International Journal of Structural Analysis & Design – IJSAD
Volume 1 : Issue 3 [ISSN : 2372-4102]
Publication Date : 30 September,2014

Building Information Modelling (BIM) for Large-Scale Construction Projects

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***Abstract*—Building information modelling (BIM) is one of the newest management and design techniques for construction. Especially for large-scale projects, using BIM, provides executing troubleless project management, Furthermore, large scale projects management purposed to reduce construction cost , to built energy efficient structure and sustainable buildings.**

Today, construction projects must have further features against the past, like scheduling, 4D and 5D cost estimation, climatization, green production, safety, new materials etc. Thus, traditional construction management methods are insufficient. It is required to manage the project process (including the operational phase) effectively. The large-scale projects which is being conducted unconsciously should be executed by BIM for effective project management and succeed the project.

***Keywords*—BIM, Building information modelling, construction project management, project coordination**

I. Introduction

During the last decade, a major shift in information and communication technology for the construction industry has been the proliferation of BIM in industrial and academic circles as the new computer aided design paradigm (Bryde et al, 2012). Building Information Modeling (BIM) is a new approach to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format. (Eastman et al. 2008).

BIM is a technology which can design a project as a single model for delivering all the project stakeholders. The principle of the BIM is based on the interoperability between stakeholders. In this study, BIM model to be produced for large scale projects. It will be divided many phases (the current situation , demolition, construction, operation, etc.) , so the whole project will be provided for effective project management . All phases can be evaluated and detected separately.

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Large-scale construction projects for this paper; defined as have 15.000 m² and over construction area and 20 milion $ and over cost. This manner of projects have complex design concepts, scheduling and cost controls. Today, all construction projects are controlled for energy, earthquake simulations, mechanical & electrical components etc. Multiply components should be designed and supervised for a perfect system. There are so many systems in the buildings anymore. Thus construction professionals need to effective tools for design and construct the structure.

It is expected that BIM will have been the closest friends of AEC industry in the very near future . As urban renewal, large-scale projects, BIM using for successful cost control, designed high-quality structures and energy efficient building design. Thus, AEC industry will have leaved a sustainable environment to the new generation.

II. Literature Research : Benefits of the BIM

Design submission of this manner of projects include so many components. Basically, paper volume of the design submission has been increasing about %20 percent against last decade. Traditionally, a structure have certain number of the sheets. These are; architectural plans, sections views, structural plans, sections, details, mechanical& electrical design sheets. Today, uncountable sheets can be submitted. For all projects have their own circumstances thus, stakeholders need more design sheets and details. Constraints of desig and regulations force to make a perfect design.
The tasks in the construction industry that can utilize BIM are as follows:
- 3D visualization (architecture/structure/MEP)
- Clash detection
- Feasibility studies
- Model-based quantity take-off and estimation
- Visualized scheduling (4D) management
- Environmental analysis or LEED certification (energy efficiency/sunshine/CO2 emission analysis)
- Creation of shop drawings and schedule management for installation of rebar/steel frame/curtain wall
- Visualized constructability review (material lifting operation planning/ temporary resources installation)
- Visual and geospatial coordination for construction of atypical shapes
- Creation of as-built model for facility management (Lee et al., 2013)

BIM has been utilised on high profile largescale projects, such as the recently constructed London 2012 Olympic 6,000 seating Velodrome cycle track and the 48 floor Leadenhall Building "The Cheesegrater," which, at 225 m, will be one of the tallest buildings in the City of London on completion in 2014 (Bryde et al, 2012).

Barlish & Sullivan to put forward benefits of BIM according to their study. They determined the beneficiancy of BIM into 2 distinguished area. First one is investment of BIM against Non-BIM projects, and the second is the return which includes change orders and schedules. Due to the study there is three cases and 3 companies determined the BIM and Non BIM situation of the projects. The project managers has been interviewed according to the research.

Case 1 – returns from Non-BIM to BIM.

Metric	Unit	Non-BIM	BIM	Δ (Non-BIM vs. BIM)
RFIs	Quantity/tool	6	3	3
Change orders	% of standard project costs	12%	7%	42%
Schedule	% behind standard schedule	15%	5%	67%

PM interviews.

Category	Increased	Decreased	Stayed the same
Contractor accountability	38%	62%	–
Contractor verification	50%	50%	–
Software/hardware costs	50%	50%	–
Learning curve	38%	24%	38%
Coordination meeting attendance	100%	–	–

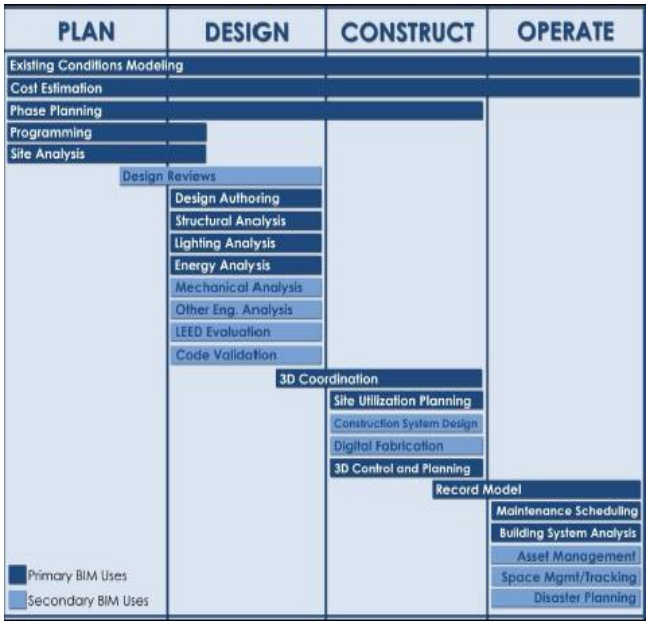
Case 2 – investments from Non-BIM to BIM.

Metric	Unit	Differential (Non-BIM vs. BIM)
Design costs		
A&E costs	% of total awarded design scope	31%
3D background model creator costs	% of total awarded design scope	34%
Construction costs		
Contractor costs	% total awarded construction scope	(−5%) (savings)
Design + construction costs		
Overall savings with BIM in design and construction	% total awarded design and construction scope	(−2%) (savings)

Figure 2. Barlish & Sullivan (2012)

There are some benefits of BIM according to master projects which has been brought up via CRC Stanford University Center for Integrated Facilities Engineering (CIFE) researched from 32 major projects which had been using BIM. The benefits of BIM into the projects in accordance with the research are ;

- Up to 80% reduction in time taken to generate a cost estimate.
- Up to 7% reduction in project time
- A savings of up to 10% of the contract value through clash detections.
- Up to 40% elimination of unbudgeted change.
- Cost estimation accuracy within 3%. (Messner, 2009)



Construction Innovation 2007 report.

Faster and more effective processes:Information is more easily shared and can be value-added and reused.
Better design – building proposals can be rigorously analyzed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions.
Controlled whole-life costs and environmental data: Environmental performance is more predictable, and lifecycle costs are better understood.
Better production quality: Documentation output is flexible and exploits automation.
Automated assembly: Digital product data can be exploited in downstream processes and used for manufacturing and assembly of structural systems.
Better customer service: Proposals are better understood through accurate visualization.
Lifecycle data: Requirements, design, construction, and operational information can be used in facilities management.

III. Master Projects with BIM

Many projects has been observed as using BIM around the world. Significant results has been reached according to studies.

A. *Aquarium Hilton Garden Inn,*

The Aquarium Hilton Garden Inn is a $46 million project consisting of the construction of a 484,000 square foot facility. The mixed-use development consists of a 14-story, 242 room hotel, a 700 vehicle parking structure, and 25,000 square foot of retail space at the ground level. The structure occupies a prominent corner in downtown Atlanta adjacent to Centennial Olympic Park and the Georgia Aquarium. The owner, Legacy Property Group, utilized a Construction Management at Risk (CM at-Risk) with a Guaranteed Maximum Price (GMP) project delivery approach contracting with Stevens and Wilkinson Stang and Newdow, Inc. as the design architect and Holder Construction Company as the general contractor. The project schedule, from design through construction was 24 months. Design and preconstruction services began in February 2005, construction began in June 2006, and substantial completion was March 2008.
(Himes. M & Steed. B, may 2008)

Atlanta, Georgia
•Project scope: $46 million, 484,000-square-foot hotel and parking structure
• Delivery method: Construction manager at-risk (CM at-risk)
• Contract type: Guaranteed maximum price
• BIM scope: Design coordination, clash detection, and work sequencing
• BIM cost to project: $90,000, or 0.2% of project budget ($40,000 paid by owner)
• Cost benefit: Over $200,000 attributed to elimination of clashes
• Schedule benefit: 1,143 hours saved

B. *St. Joseph Health System in Orange, California*

Jim Bostic, vice president of construction at St. Joseph Health System in Orange, California, typically budgets $250,000 to $500,000 for a single exterior envelope mock-up, focused on a project's most potentially problematic condition. On the new Mission Hospitalfacility, his design team proposed allmetal cladding, a new approach for St. Joseph, and he was concerned about its constructibility... Mission Hospital is scheduled for substantial completion in September 2009, and Jim is now requiring BIM for the design and construction of all his future projects, as well as involving more team members earlier in the process. From his 40 years of building experience he is sure BIM will save significant time and money for St. Joseph Health System. (McGraw Hill Report, 2008).

C. *MIT Koch Institute*

MIT Koch Institute is a 360,000 square feet nine story cancer research building located in Cambridge, MA. Designer of the project is Ellenzweig. The construction manager is William A. Berry & Sons Inc. The building consists of 45,000ft2 vivarium, and 275,000ft2 wet labs, 10,000ft2 lobbies and common spaces, and 30,000ft2 mechanical space, and underground tunnels to Stata Center and Building 68.

At MIT Koch project, the construction manager and its subcontractors has implemented five out of the six BIM uses identified in the literature review: visualization, 3D coordination, prefabrication, construction planning, and record model. The only BIM use that was not introduced to the project was the cost estimation known as 5D BIM (Hergünsel, 2011).

BIM Use	MIT Examples	BIM Benefits
Visualization	-Renderings -Animal holding room mock up	-Collaboratively visualize expectancy and needs of the project.
3D coordination	-Vico model -MEP coordination	-Reduced MEP coordination time -Reduced RFIs -Avoid additional costs.
Prefabrication	-Chilled water and steam manifolds -In-wall drops	-Faster and higher quality materials. -Save time and labor in the field.
Construction planning	-AHU rigging plan	-Avoid schedule delays during construction. -Avoid cost during construction.
Cost estimation	-N/A	-N/A
Record model	-Vico model	-Positive last impression to the owner.

Fig.1 BIM Use and Benefits at MIT Koch Project (Hergünsel, 2011)

IV. Model Proposal Using BIM for Large-Scale Projects

BIM is an effective tool for project management especially the large scale construction projects. As mentioned in this paper, all project phases can be executed by BIM. The construction and its management process distinguished 3 phases as below. All suggested phases accomplish with BIM. The phases

Design

Collaboration (Simulation)

Inspection & Approvals (by public authority)

1. *Design:* This is the first step of the project. Concept drawings for offers, definition drawings for promoters can be composed easily and alternatively in a short time, against traditional way. All design shareholders design their projects via BIM and they shoud be ready for a unique model. It is necessary that a one model should be a central model. All shareholders study on this model but just their profession. In design stage all required information is gathered. Estimated cost is occured automatically. Required visualization should be completed in this phase. Whole design products should be ready to collaborating with shareholders.

In fact, when the design team finish concept projects detailed design almost finish. Required drawings with detailing can be formed from the concept. This method obstruct the faults which to be occured by concept design implementation. Contructors can be carried out the detailed project, no need to wait along time for reach it.

Summary : Desing the project with BIM. A unique model is created. All diciplines develop the design for their own fields. Designs are prepared for collaboration.

2. *Collaboration :* This proposed phase is the brand new project process with BIM. Collaboration process is covered the whole process of the project. In fact that design phase is into the collaboration.But start key is design for the BIM. Especially design and collaboration is almost start together but the design is a little bit earlier. After design creation, collaboration continue among design team, official authority for approval, site management, planning department and procurement department.

Design information can be circulated among the shareholders by BIM;

Design Team : Architectural, structural, mechanical-electrical, insulation, enengy control specialists make their project by BIM. They can solve the problems by 3D visuilation and clash detections.

Official authority : The concept design send to the authority for preview by owner of the project. Prepared model accord with the office BIM program. They adopt it into their software using ifc data. Approval process can be execute with sharing and less time.

Site Team : On the site, engineers can adapt their site scenario with BIM. They organize the site settlement which includes container location, machines entry , equipment area, stock field. After this organisation site authorities can start the system by simulation. The problems about site operation to be determined and consequences caused to overcost can be avoided. With 4D scheduling, total scenario is animated, thus all process can be viewed and observed.

Planning department : The main purpose of the planing dept. is preparing the 4D model for the construction. The structure and construction process is discussed. Production, assembly, reusorces and equipment situation and logistics are controlled by visuliation according to the 4D model.

Procurement department : If all shareholders of the project deal with each others procurement department start to negotiation with the suppliers for equipment, materials and required machines. This department use to 4D tool for the timing and announcing the date of material coming. Procurement department share the all information with site via BIM.

Large-scale projects have 1000 or more detail design sheets. Many times design submission is a big trouble. With BIM large scale project design sheets can deliver on time or the specialist who needs a detail can reach the sheet with his/her own attempt. The model can be reached by all stakeholders, so the required detail can be extracted from the model easilly. No need to formal submission.

Summary : The heart of the proposed model is collaborating phase. It prevents to the project against the big mistakes. All phases depend on collaborating. Planning and procurement department gathered the information. These departments occur the 4D scheduling and 5D cost planning. Construction (site) team organize the operation according to design and planning. In traditional way, nobody can talk about the total collaboration. There are many sheets, drawings and more than one model. Sometimes site engineers realised that wrong drawings can be used. But with BIM this situation is impossible according to the unique model. The model is on the server and

the site engineer can get it digitally. And production can be contiuned failureless.

3. Inspection & Approval: Municipal authority, control designs with BIM, considering the regulations. Effective and faster inspection process can be achieved against the tradition way. The model is given by the project owner to the governer. After recieving the model, authority can detect the model with BIM includes the regulation constraints. Every authority can create a script into the BIM software according to local regulations for detecting. Inspection takes couple of hours by the inspectors / reporters. (This takes approximately min 15 days around the world by traditional project control manner). Reporter can approve / deny the project after the observation. BIM can give less fault of controls opportunity to the governer . Thus, governer can carry out the rules to the everyone equitably. If required correction to be occured designer can correct the faults after then they return the corrected drawings to the governer. This cycle is a big problem for the traditional project approval. Altough, with this proposal BIM can manage the process faster than other. On the other way, system won't permit the making faults to return the projects again.

Conclusion : AEC sector is at very distinctive position against past. Today, especially large scale projects should be considered many parameters. For big construction projects; energy analysis, complex structural solutions, alternatively architecture designs and accurate cost estimations should be done. Traditional methods accomplish to these very hardly and open for the big faults. All essential project parameters can be conducted in a short time, close to '0' faults and easilly after the unique model constituted by BIM.

Large scale projects have dozens of sheets, complex site works and tousands activities included schedules. Project management is very hard. Many times failures can not be avoided. BIM have abilities like, organizing design management, , material management, consturction management, time management (scheduling) and inspection approvals.

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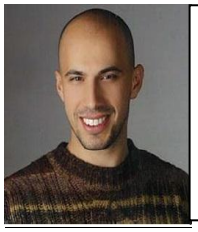

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