIS, GPS, green tech, nanotech, or alternative technologies is aimed to achieve green construction. At present, engineers and architects are utilizing BIM to perform various tasks more efficiently than in the past. The advantages of BIM concerning the green construction can be discussed in three major processes; preconstruction, construction, salvaging and recycling [51].

4.3.1 BIM and Preconstruction:

The most important part of sustainability in regard with the preconstruction phase is the selection and utilization of materials. In this phase, BIM can be employed to add information to the building components; for example, information about the input percentage of the recycled quantity such as the ratio of fly ash to be used in a concrete mix or the recycled rubber material in tile carpeting. Other pertinent information may be reclaimed material quantities and the locations for separate scheduling or the manufacturing location information to determine the materials that might have been sourced regionally. BIM updates the quantities and volumes of materials as the building is modeled; for this reason, we can understand the accurate percentage of materials contained in the model's latest version. This helps to analyze quickly whether we have achieved Leadership in Energy and Environmental Design (LEED) credits or the pre-defined project goals. Additionally, by means of material quantity schedules in Revit, separate schedules can be created; thus the material information can be put into the model. At the later stages of the project, these material percentages make easy the LEED reporting process and help to compare cost and weight of the materials to those of other materials [51].

4.3.2 BIM and Construction

BIM helps to integrate the teams and the process to work closer on the model and documentation, which causes the following advantageous [51]:

- Zero waste
- Zero carbon emissions
- Energy saving and efficiency
- 100% power through renewable energy
- Zero claims (effective project management system)
- Zero accidents (through efficient health and safety protocols)
- Paperless document management system

4.3.3 BIM and Post construction

4.3.3.1 Salvaging and Recycling:

In the green construction, the end of the life cycle buildings is taken into account. Here, life cycle indicates that each building has a limited life span. In other words, no building is constructed to last forever. A negative point is that buildings usually outlive their technology to the point where the systems used in a building are outdated, the material research is completed, and the environment in which they are located are changed in terms of use ,density, or function. Generally, many people see these types of structures as landfill material; however, this is not often the case. Indeed, with a minimal investment of natural resources and time, lots of materials used in a building can be reused for other purposes [51].

4.3.3.1.1Salvaging:

The greenest way for reintroducing materials to the stream of building construction is salvage. BIM provides the best way for reusing the building's materials. For example, the facility manager is able to extract all of the building's components, quantities, manufacturers, and recipes of assembly from the BIM and deliver them to the deconstruction contractor. Then the deconstruction would be capable of quantifying the materials in a building that are to be decommissioned and s/he can find resources for these materials before dismantling the structure [51].

4.3.3.1.2 RECYCLING

In recycling process, BIM functions in two ways. First, by means of site logical plans, which determine the location of roll off sand bins, it helps the team to find these locations and helps subcontractors to take care of scraps. Second, it reduces the amount of printed documents through persuading the users to use digital tools [51].

5. **Obstacles and limitations of BIM implementation**

According to the previously-conducted studies during the past two decades, the following stumbling blocks have been found to the implementation of BIM [21, 22, 24, 52-55]:

- Project participants mostly work with some special tools (hardware and software) and data transfer is often limited because of incompatibility and transmission of the consistent information to other participants. The data that are not transferred are required to be recovered and additional efforts are needed to perform it or add the information to other special tools;
- Project participants employ intelligent models for parts of the project scope in order to assist them with their conventional activities (not limited to time, cost, and design evaluation). It is mostly concentrated on the scope of work that is the most expensive or appears the most risky and required to be assessed in details according to reliable information sources;
- The use of some intelligent approaches such as virtual project development for the first time and the committed mistakes indicate the lack of experience, which leads to time-consuming searching activities. The virtual background and prepared models are mostly treated as superficial and they cannot be trusted;
- Achieving the utmost benefits from BIM is correlated directly to the maximization of collaboration in the given project;
- For an effective use of BIM, the project should be delivered with a collaborative approach (as it is common to use 3-D/4-D models) such as in Design-Build (DB) or Construction Management at-Risk (CM@R) projects. On the other hand, experience shows that there are still particular benefits in conventional Design-Bid-Build (DBB) projects;
- Many barriers keep project participants from utilizing BIM and the latest technology, including fears of big failure or too low success, high costs of initial investment, being not skilled to use the software appropriately, and perhaps the biggest barrier for many is the lack of support from the company's senior leadership;
- For carrying out 4-D modeling efficiently, some issues should be resolved, including what 3-D/4-D modeling software to employ, the professional and organizational qualification alignment, the limitations associated with 3-D/4-D modeling software tools, issues that stem from data exchange, and efficient hardware to employ;
- Lack of knowledge regarding strict implementation standards of BIM, rules for certain project participants, the contract obligations in some countries, or the unified form of documentation for some regions (e.g., Americas, European Union, Asia, etc);
- Necessity of using cost-benefit analysis with the aim of convincing practitioners regarding the benefits of BIM implementation and justifying the upfront investment.

6. CONCLUSION

Due to innumerable advantageous involved in the utilization of BIM, it would be regarded as a panacea to reduce the deficiencies occurred throughout the whole lifecycle of construction project. In light of this, this paper presented the benefits regarding the use of BIM in three different stages of construction project, including preconstruction, construction, and post construction. Furthermore, the stumbling blocks to the implementation of BIM have been addressed. In short, the authors concluded that the use of BIM would have certainly the following positive impacts on the construction projects:

- Diminishing the design errors and reworks pertaining to the construction activities
- Enhancing the integration of time and cost
- Increasing the integration of design and construction phase
- Decreasing the hazardous construction activities associated with safety issues
- Rectifying the traditional delivery and procurement process
- Facilitating the site layout plan
- Increasing the possibility for reusing materials
- Eliminating the necessity for traditional documentation

REFERENCES

[1] Alshawi, B., Ingirige, B, 2003. " Web-enabled project management an emerging paradigm in construction". Automation in Construction 12 (4), 349–364.

[2] Williams, T.(2002)."Modelling Complex Projects". Wiley, London, UK.

[3] Chan, A.P.C., Scott, D., Chan, A.P.L, 2004. "Factors affecting the success of a construction project". Journal of Construction Engineering and Management 130, 153–155.

[4] Clough, R.H., Sears, G.A., Sears, S.K, 2008. "Construction Project Management: A Practical Guide to Field Construction Management". Wiley, New Jersey.

[5] Taxén, L., Lillieskölд, J, 2008. "Images as action instruments in complex projects". International Journal of Project Management 26 (5), 527–536.

[6] Succar, B, 2009. "Building information modelling framework: a research and delivery foundation for industry stakeholders". Automation in Construction 18 (3), 357–375.

[7] B. Becerik-Gerber, F. Jazizadeh, N. Li, G. Calis, 2012."Application areas and data requirements for BIM-enabled facilities management". Journal of Construction and Engineering Management. 138, 431–442.

[8]A. Akbarnezhad, K. Ong, L. Chandra, Z. Lin, 2012. Economic and environmental assessment of deconstruction strategies using building information modeling, Proceedings of Construction Research Congress 2012: Construction Challenges in a Flat World, West Lafayette, USA, pp. S. 1730–S. 1739.

[9]Teicholz Eastman, Liston Sacks, 2011. BIM Handbook — a guide to building information modeling for owners, managers, designers, engineers and contractors, Aufl, 2, Wiley, Hoboken.

[10]C. Nicolle, C. Cruz, 2011. Semantic Building Information Model anmulti media for facility management, Web Information Systems and Technologies, Lecture Notes in Budiness Information Processing S. 14–S. 29.

[11] L. Sabol, 2008. Building Information Modeling & Facility Management. Design+Construction Strategies, Washington.

[12] J. Lucas, T. Bulbul, W. Thabet, 2013.An object-oriented model to support healthcare facility information management, Automation in Construction(31) 281–291.

[13] B. Becerik-Gerber, S. Rice, 2010. The perceived value of building information modeling in the U.S. building industry, IT construction, (15) 185–201.

[14] ISO Standard, ISO 29481-1:2010(E), 2010: Building Information Modeling — Information Delivery Manual — Part 1: Methodology and Format.

[15] T. Cerovsek, 2011. A review and outlook for a "Building Information Model (BIM)": a multi-standpoint framework for technological development, Adv. Eng. Inform,(25) 224–244.

[16] A. Borrmann, E. Rank, 2009. Specification and implementation of directional operators in a 3D spatial query language for building information models, Adv. Eng. Inform. (23) 32–44.

[17] J. Wong, J. Yang, 2010. Research and Application of Building Information Modelling (BIM) in the Architecture, Engineering and Construction (AEC) industry: a review and direction for future research, Proceedings of the 6th International Conference on Innovation in Architecture, Engineering & Construction (AEC), Loughborough University, U.K., Pennsylvania State University, pp. S. 356–S. 365.

[18] A. Watson, 2011. Digital buildings — challenges and opportunities, Adv. Eng. Inform.(25) 573–581.

[19] P. Tang, D. Huber, B. Akinci, R. Lipman, A. Lytle, 2010. Automatic reconstruction of as-built building information models from laser-scanned point clouds: a review of related techniques, Automation in Construction. (19) 829–843.

[20] G. Lee, R. Sacks, C. Eastman, 2006.Specifying parametric building object behavior (BOB) for a building information modeling system, Automation in Construction,(15) 758–776.

[21] Ford, S., Aouad, G., Kirkham, J., Brandon, P., Brown, F., Child, T., Cooper, G., Oxman, R., Young, B., 1995. An information engineering approach to modelling building design, Automation in Construction 4(1), pp. 5-15.

[22] Smith, D. K., Tardif, M., 2009. Building Information Modeling: A Strategic Implementation Guide For Architects, Engineers, Constructors, And Real Estate Asset Managers. John Wiley & Sons, p. 216.

[23] Migilinskas, D., Ustinovichius, L., 2006. Computer-aided modelling, evaluation and management of construction project according PLM concept, Lecture Notes in Computer Science 4101, pp. 242-250.

[24] Popov, V., Juocevicius, V., Migilinskas, D., Ustinovichius, L., Mikalauskas, S., 2010. The use of A Virtual Building design and Construction model for developing an effective Project concept in 5D environment. Automation in construction 19(3), pp. 357-367.

[25] Froese, T, 2003. Future directions for IFC-based interoperability, IT construction Vol. 8, Special Issue IFC - Product models for the AEC arena, pp. 231-246, in: http://www.itcon.org/2003/17

[26] Roorda, D. and Liu, M., 2008.Implementation of Building Information Modeling (BIM) on the Renovation of the Art Gallery of Alberta in Edmonton, Alberta. Structures Congress 2008: pp. 1-15.

[27] Rebekka Volk, Julian Stengel and Frank Schultmann., 2014. Building Information Modeling (BIM) for existing buildings — Literature review and future needs. Automation in Construction 38, 109–127.

[28] Department of Business, Innovation and Skills, 2011.A report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper (Retrieved from:), https://connect.innovateuk.org/c/ document_library/get_file?uuid=6842e020-20df-4449-8817-08ce2ba9ef7c&groupId=689092011.

[29] T. Garrett, M. Garside, 2003. Fab pilot of a multi-dimensional CAD system, Future Fab International 14.

[30] Willem. K. 2008. Building Information Modeling: planning and managing construction projects with 4D CAD and simulations: McGraw-Hill Construction Series

[31] Richard. Lambeck 2009 .Urban Construction Project Management": McGraw-Hill Construction Series

[32] Grilo, A., Jardim-Goncalves, R., 2010. Value proposition on interoperability of BIM and collaborative working environments. Automation in Construction 19 (5), 522–530.

[33] Olatunji, O.A., 2011.Modelling the costs of corporate implementation of building information modelling. Journal of Financial Management of Property and Construction 16 (3), 211–231.

[34] Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., O'Reilly, K., 2011. BIM adoption and implementation for architectural practices. Structural Survey 29 (1), 7–25.

[35] David Bryde, Martí Broquetas, Jürgen Marc Volm., 2013. The project benefits of Building Information Modelling (BIM). International Journal of Project Management (31) 971–980.

[36] Z.Z. Hu, J.P. Zhang, M. Lu, M. Cao, S.D. Gao, 2006. Simulation and optimization of prefabricated steel-structure installation operations, Proceedings of 1st International Construction Specialty Conference. Calgary, Canada.

[37] B. Koo, B. Fischer, 2000. Feasibility study of 4D CAD in commercial construction, Construction Engineering and Management 126 (4) 251–260.

[38] B. Akinci, K. Tantisevi, E. Ergen, 2003. Assessment of the capabilities of a commercial 4D CAD system to visualize equipment space requirements on construction sites, Proceeding of Construction Research Congress in Construction—Winds of Changes: Integration and Innovation, Honolulu, Hawaii, USA.

[39] J. Tulke, M. Nour, K. Beucke. 2008. A dynamic framework for construction scheduling based on BIM using IFC", in: Proceedings of the 17th IABSE Congress, Chicago, USA.

[40]- J. Tulke, J. Hanff,. 2007. 4D construction sequence planning – new process and data model.in: Proceedings of the CIBW78 24th International Conference on Information Technology in Construction, Maribor, Slovenia, pp. 79–84.

[41] K.W. Chau, M. Anson, J.P. Zhang, 2005. 4D dynamic construction management and visualization software": 1, Development, Automation in Construction 14 (4) 512–524.

[42] Kasirossafar, M. and Shahbodaghlou, F. 2012.Building Information Modeling or construction Safety Planning. ICSDEC 2012: pp. 1017-1024.

[43] Suermann, P.C. and Issa, R.R.A., 2007. Evaluating the impact of building information Modeling on construction, Proceedings of the 7th International Conference on Construction Applications of Virtual Reality, The Pennsylvania State University, October 22-23, USA, 10 pp.

[44] Kasirossafar and Reza Latifi Shahandashti., 2012. Developing the Sustainable Design with PtD using 3D/4D BIM Tools, Proceedings of the World Environmental & Water Resources Congress (EWRI-ASCE), New Mexico, USA, May 2012

[45] Kasirossafar, M., Shahbodaghlou, F., 2012. Application of Visualization Technologies to Design for Safety Concept, Proceedings of 6th Congress on Forensic Engineering (ASCE), October 2012, San Francisco

[46] D.A. Young, C.T. Haas, P.M. Goodrum, C.H. Caldas, 2011. Improving Construction Supply Network Visibility by Using Automated Materials Locating and Tracking Technology, Journal of Construction Engineering and Management 137 (11) 976–984.

[47] J.D. Goedert, P. Meadati, 2008. Integrating construction process documentation into building information modeling, Journal of Construction Engineering and Management 134 (7) 509–516.

[48] F. Leite, A. Akcamete, B. Akinci, G. Atasoy, S. Kiziltas, 2011.Analysis of modeling effort and impact of different levels of detail in building information models, Automation in Construction 20 (5) 601–609.

[49] M.A. Alder, 2006. Comparing Time and Accuracy of Building Information Modeling to On-Screen Takeoff for a Quantity Takeoff of a Conceptual Estimate, Brigham Young University, UK.

[50] R. Sacks, M. Treckmann, O. Rozenfeld, 2009. Visualization of work flow to support lean construction, Journal of Construction Engineering and Management 135 (12) 1307–1315.

[51] Brad H., 2009. BIM and Construction Management: proven tools, methods and workflows": Willey publishing

[52] Migilinskas, D., Ustinovichius, L., 2006. Computer-aided modelling, evaluation and management of construction project according PLM concept, Lecture Notes in Computer Science 4101, pp. 242-250

[53] Associated General Contractors of America (AGC), 2007. AGC Contractors' Guide to BIM, in:http://newsletters.agc.org/buildingmaterial/2010/02/15/the-contractors-guide-to-bim-2nd-edition

[54] Gao J., Fischer, M., 2008. Framework & Case Studies Comparing Implementations & Impacts of 3D/4D Modeling Across Projects. CIFE Technical Report #TR172 March 2008 Stanford University, in: http://cife.stanford.edu/node/141.

[55] Thomassen, M., 2011. BIM & Collaboration in the AEC Industry. Construction Management, Master's (MSc) Thesis (Released 31 August 2011, p. 120, in: http://projekter.aau.dk/projekter/files/55376698/BIM_Collaboration_in_the_AEC_Industry_by_Mat_Thomassen.pdf