DEVELOPMENT OF BUILDING INFORMATION MODEL FOR RESOURCES OPTIMIZATION IN CONSTRUCTION PROJECT

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ABSTRACT: The aim of the study is to develop the 3D visualization of Building Information Model and integrated 4D model for optimization of resources in the construction project. This study discuss the process of methodology and creation of 4D model of the project and simulate it to monitor the workflow at the site. Different stages of the construction process and activities are generated by using Revit and MS Project. MS project has been used for creation of the schedules and these are linked with the Revit for 3D modeling. The time used as the fourth dimension and 4D model created by using Navisworks Time liner software. Narges shopping center is presented as a case study to realize the actual uses and benefits of Building Information Model (BIM). Narges shopping mall is located in Tehran, Iran. As a part of Hekmat master plan, Narges shopping center is an 11 stores building with a total area of 30000 Sq.m. This shopping and entertainment center is comprised of 150 retails and two multi-use public halls with a capacity of 400 persons each and underground parking with total 400 parking space. The main purpose of architecture was to create an urban public center along with its revolving, spiral like form and an ever changing continuous façade by means of different colors, materials, which is in harmony with the other building of the master plan. The approximate cost of the project is $17 million and duration of the project schedule is 30 months. The developed Building Information Model enabled us to identify the potential collisions or clashes between various structural and architectural systems. 4D model has been used for limiting the interaction between subcontractors installing the different systems so rework could be avoided and productivity maximized. It is also observed that the utility of BIM for construction stimulation and clash detection is the best suitable method. Clash detection before the implementation of work is highly recommended to avoid rework.

Key Words: Building Information Model, Work Breakdown Structure, Resource Optimization, Project Schedule

1. INTRODUCTION

The construction industry is the largest industry in the world, with distinguishing characteristics such as highly fragmented organizations, unique projects, relatively short period of production, outdoor and unstructured working conditions, and labor-intensive activities. Successful completion of building projects requires collaboration of numerous multidisciplinary and sometimes geographically separated team members. Continuous, accurate, and real-time information sharing among project participants is key to resolving conflicts, speeding up solutions, and keeping projects on time and on budget.

The current day demand of construction industry requires a highly accurate planning, scheduling and management process of the project, which can enable the overall optimization of the cost, time and resources. The older system of usage of MS Project and Primavera for scheduling, AutoCAD drawings and taking a lot of strain and explaining the status of the project to the client is very difficult and time consuming, owing to the fact that the client and the store manager might not be fluent with the technical terms used in the schedules and graphical representations. Instead of using the older, traditional methods of CAD drawings and schedule sheets, one can integrate them on a platform to create a 4D view of the project. The traditional approach for scheduling and progress monitoring techniques likes bar charts, CPM, PERT etc. are still being used by the project managers for planning. These are a serious disadvantage in the decision making purpose, as they fail to provide the necessary spatial aspects and data. There is a gradual increase in the pressure on the project managers to shorten the delivery time and decrease the costs involved in the process, without a decrease in the quality of the product. Construction planning and control is identified among the top potential areas needing improvements. A pertinent literature and case studies confirms typical problems regarding separation of execution from planning and fact variance detection. Several researchers agree that major causes of these problems are inadequacy of traditional project management theory and improper applications of information technologies. Currently, management is much more concerned about contract and cost rather than production at construction work face. Furthermore, a review of IT applications in construction highlights the need for tools and techniques for execution planning and management of resources. For planning and control technique, the classic Critical Path Method (CPM) has been widely used in the construction industry since its invention in the 1950s. The CPM applications have well served project managers in preparing project proposals, managing personnel and resources, tracking delays and change orders, instituting as a basis for progress payments, and coordinating with subcontractors. However, its suitability has been widely criticized and three major drawbacks can be identified such as inability to cope with non-precedence constraints in the real world, construction possess various kinds of constraints ranging from physical constraints (i.e. topology, space, safety, and environment), contract constraints (i.e. time, cost, quality, and special agreement) to resources and information constraints (i.e. availability and perfection). Unfortunately, CPM considers only time and precedence constraints among activities. Its underlying network representation is proven to be inadequate to represent and integrate more problems in construction management.

Today's fast development increases priority of the time target. The project activities delays cause direct increase of financial losses during construction for contractor. The late commissioning of the building delays cash generation for the customer-financial losses. This delay in addition creates conflict between contractor and customer, which very often lead to long dispute resolutions in the court. It is evident, that traditional procedures of the project development with limited use of the IT solutions leads to waste of time for documentation checking, drawing and redrawing, long duration of variation orders resolution during both design and construction stages. The opportunity to have wide analysis and synthesis of alternatives is very limited there. Therefore it is very difficult to find rational solutions and ensure adequate costs for required fit for purpose of the developed premises. Projects' complexity requires multidisciplinary teams, where works are unnecessary duplicated very often.

The main aim of the study is to identify the qualitative and quantitative parameters of construction project and integrate the 3D model with MS project and Navisworks for creating 4D visualization of the project. Optimize the project cost and duration by using building information model. The essence of the BIM involves the fact that a design is treated as an integral part of the building life cycle. Segmented work between the design parts and members is replaced by the adjusted process. This is achieved by changing the design technology substantially, switching from the development of a set of 2D drawings to the development of a 3D computer aided model of a building, comprising all the parts of the design, such as architectural, structural, mechanical, technological, construction management process.

Resource allocation, smoothing or leveling procedures are incapable of ensuring full continuity for a production crew or process. For complex projects, field personnel find the CPM schedules confusing and, therefore, less useful [1]. Large amount of efforts are required to re-plan and redraw the network each time it was updated. Furthermore, the CPM has inflexibility and lack of expressiveness to cope with the varied pattern of construction in the field. The future system should have flexibility and agility to respond both proactively and reactively to variability of construction constraints affecting work status. Advanced visualization techniques such as time is the 4^{th} dimensions (4D) and virtual reality should be utilized for more effective evaluation and communication of schedule and constraint information [2]. In this study, the system should allow planners to simulate various construction alternatives and inform possible constraints like technological dependencies, spatial conflicts, hazardous working conditions, as well as availability of information and resources for each alternative.

2. UTILITY OF BUILDING INFORMATION MODELING

Building Information Modeling (BIM) is the process and practice of virtual design and construction throughout its lifecycle. It is a platform to share knowledge and communicate between project participants. The BIM is primarily a three dimensional digital representation of a building and its intrinsic characteristics. It is made of intelligent building components which includes data attributes and parametric rules for each object. For instance, a door of certain material and dimension is parametrically related and hosted by a wall. Furthermore, BIM provides consistent and coordinated views and representations of the digital model including reliable data for each view. This saves a lot of designer's time since each view is coordinated through the built in intelligence of the model. According to the National BIM standard, it is a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle.

Building information model is a digital representation of physical and functional characteristics of a facility. It is considered as one of the most promising developments in the construction industry and will become the facilitators of integration, interoperability and collaboration in the future of the Architect, Engineering and Construction (AEC) industry [3]. As architects move more rapidly to BIM, the opportunities to leverage digital design data for downstream building asset and facilities management become more prevalent. BIM in its present state is commonly used on complex projects such as high-rise buildings, bridges, arts centers, stadiums, and medical facilities. The term is most commonly applied for planning, design, construction, and management of buildings; however, its capabilities are being extended to challenging and complex civil engineering projects. 3D modeling is just one aspect of BIM that has hogged the limelight, but its real strength and power lies in the knowledge database, which can be used in conjunction with other software to deliver quick and reliable information in areas of sustainability, estimating, structural analysis, demolition and re-construction.

The architecture, engineering, and construction industry has long sought techniques to decrease project cost, increase productivity and quality, and reduce project delivery time. Building information modeling (BIM) offers the potential to achieve these objectives [4]. BIM simulates the construction project in a virtual environment. With BIM technology, an accurate virtual model of a building, known as a building information model, is digitally constructed. When completed, the building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building. BIM characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories, and project schedule. As the model is being created, team members are constantly refining and adjusting their portions according to project specifications and design changes to ensure the model is as accurate as possible before the project physically breaks ground [5].

BIM represents a new paradigm within AEC, one that encourages integration of the roles of all stakeholders on a project. It has the potential to promote greater efficiency and harmony among players who, in the past, saw themselves as adversaries [6]. BIM also supports the concept of integrated project delivery, which is a novel project delivery approach to integrate people, systems, and business structures and practices into a collaborative process to reduce waste and optimize efficiency through all phases of the project life cycle[7].

3. METHODOLOGY

The use of BIM especially enhances the collaborative efforts of the team. The architect and engineer can test their design ideas including energy analysis. The construction manager can provide constructability, sequencing, value and engineering reports. They can also start 3D coordination between subcontractors and vendors during early stages of design. Overall, the BIM promotes the collaboration of all of the projection participants. There are beneficial uses of BIM during the construction phase.

This study is to discuss the methodology for the creation of a BIM based 4D model of the project and simulate it to monitor the workflow at the site. Different stages of the construction process and activities are generated by using Revit and Naviswork softwares. Microsoft project planner was used for creation of the work schedules and these are linked with the Naviswork. From the 2D AutoCAD drawing 3D model was created by using Revit autodesk software. Clash detection was done by exporting the workflow process from Revit file to Navisworks. Finally, 4D model was developed by using 3D visualization in Navisworks with time liner. In this study, Narges shopping mall was selected as a case study. Narges Shopping Mall located in Tehran, Iran. The steps that are involved in this process of generation of the 4D model are described in the following:

Step 1: Creation of Architectural Drawings using AutoCAD.

Step 2: Identification of the Work Breakdown structures.

Step 3: Scheduling the activities using MS project planner.

Step 4: Modelling of 3D visualization using Revit software.

Step 5:Integration of the 4^{th} dimension as a time in 4D building information model.

Step 6: Optimization of time for total construction project.

3.1 Creation of Architectural Drawings in AutoCAD

The first step is the creation of the plans of the project. For a better model, it is required to have the plans for different group of works and level of the project, i.e., different plans for architectural and structures works. The plans for foundation, floors and roof and etc., were generated in AutoCAD for the creation of the models at different levels in 2D format.

3.2 Identification of the Work Breakdown Structure

The process of identification of the Work-Breakdown Structure (WBS) involves a different approach for different projects. For This study, whole work was classified into various levels such as foundation, plinth beam, floor, columns, exterior and interior wall, ceiling and the roof, etc.

3.3 Scheduling the Activities using Microsoft Project Planner

The activities are scheduled based on the Critical Path Method. Microsoft project planner 2007 is used as the tool to prepare the activity schedule. The sufficient float is identified for each activity and the final schedule is made.

3.4 Modelling of 3D visualization using Revit software

This step involves the exporting of the plans from AutoCAD drawings into Revit autodesk software. The elevation details, which are already identified, are now used as the base heights and extrusions. After defining the materials in layer wise in Revit software and the linking was created in each level from AutoCAD to related level in Revit.

3.5 BIM integration of 4th dimension as a time

The crucial step of the process is the integration of the schedule with the 3D model of the project. Using the time liner option in Navisworks for importing MS Project 2007, the schedule, along with its details is exported as a database. Each activity of the project is then time enabled, should link to related items in three dimensional visualization.

3.6 Optimization of Total Project Time

The final step is the simulation of the total project time. The time feature of the spatial data is utilized for this process. The process of simulation sequence is shown in Figure 1. Each activity is linked with its start and end times. Then, the time zone is changed and required time offset is selected. Thus, the simulation is obtained.

4. CASE STUDY DESCRIPTION

Narges shopping center is located in Tehran, Iran. As a part of Hekmat master plan, Narges shopping center is an 11 storey building with a total area of 30000 Sq.m. The total cost of the project is $ 17 million dollars approximately and total duration of the project is 30 months. This shopping and entertainment center is comprised of 150 retails and two multi-use public halls with a capacity of 400 persons each and underground parking with total 400 parking space. The main purpose of architecture was to create an urban public center along with its revolving, spiral like form and an ever changing continuous façade by means of different colors, materials, which is in harmony with the other building of the master plan. The Narges Shopping Mall project comprises the mixed-use restaurant, retail shops, and a parking deck.

5. DISCUSSION OF RESULTS

Building Information Model has been developed and used for clash detection, design coordination and work sequencing and also used for limiting the interaction between subcontractors installing the different systems, so rework can be avoided and productivity maximized. Total actual project duration is 137 weeks, but it is calculated by using MS Project planner is 152 weeks. The total delay is 105 days increased during the process of construction. However, based on the BIM simulation the total delay days reduced from 105 to 61 days. After considering on delays and their causes, it is seen from the results that, some of delays happen due to lack of collaboration and communication between contractors and engineers, non available of men and materials at site. This can be avoided through visualization of work progress during construction process.

The 4D model has an advantage to visualize the day to day work progress and avoid the delays by solving the problem on site or with immediate action. BIM based 4D model used for clash detection in pre-design step of the project to optimize the time of the project. The stage wise creation of 4D visualization for Narges Shopping Mall using Naviswork software is shown in Figure 1. Bar chart shows the delay days versus delay resources and is given in Figure 2. It is observed from the Figure 2 that, the maximum delays occurs due to contractors, owners and labours. Table 1 shows the simulation of delays resources from MS Project and BIM and compared with normal schedule. The delays resources have been calculated by using MS project and BIM simulation and compared with normal schedule. It is seen from the Table 1 that, the maximum delay occurs due to insufficient supply of labour, machinery and equipment. The delay varies within a variation of 50 to 70 percent of the total delays. Delay occurs due to contractors and owners, it varies within a of 30 to 40 percent of the total project delay.

6. CONCLUSIONS

Building Information Model has been developed and used for Narges shopping mall, Tehran, Iran. The use of BIM and its benefits have proven to be a value to construction projects. These benefits are achieved by the collaboration of the construction team and the utilization of BIM tools for optimizing on scheduling and planning of the project. The 4D model has an advantage to visualize the day to day work progress and avoid the delays by solving the problem on site or with immediate action. BIM based 4D model used for clash detection in pre-design step of the project and also optimize the delay time during the construction of the project. BIM used for clash detection, design coordination and work sequencing and also used for limiting the interaction between subcontractors installing the different systems, so rework can be avoided and productivity maximized.

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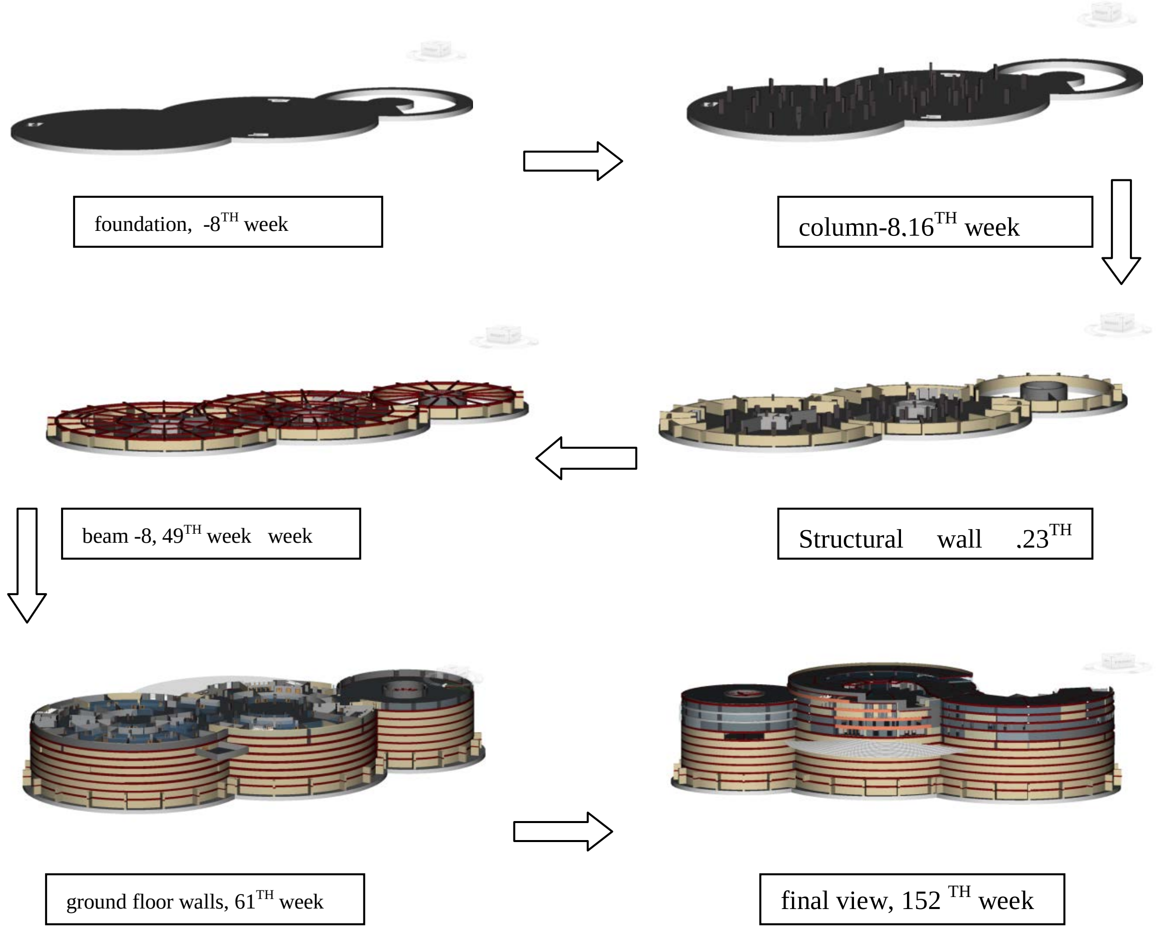

Figure 1 Shows the stage wise creation of 4D visualization for Narges Shaopping Mall using Naviswork

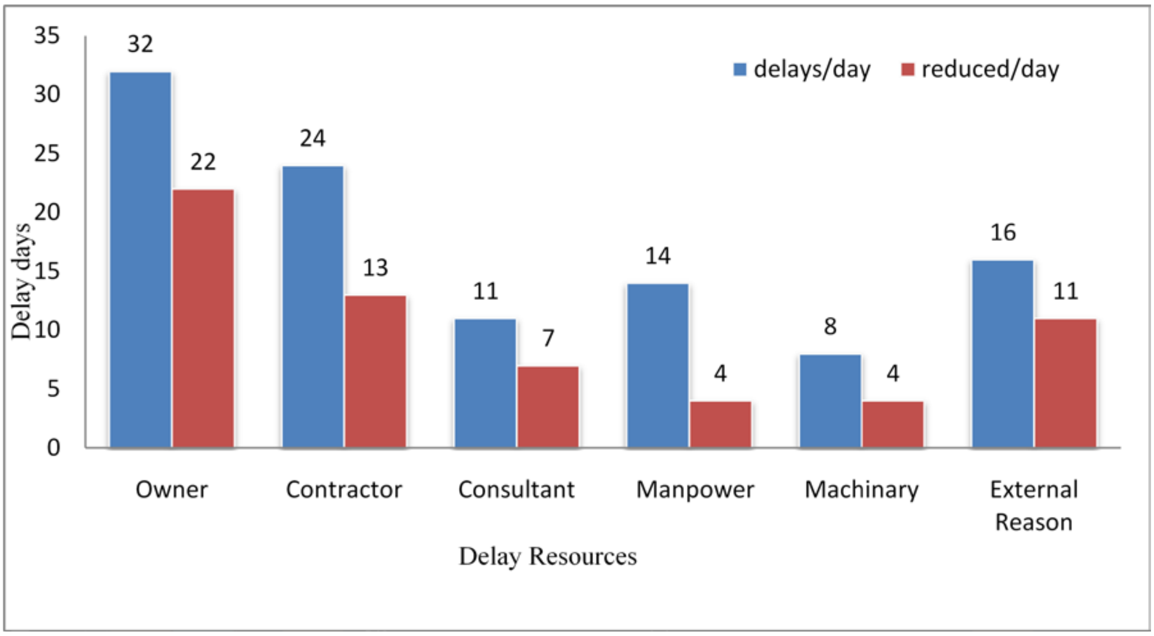

Figure 2 Bar chart shows the delay days versus delay resources

Table 1 Simulation of delays resources from MS Project and BIM and compared with normal schedule

Delay Resource	Delay days in MSP (Days)	Delay days after BIM	Percentage Reduced (%)
Owner	32	22	30
Contractor	24	13	45
Consultant	11	7	40
Labors	14	4	70
Equipment& Material	8	4	50
External reason	16	11	30
Total	105	61	44.167