EXPLORING THE CAPABILITIES OF BUILDING INFORMATION MODELLING FOR A REAL LIFE STRUCTURE

Muhammad Tufail Khalil, Johar Hafeez, Muhammad Hasnain, Adeed Khan, Mohammad Adil, Mehre Munir

Department of Civil Engineering, Iqra National University, Pakistan

Department of Civil Engineering, UET Peshawar

Correspondence Email: tufailkhalil92@gmail.com

https://doi.org/10.26782/jmcms.2019.04.00013

Abstract

Building information modelling (BIM) is a new way of approaching the design and documentation of building projects. The objective of BIM is not only to model and manage graphics, but also information – information that allows the automatic generation of drawings and reports, design analysis, schedule simulation, facilities management, and more – ultimately enabling the building team to make better-informed decisions. This thesis documents the modelling of a real life structure (Qayyum Stadium) as well as implies interoperability checks between BIM tool and SAP2000 analysis software.

The Pavilion of Qayyum Stadium is located in Saddar, Peshawar. The data like plans of the structure was acquired. The structure was modeled in BIM tool, Tekla Structures v20. The structure was then exported to SAP2000 for analysis. In SAP2000 Gap analysis was performed to determine the structural elements which were not translated by SAP2000 like curved slab, column beam joints. The component catalog option is an important asset in BIM tool, Tekla Structure, making it easy to counter various flaws during the reinforcement placing. The reinforcement detailing of the structure are done using Tekla Structures. Drawings are generated, quantity take offs are done, Clash Detection tool was applied, which is one of the important tool in Tekla Structure (BIM).

Nowadays the Architecture, Engineering, Construction (AEC) sector has the intentions to deliver a product through formal procedures, which will not depend on design process. With the development in technology, many sectors (production and business) other than construction industry of production and business (outside of construction) are being modified and refurnished, due to which the construction industry lays behind. Presently construction process is same as it previously hundred years before, from the set of drawings. Mostly these drawings have errors and limitations which ultimately results in delays, increase in project cost and delay in project completion. These limitations and errors can be improved through Building Information Modelling tool.
Keywords: Building information modelling (BIM), design analysis, (AEC) sector, SAP2000 analysis software, Tekla Structure.

I. Introduction

Building Information Modelling (BIM) is a tool that disrupted traditional methods of representation and collaborations to architecture in the recent past. Building Information Modelling (BIM) is a term that has become universal in the design and construction fields over the past 20 years. [VII, X] During the 1970s and 1980s development continued around the world. The “Building Description System” (BDS) approach tended to be described as “Building Product Models” in the USA, and “Product Information Models” in Europe. These phrases then merged to become “Building Information Model”. [II] (Who was a creator of Generative Components but is now a member of Autodesk Research) first documented the term “Building Modelling”, in the sense we use BIM today, in 1986.

Building Information Modelling (BIM) is becoming more and more important for managing complex collaborations and communication processes in building and infrastructure projects. BIM comprises of two main aspects; an intelligent model and an approach for integrated collaboration, with focus on open information sharing and integration. BIM also comprises of framework and technology. [VIII, XI] BIM is an intelligent 3D model based process which gives us an insight for creating and managing projects much faster more economical and with less environmental impact. In other words, it is an effective communication between different stakeholders like Engineer, contractor, project manager, and fabricator etc.

BIM is a powerful visualizing tool as well. BIM allows us to visualize finished product and construction staging and not just rely on our imagination based on interpretation of 2D drawings. With BIM we essentially construct a project digitally in a virtual environment. We can even locate the structure spatially in the precise global coordinates and orientation so that we can predict its effects and responses on its surroundings for a variety of conditions or times. [IX]

The scope of our work is to explore the capabilities of BIM for a real life building project, to exchange the information between different software and explore any data loss. Building Information Modelling has variety scope in 4D where time is incorporated to produce real time lines and also has scope in 5D which is cost which provide the estimation.

The purpose of this thesis is to study the scope and implementation of BIM tool in civil engineering construction Industry. The efficiency of construction industry can be enhanced by exploring the benefits of Building Information Modelling. For this purpose knowledge about BIM tool and its mythology (how it works) has been explored.

The old Pavilion at Qayyum Stadium Peshawar is a reinforced concrete moment resisting frame building. The structure is about 50 years old. A three stories new building has been proposed inside the Pavilion structure of the stadium.

The base of the whole building is supported with 12” thick RC centric spread footing with haunch. The Pavilion Structure is supported on the interior side with rectangular
columns of size 24” x 24” and on the exterior side with tapered columns of size 24” x 56”. RC roof slabs with beam running in two orthogonal directions of the building. The RC slabs (shells) are 6” thick.

II. Literature Review

There are many positive, negative and unknown aspects of BIM during its implementation. This chapter will give a review of research that was done about the background of BIM including the positive and negative effects and its efficiency in Architect, Engineering and Construction (AEC) sector.

According to [I] a phenomenon called Interoperability has ability to exchange data within various programs and has the ability to serve the overall building community throughout facilities life cycle, for this 3D model acts as a medium to transfer information that could be accessed by other industry sectors.

[III] Suggests that BIM tool take 3D imaging techniques for time (real), data gain, visualization of object based so act as a tool for all industries.

[IV] In his paper invent that the process of administration in construction sector currently is being modified. The construction process is being digitalized due to which 3D Modelling can be done, which act as an important tool showing the spatial relationships in drawings so it become very easy to clients and contractors to understand it. Previously 2D drawing were very difficult in understanding, having clashes, time wastage and unfriendly to environment. BIM tool induces the ability in its users to control and incorporate data and information in newly invented process and in that format so that information can be exchanged among various soft wares. Using this tool digital design
can be generated that is incorporated for timeline production, estimation, analysis of structure design and energy, GIS based integration and for management procedures(Facilities management, safety management, quality management).

According to [VI] one of the important aspects of BIM tool is 5D which is implied for cost estimation. 5D is used to estimate materials required for construction and is proficient for forecasting of cost.

[V] Concludes in their research that there are a lot of difficulties and limitations in construction sector of Pakistan regarding the implementation of construction project especially during the stages of execution of these projects. These problems result in delay in projects and miscommunication among the stakeholders. Main stakeholders do not want to follow modern techniques in construction like BIM tool. This research work recommends that the usefulness of BIM tool should be highlighted.

III. MODELLING IN BIM

Building Information Modelling has the advantage over conventional drawings (2D) that it gives such a view of structures which include all the contents of structure from all the angles and to detect errors at the earliest thus preventing the change in cost orders. Truly parametric design saves time by creating and editing multiple design portions simultaneously. Sections, elevations and three dimensional views can be created instantly, reducing the need for check plots. Changes to any one of these elements affect all of the others, including materials, costs and construction schedules. The two-dimensional printed documentation becomes the quick and accurate byproduct of parametric design.

Modelling will be done using Tekla structures v20 which can be downloaded from Tekla website. Here we will be using Student license version which only provided for educational purpose. Tekla Structures allows structure and design engineers to collaborate with other project participants like architects, supervisory engineers and construction engineers on site using the same shared model. On-site shop drawings made by contractor can be inserted within the model and sent to architect and structural engineer for review.

Pavilion of Qayyum stadium is used to explore the capabilities and benefits of BIM in detail. The study includes the utilization of BIM for visualization, 3D coordination, construction planning and Interoperability check between SAP2000 v15 and Tekla structures v20.

The plans for footings, columns, slab and reinforcement detailing were obtained from the site. The whole structure was then modeled in Tekla structures v20 and exported to SAP2000 for Gap analysis. After analysis the model was exported to Tekla Structures for detailing and other operations (clash detection tool). At the end drawings were generated and quantity takeoffs are done. The process of methodology is shown below;
The gridlines for the structure were made using AutoCAD 2015 by using the curve line command or by circle command by giving the radius and then draw radial line at an angle of 3° as shown in figure;

![Gridlines made in AutoCAD 2015](image)

Once the gridlines were made it is saved in AutoCAD 2004.dxf for the purpose to export it to Tekla Structure v20.

Tekla structure also have radial gridlines option which can be accessed from the component catalog option which allow us to have access to various detailing tools regarding the structure as shown;
Figure 4: Gridlines Imported to Tekla Structures and Labeled According to the Plans

Once we have the grid lines, the process of Modelling can start with the footings. To model the footings, the first step is to define shape, size and material of types of footings to be used in the model and save them as different footing types in library in Tekla Structures. Later on, one such type of footing can be selected from the library and placed in its specified location. Footings vary in shape, size and depth because of the structural load of varying structural members i.e. columns, beams etc.

The Pavilion of Qayyum Stadium is composed of existing footings and proposed footings, to differentiate between both footings different colors are assigned to footings in Tekla as shown in figure;

Figure 5: Existing Footings in Green while Proposed Footings in Brown Color
After Modelling footings, the next structural members to be modeled are the lower-level columns. As done before for footings, different columns shapes and sizes to be used are first saved in the built-in library of Tekla Structures. Each column can be selected later from the library and placed in its proper position. The material properties, outer finish and pour sequence of columns can be changed from the properties section. The sizes of beams and columns are taken from plans obtained.

Similarly, beams and structural walls can also be modeled by the same method. Tekla Structures is capable of running a scan for clash detection, a process of discovering the building system conflicts and issues during Modelling process. Clash detection is sometimes referred to as interference checking. Clash detection tool can be used to examine the model for interfering members which helps in preventing costly errors and delays.

**Table 1: Types and Size**

| S.NO | TYPE          | SIZE      | Fe’(Psi) |
|------|---------------|-----------|----------|
| 1    | Rectangular columns | 24” x 24” | 3000     |
| 2    | Existing columns  | 24 x 56”  | 3000     |
| 3    | Beams          | 24” x 59” | 3000     |
| 4    | Slab           | 6”        | 3000     |
IV. INTEROPERABILITY

The exchange of design models in the design and construction industry is evolving away from 2-dimensional computer-aided design (CAD) and paper towards 3-dimensional digital models. This approach, known as Building Information Modelling (BIM), is anticipated to become the primary means of information exchange between the various parties involved in construction projects.

Interoperability is the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged. For interoperability purpose Tekla Structures analysis models are to be merged with some external analysis applications like SAP2000. This means that you can make changes to Tekla Structures physical and analysis models even after you have exported them to an analysis application, and still keep the additions you have made to the exported models in the analysis application. For example, you can create a Tekla Structures model, create an analysis model of it, export the analysis model to an analysis application, add special loads to the model in the analysis application, and then run the analysis. If you then need to make changes to the physical or analysis model in Tekla Structures, you can merge models with the analysis application. If you do not merge models and you re-export the changed Tekla Structures analysis model to the analysis application, you will lose the additions you have made to the model in the analysis application.

After the Modelling was done in BIM tool, Tekla Structures it was exported to analysis tool for Gap analysis i.e. which of the structural elements made in Tekla structures are readable by SAP2000 and which are not. The model was then exported in the form of
IFC (Industry Foundation Classes) format. The procedure can be seen in figure 5.1 below;

Go to file, then Export, the following dialog box will appear, click on the IFC option, and give it a name and Export. A new file will be created in IFC format in the Modelling fold.

Open this file by going into SAP2000, File then Import and browse to the file.
The Model exported to the analysis software which in our case is SAP2000 can be seen below in figure

Figure 9: Model exported to SAP 2000
V. BENEFITS OF BIM

BIM is not a technology, it is a process. BIM applies to all aspects of the construction of a building, from the design, the estimating, the supply chain, the delivery of goods during the build, the build process, the resource allocation, the productivity requirements to meet targets and on in to the post-handover phase through Facilities and Asset Management.

BIM is so much more than just a detailed 3D model of a building. The concept is most easily explained by the term “build 4 times” which means build three times in the model and once on the ground. The accuracy of the model combined with animations allows contractors to access the design layout before the construction takes place and can make modifications. This means that when the build takes place, there are fewer errors and far less rework required. This moves the construction procurement process from design and build to design build by bringing the construction team in to the design process rather than them simply having to respond to a tender for construction after the design has been completed.

“Parametric Modelling” is a key principle of BIM. Essentially this means that everything in the model is connected to all the concern elements. If you move the location of a wall, the elements attached to the wall also move. If you change the volume of a floor, the quantities of material needed to lay the floor change. If you move ducting in the ceiling, all aspects associated with the ducting update and conflicts are highlighted. All the changes made will automatically update the project throughout the multiuser environment.

As the BIM provide a visualized model before construction so we remove the conflicts and reducing rework by fixing problems early, means fewer issues in the plans and ultimately fewer hassles in the field. Reducing rework can help keep budgets in line. In any project material reduction is achieved by good management and by knowing the exact quantity to be used on the per day basis. BIM tool’s provide the exact quantity to be used and hence will help in the reduction of material wastage.

BIM providing scheduling of activities in the project it reduce the overall time of the construction project, gives better performing completed infrastructure.

VI. CONCLUSION AND RECOMMENDATIONS

Building Information Modelling has revolutionized construction industry which allows the Designers/Architects to design structures, and the tool generates the proper drawings and sections which is incorporated during the stages of construction project. A very good advantage of this software is that the conflicts in drawings and design are detected and resolved before the execution of project.

CONCLUSION

Since with the discoveries of tools and techniques in the modern era the knowledge of BIM tool can be used for implementing it in construction programs, but there are some limitations that are to be resolved before the acceptance of
implementation of the tool generally. The productivity of AEC industry will be improved once these shortcomings are resolved. BIM will be only then proficient when it is used by Engineers, Architects and Contractors simultaneously. BIM tool has to be incorporated in conjunction with other used software, which concludes that it is not the “end all” tool.

VII. RECOMMENDATIONS

- BIM program is easy to be used in construction industry and it is very proficient if it is adapted in this industry.
- Due to advancement in modern technology this is the need of modern era to shift conventional techniques(CAD) to modern techniques(BIM).
- Difficulties in conventional methods includes that they create a lot of confusions in drawings, low quality construction, hundreds and thousands of documents for each project, lack of clash detection tool before construction. Solution to these problems is BIM.
- BIM includes clash detection tool, single file data base as a result high quality construction work is achievable.
- In Pakistan the use of BIM program is very less. Only few firms adopt this software in this country. A course of Building Information Modelling (BIM) should be introduced in institutions which will help them to incorporate various challenges in work field. For this purpose the role of Pakistan Engineering Council is of key importance.
- Students will learn how to design and communicate more fluently. Also, the students will have a hand on experience on the latest tools available for the construction projects.

VIII. RESEARCH GAP

This research explores the various capabilities of Building Information Modelling. Pavilion of Qayyum stadium is being modeled in Tekla and interoperability is applied on it. Clash detection tool is used to detect clashes, and detailing of reinforcement is done and benefits of BIM tool are described.

Also other operations can also be performed using this tool. These include cost estimation, scheduling, construction management, safety management etc.
References:

I. Aranda-Mena, G., Crawford, J., Chevez, A., & Froese, T. (2009). “Building information modelling demystified: does it make business sense to adopt BIM?”. *International Journal of Managing Projects in Business*, 2(3), 419-434.

II. Arayici, Y., Khosrowshahi, F., Ponting, A. M., & Mihindu, S. (2009). “Towards implementation of building information modelling in the construction industry”.

III. Azhar, S., Hein, M., and Sketo, B. (2008). “Building Information Modelling (BIM): Benefits, Risks and Challenges”. Proceedings of the 44th ASC Annual Conference (on CD ROM), Auburn, Alabama, April 2-5, 2008.

IV. Bernstein, P.G., and Pittman, J.H. (2005). “Barriers to the Adoption of Building Information Modelling in the Building Industry”. *Autodesk Building Solutions Whitepaper, Autodesk Inc., CA*.

V. Building Information Modelling (BIM): A new paradigm for quality of life within Architectural, Engineering and Construction (AEC) industry By Roshana Takim* Mohd Harris, Abdul Hade Nawawi.URL www.sciencedirect.com

VI. Ding, L., Drogemuller, R., Akhurst, P., Hough, R., Bull, S. and Linning, C. (2009). “Towards sustainable facilities management”. In P. Newton, K. Hampson, & R. Drogmuller, *Technology, Design and Process Innovation in the Built Environment*. pp. 373-392. Taylor & Francis.

VII. Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011). *BIM Handbook, a Guide to Building Information Modelling* 2nd Ed. Hoboken: John Wiley & Sons, Inc.

VIII. Fischer, M., Kunz, J. (November 12, 2006). “The Scope and Role of Information Technology in Construction” [WWW document]. URL http://cife.stanford.edu/online.publications/TR156.

IX. Integration of Agents in the Construction of a Single-Family House through use of BIM Technology Faustino PatiñoCambeiro*, ItziarGoicoecheaCastaño, MaríaFenolleraBolíbar, Javier Rodríguez. URL www.sciencedirect.com

X. Is BIM Adoption Advantageous for Construction Industry of Pakistan? By Masood, R.a*Kharal, M.K.N.bNasir, A.R.c URL www.sciencedirect.com

XI. Tekla Structures Official website. URL http://tekla.com/international/Pages/Default.aspx