Bim Based Analysis of Time and Cost for Multi Storey Commercial Building

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Abstract—With the advent of Building Information Modeling (BIM) software, the Designer/Architect is given the opportunity to design the building, and the software develops the appropriate plans and sections needed for construction. Among the new developed concepts and BIM applications, two of the concepts most frequently used with the support of BIM technology in the planning, organization and scheduling of projects are 4D and 5D in which a 3D model is tied to its time of execution (4D) and its corresponding cost (5D). Purpose of this study is to develop the BIM model for visualization of building information to meet the needs in conjunction with the specially tailored programs developed for designers and builders. World Trade Center that is coming up in Kochi, Kerala has been taken up as the case study. A 3D model has been created using Autodesk Revit with the 2D AutoCAD drawings. Subsequently, a prototype 4D Building Information Model was created and studied. Furthermore, the BIM-based schedule was integrated to the 4D model and also the corresponding cost estimation (5D) is also done. Results of this study prove that BIM can be used to improve jobsite productivity. This study gives a clear idea of benefits that can be obtained using BIM process saving Time and Cost of Construction and as how the construction Documentation becomes easier.

Index Terms—Planning and scheduling, time and cost, building information modeling.

I. INTRODUCTION

With the rapid adoption of BIM in the construction industry, and its gradual implementation in the design industry, careful considerations have to be taken when making the change over from the traditional method of creating construction documents towards a BIM approach.

A. Principles of Building Information Modeling

International Alliance for Interoperability (IAI) was formed in September 1995, and since its release, has published three major releases of the Industry Foundation Classes (IFC). This was the beginning of setting standards for object based data modeling.

The BIM process has the potential to remove the guesswork about how the most difficult parts of a building come together, which tend in most cases to be the corners. These models also transcend 3D and can be manifest in 4th dimension (4D) and 5th dimension (5D). Four D (4D) models link components in 3D CAD models with activities from the design, procurement, and construction schedules. Resulting 4D models allow project stakeholders to view the planned construction of a facility over time on a computer screen and to review the planned or actual status of a project in the context of a 3D CAD model for any day, week, or month of the project (Fisher and Kunz 2004) [1]. Once Autodesk decided to acquire Revit (the same company that controls the most widely used computer drafting program, AutoCAD) the BIM era began to hit the main stream. With so large of a parent company, Revit has become the staple in the industry for BIM.

A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life Cycle; defined as existing from earliest conceptualization to demolition. It is considered as one of the most promising developments in the AEC industry (Sheryl and Athul 2007) and will become the facilitators of integration, interoperability and collaboration in the future of AEC industry [2].

TheAEC industry has long sought techniques to decrease project costs, increaseproductivity and quality, and reduce pr oject delivery time. BIM offers thepotential to achieve these objectives. BIM also supports the concept ofintegrated proje ct delivery, which is a novel project delivery approach tointe grate people, systems, and business structures and Practicesinto a collaborative process to reduce waste and opt imize efficiency throughall phases of project Life Cycle (Az her *et al*. 2008) [3].

B. Collaborative Working and Productivity

The most beneficial aspect of using BIM technology with software like Revit is the way it changes the design process. A BIM's goal is to recognize the potential benefits that collaborative working through all stages of design and construction can offer. This happens to be the hardest thing to implement in the design process being that there are complications for the interoperability of the design data. Contractors can make many "partial uses" of BIM such as assisting with scoping during bidding and purchasing, reviewing portions of the project scope for analyses such as value engineering, coordinating construction sequencing, demonstrating project approaches during marketing presentations, and so on (Khemlani, 2006) [4]. Small firms are hesitant to invest in research and development (R&D) or optimal computer programs to improve productivity. There are number of barriers that keep contractors from using the latest technology, including fears (legal/risk fears, fear of change, fear of the unknown, etc.), initial investment costs, the time to learn how to use the software, and perhaps the lack of support from the senior leadership of the company. Building Information Modeling requires both research and development to implement into a construction companies process and a rather large investment. Software that can manipulate BIMs, like Revit®, cost about $6,000 per license.

Cost of the software and training make it difficult for small construction companies to justify purchasing and implementing.

"Construction Productivity: Measurement and Improvement" written by Adrian (2004) specifics and considered in determining BIM's impact on productivity were Adrian's ten step program for improving productivity [5].

During the design phase of a project, the architect will prepare several levels of estimates on the size, quality, and cost of the building. This is based on their conception of the cost for building the project. There is no doubt that if the estimates are grossly incorrect, both the quality of the project and the time it takes to complete it, suffer (Adrian 2004) [5].
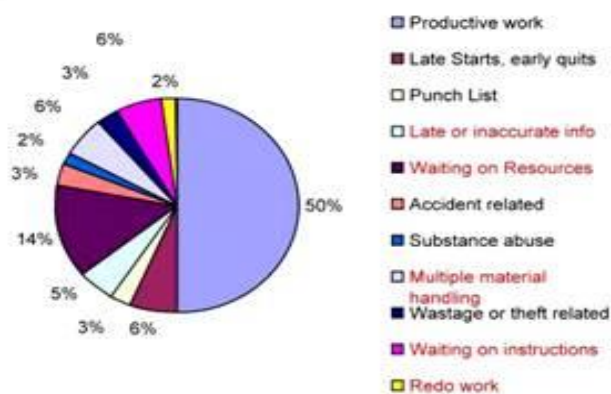

Fig. 1. Analysis of productive and non-productive time during a typical construction project (Adrian 2004)

Because the true benefit of a BIM is to the project owner, the push to use a BIM will most likely be a client-driven development. Many owners see the single point of responsibility in integrated practice as an attractive alternative to the "over-the-wall method" of design and construction in which an architect completes a design and hands it over to a contractor for construction (Elvin 2007) [6]. The value is in the significant building efficiencies and initial cost savings and extends to the operations and maintenance of the facility (Guidelines for Improving Practice 2007). Speed, accessibility, communality, and adaptability are achieved by the use of a common database, early information user input, knowledge representation and information technology, team collocation, and information exchange in small batches (Elvin 2007) [6].

This study describes the potential use of BIM in the AEC industry and how it can improve productivity for construction managers. A BIM is a design methodology that breaches the gap between the design intentions of architects and engineers, and the implementation of design by construction managers. It is a computer model that fulfills the needs of all parties involved in the AEC industry, offering CAD services, cost calculations, energy simulations, building code checking, life cycle analysis, and it is formatted to be interoperable with other programs that are specific to the AEC industry.

C. BIM in Construction Management

There are various uses of Building Information Modeling

for each project participant such as for planning, design, construction and operation. During the design phase, the use of BIM can maximize its impact on a project since the ability to influence the cost is highest. They enable the exploration and improvement of the project executing strategy, facilitate improvements in constructability with corresponding gains in on-site productivity, and make possible the rapid identification and resolution of time-space conflicts.

II. METHODOLOGY AND MODEL DEVELOPMENT

This study describes the potential use of BIM in the AEC industry and how it can improve productivity for construction managers. A BIM is a design methodology that breaches the gap between the design intentions of architects and engineers, and the implementation of design by construction managers. It is a computer model that fulfills the needs of all parties involved in the AEC industry, offering CAD services, cost calculations, energy simulations, building code checking, life cycle analysis, and it is formatted to be interoperable with other programs that are specific to the AEC industry.

Productivity improvements for the construction industry were researched by reading various books and articles to understand the workings of a very labor intensive industry. History of BIM was researched to determine the purpose of the program and the limitations that it may have. The BIM program used for this study was Autodesk Revit because Autodesk is the biggest software provider for the A/E industry.

A. Process of BIM

This research also involved learning the process of BIM first hand from continued use, information seminars, and tutorials. Autodesk Revit seems to be the program of choice for the A/E industry with their drafting program, AutoCAD therefore; the program that was used for this experience was Autodesk's Revit. Revit gives the user an interface that is not very similar to AutoCAD. This is one of the first drawbacks to changing from a drafting program to a BIM approach. Most of the A/E industry utilizes AutoCAD in their operations. It is easier to learn BIM having no computer drafting experience at all than it is with 10+ years of computer drafting experience.

B. 2D CAD vs BIM Revit

Revit is a BIM (Building Information Modeling) program. The idea is to create a 3D model or "virtual" representation of the real physical building. Each 3D element has Information input into it so that the data can be scheduled automatically, and shared downstream with other stakeholders and team members who may use Revit or other programs such as Navisworks to combine all models from the various designs into a "Master Model" and perform3D clash detection, 4D scheduling and 5D cost estimating.

The AEC industry is quickly advancing into a BIM delivery method and leaving 2D CAD behind as it is an antiquated way of designing and documenting projects. For an existing building which is to be renovated, it has always been a challenge how to document the existing conditions.

Recent breakthroughs in Laser Scanning and Point Cloud technology have enabled the process to go "digital" and in 3D. Revit 2014 supports Point Cloud data, so it can be imported into Revit and used as a "3D background" to create a 3D model in Revit of the existing facility. Revit also uses "Phases" to distinguish existing, demolished and new construction automatically.

So, as BIM becomes the "norm" and 2D Cad drafting fades away. The Federal Government is now requiring BIM on all of their projects (do a quick search about GSA and BIM) and they have been at the forefront of the laser-scan/point cloud/BIM workflow.
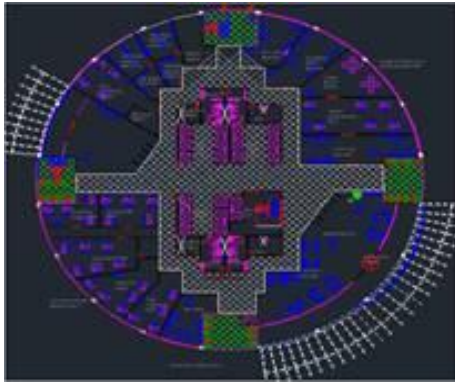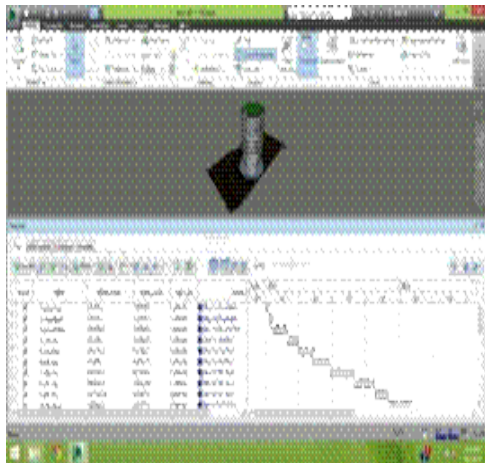

Fig. 2. DCAD layout of ground level.

Fig. 3. Imported 3D revit model of ground level A.

C. Conversion of AutoCAD data into Revit 3D

The steps for converting 2D CAD model (Figure 3.1) to Revit Autodesk software for making 3D model Go to the inert tab Select "import CAD" Browse for the CAD file that you wish to input (Fig. 3.4) On the positioning tab leave the default position "center to center"; On the "place at" tab select the level you want to input Pick your color preference on the "colors" tab On the layers tab leave "ALL" selected, if you want to import all the layers from the file. Otherwise, you can select which layer to import individually. By doing so it will not import any object on unselected layers. Leave the "import units" as auto detect.

Select "open": Once the file is imported you can edit the CAD drawing as a Revit file shown in Fig. 3.2; 2D CADlayout of the ground level is shown in Figure 3.1 w hich is imported to Revitand modeled in to a 3D model as sh own in Fig. 3.2 giving the component inputsto each unit as p er the drawing. In this way each level is subsequentlyimport

ed to Revit and the complete 3D structure is developed 2D C AD layout ofthe ground level is shown in Fig. 3.1 which is i mported to Revit and modeledin to a 3D model as shown in Fig. 3.2 giving the Components inputs to eachunit as per the drawing. In this way each level is subsequently imported tor evit and complete 3D structure is developed.

D. 4D Modeling

Revit to Neviswork:

There isa Revit plugin to export a Navisworks file directly from Revit which maintainsmuch of the data related to the Revit file. This function will save the file asa Navisworks .n wc file which can be opened directly in Navisworks.

Initially Begin with the model in Revit with the main 3D view open. In the main toolbar, select "Tools", "External Tools", "Navisworks" An export dialog box will show up. Pick the place where you would like the Navisworks file to be saved, and name the file what you would like. Open Navisworks by double-clicking on the saved file. This will open the file in Navisworks. Developed 4D model of the construction project in Navisworks Time liner is shown in Figure 3.3 displaying activity wise planned start and planned end date of complete project.
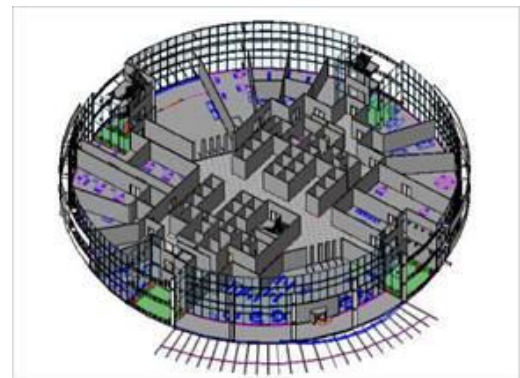

Fig. 4. D Scheduling of the project in naviswork timeliner.

III. CASE STUDY

The main purpose is to provide international trade, Encouragement research and development facilities, to provide trade information, to provide education facilities, to provide workplace for trade promotion cells, to provide residential accommodation at subsidized rated for the business traveler, to provide workplace for the trade promotion cell.

A. Study Area Description

The commercial world trade centre, that is going to come up in Kochi, Kerala state, and which is proposed is a 37 storey building with a total area of 105060 Sq m is taken up as case study. It is comprised of a shop convention centre, shopping mall, club house, multi-level parking and 5 Star hotel. The city-based Mather group holds a licence from WTCA to establish a centre here. The Kochi WTC will connect well with projects like the Smart city, Vallarpadam International container transhipment terminal and the LNG terminal as well as the growing tourism ventures. This section provides results on the use of Building Information Model. This includes formation of 3D prototype building information model using Revit. A 4D model

(time/sequencing) was developed for limiting interaction between subcontractors installing the different systems so rework could be avoided and productivity is maximized. A 5D (cost estimating) modelling is also done.

Fig. 5. Site surroundings.

B. 3D Modelling of WTC

The creation of a 3Dmodel using the Revit Architecture 2014 showed the powerful features of Biomother creation of an element on a view such as floor plan translated correctly to a different view such as elevation view. This saved a lot of time in comparison to if the design were drawn in traditional 2D view. Furthermore, the parametric modelling detected the conflicts of elements. The use of this feature eliminated duplication or overlapping of elements. Fig. 6 depicts the prototype Revit model created for this project.
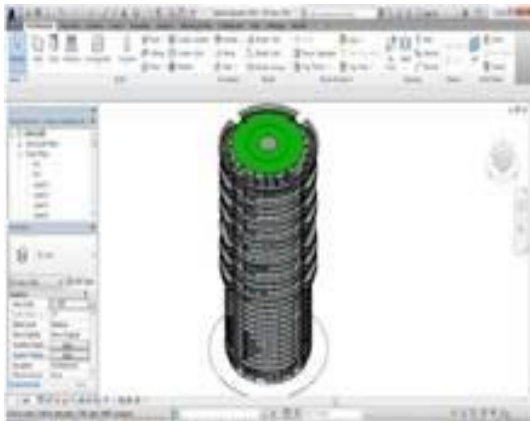

Fig.6. Prototype revit model of WTC.

C. Technology Support

To create 3D building model, usually, just single software like Autodesk Revit Architecture/Structure or Bentley Architecture could do that. However, when it comes to the idea of BIM on site, more software need to be involved to create as it-linked building model that carried all the necessary database information. For 3D, 4D and 5D model AutoCAD 2014, Revit 2014, Nevis work 2014 and MS Office Excel 2007 are used.

IV. RESULTS AND DISCUSSIONS

As soon as The Building Information Models are produced, the quantities are taken off. The produced 3D model is then integrated to a 4D model using Nevis work Time liner for the scheduling. 4D scheduling helps better understanding of the construction components and schedule progress that in turn results better construction planning.

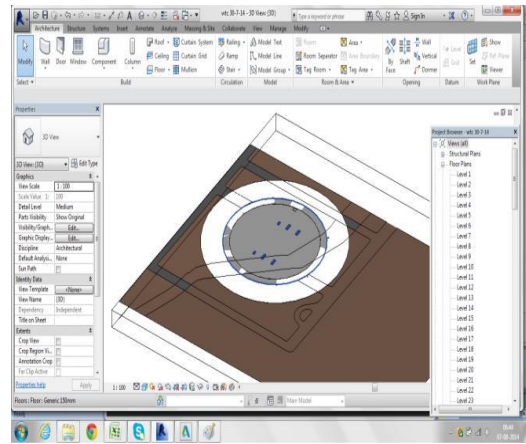Furthermore, a 5D costing model is evaluated.
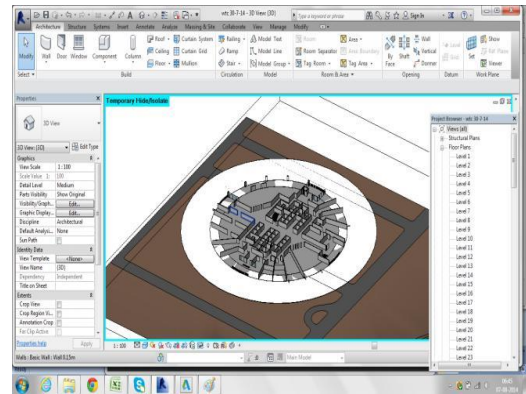

Fig. 7. Foundation of WTC
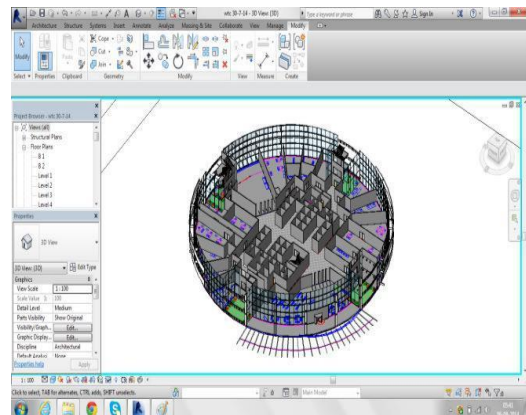

Fig. 8. 3D View of ground level.

Fig. 9. Sectional view of plan showing the CAD layout of ground level.
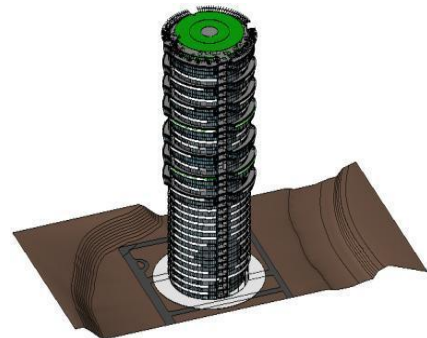

Fig. 10. Exterior 3D view of WTC.

D. Creating 3D Model in Revit

The BIM package in the current case is Autodesk Revit. For the creation of building levels are to be identified for

each floor. These levels are then given in the elevation and are created. Next step depends on details in columns, beams, doors, windows and the other details, families are prepared which should be loaded in each step of project. After creating the levels and families group create individual grid lines in each level and start placing the walls, stairs, etc. as per the tools in the BIM.

Second step is making each item of project separately i.e. Foundation, Column, Beams, Floors, Ramp & staircase, Structure wall, Roof, Interior wall, Doors & windows, Facade (curtain wall). Firstly, the foundation level is created giving the elevation details as shown in Fig.7 and Fig.8. Subsequently the details of column, beams, doors, windows etc are modeled with the families present in the software as per the project requirement. A sectional view of plan showing the CAD Layout of ground level is shown in Fig. 9. In this way each level of the building is modeled with detailed inputs.

E. 4D and 5D Modeling with BIM Platform

4D model is a 3D Revit model attached to the fourth dimension of time via a schedule. Through the concept of 4D scheduling has been around over 20 years. It has not been popular due to some technical challenges associated with it. The continuous advancement in technology and the emergence of BIM have removed all challenges associated with 4D scheduling. With the increasing success of BIM in the realm of designs, the adoption of 4D modeling is becoming more now a days. 4D model is a further development over 3D model. It challenges and changes many of the practices of conventional scheduling. The benefits of 4D models based on BIM platform can be measured in two categories: (1) Tangential Benefits, and (2) Intangential Benefits.

Tangential Benefits: Saving in Cost and Time. Reduction of Complaints. Improved Productivity Enhanced Quality Etc.

Intangential Benefits: Improved Communications among Various Divisions Communicate project parameters visually to non-technical stake holders and get their buy-in.

F. Creation of 4D and 5D Model

The shape files are to be added to different layer of Naviswork file and different activity of scheduling for creation of 4D models. The process involves identification of items in 3D view and importing the data as attributes of the levels. The result of linking 3D view with scheduling and the quantity takeoffs is shown in Fig. 11.
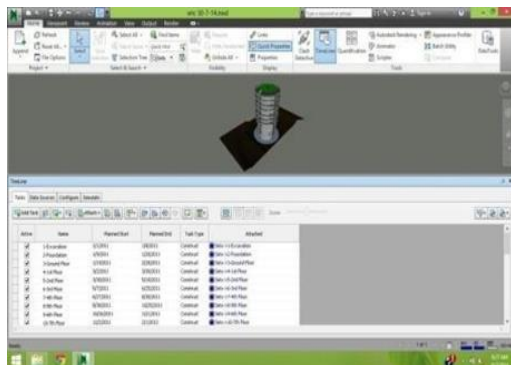

Fig. 11. 4D scheduling in Naviswork 2014 Timeliner

TABLE I. ESTIMATED AND ACTUAL DURATION AND COST OF EACH ACTIVITY

S. N o.	Activity	Est. Duration (Days)	Actual Duration (Days)	Estimated Cost (Lakhs)	Actual Cost (Lakhs)
1	Excavation	8	8	29.87	29.87
2	Foundatin	12	12	648.05	648.05
3	G Floor	41	41	398.5	398.5
4	1st Floor	29	29	511.6	511.6
5	2nd Floor	42	42	338.7	340
6	3rd Floor	50	50	398.5	398.5
7	4th Floor	65	70	398.5	398.5
8	5th Floor	57	60	398.5	398.5
9	6th Floor	37	40	398.5	398.5
10	7th Floor	62	60	398.5	398.5
11	8th Floor	43	43	398.5	398.5
12	9th Floor	56	60	398.5	398.5
13	10th Floor	52	50	398.5	398.5
14	11th Floor	58	58	398.5	398.5
15	12th Floor	32	32	398.5	398.5
16	13th Floor	27	27	398.5	398.5
17	14th Floor	36	36	398.5	398.5
18	15th Floor	30	30	398.5	398.5
19	16th Floor	36	36	498.5	498.5
20	17th Floor	36	36	398.5	398.5
21	18th Floor	34	34	498.5	498.5
22	19th Floor	28	28	498.5	498.5
23	20th Floor	33	33	498.5	498.5
24	21th Floor	41	41	498.5	498.5
25	22nd Floor	35	35	498.5	498.5
26	23rd Floor	30	30	398.5	398.5
27	24th Floor	22	25	398.5	398.5
28	25th Floor	32	32	498.5	498.5
29	26th Floor	30	30	498.5	498.5
30	27th Floor	33	33	398.5	398.5
31	28th Floor	37	37	498.5	498.5
32	29th Floor	52	50	498.5	498.5
33	30th Floor	52	52	398.5	498.5
34	31st Floor	28	28	498.5	498.5
35	32th Floor	16	16	498.5	498.5
36	33rd Floor	40	40	398.5	498.5
37	34th Floor	77	77	498.5	498.5
38	35th Floor	42	42	498.5	498.5
39	36th Floor	63	63	398.5	398.5
40	37th Floor	77	77	171.015	180
Estimated Duration: 1611 Days				Estimated Cost: 170,46,73,500 Rupees	
Actual Duration: 1623 Days				Actual Cost: 172,57,02,000 Rupees	

G. Statistical Analysis

The R2 value is taken out for both actual versus estimated

duration and time of the of the construction project and is shown in a scatter graph. It is observed from Fig. 12 and Fig.13 that there is a strong positive linear relationship for the duration and cost which proves that 4D scheduling and 5D costing estimation models developed resulted in a better construction planning with no much variation in the estimated and the actual schedule and cost.
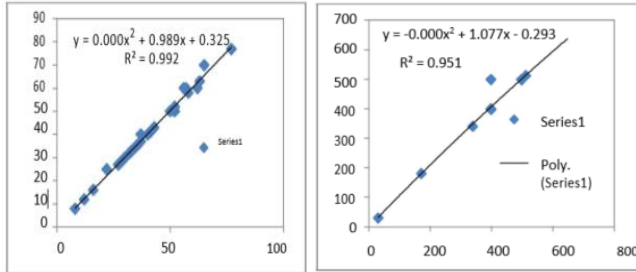

Fig. 11. Scatter graph of between actual vs. estimated duration and estimated cost respectively.

V. SUMMARY AND CONCLUSION

A. Summary

A BIM is designed to be the mediating program between the specific programs used by architects, engineers, contractors and suppliers/venders. It moves towards a completely universal and interoperable program working with computer based models in 3D, 4D and 5D. From the 3D model, plans and sections can be developed. The 3D capabilities of the program will visually solve any questions about material and spatial relationships. This makes conflict resolution easier to detect as well. Engineers can design their respective systems and coordinate with each other. Once the model is composed, installers can follow the BIM to prevent any conflicts in future construction. Models can then be created in 4D so contractors can both visualize construction before it actually takes place, and predict the best locations for construction equipment and lay down areas.

World Trade Centre that is go in to come up in Kochi, Kerala is taken up as a case study to realise the actual uses and benefits of Building Information Model(BIM). BIM tools were further analysed by developing a prototype 3D model from a 2D AutoCAD drawing using Autodesk Revit. A 4D model (time/sequencing) was developed using Naviswork Time liner for limiting interaction between subcontractors installing the different systems so rework could be avoided and productivity is maximized. A 5D (cost estimating) modelling is also done. Based on the results, it is observed that the utility of BIM in construction is the best suitable method for feasibility in construction and increase in productivity at each level.

B. Conclusion

True benefits of BIM will be realized when architects, engineers, and contractors use the software seamlessly between each other. The following conclusions have been drawn and are presented as follows:

The building information model has been developed integrating 2D AutoCAD drawing to 3D visualization using Revit software called as Building Information Model.

The developed Building Information Model (BIM) has been used to optimize the duration of the project using Naviswork. The activity wise time schedule has been prepared and shown in Table I. Figure 5.6 shows the Bar Chart of the Activity versus Duration.

The 5D cost estimation of the model is done. Figure 5.7 shows the Bar Chart of the Activity versus Cost of the complete construction project.

As seen in Figure 5.5 the BIM based 4D scheduling helps understanding of the construction components and schedule progress that in turn results better construction planning. Unlike the 2D paper work using Revit modeling cost and time can be saved especially in large projects. It provides economic insights and opportunities for growth to the construction industry.

From the study it is seen that, with the help of Revit software, quantities of materials have been prepared during making 3D model which could reduce time staff number in office.

It is concluded from the study that Easy understanding of 4D model except of benefits for team work during project (architect, engineer, and Manager) could become profitable for owner in his marketing or costumers.

It is observed from Figure 5.10 and Figure 5.11 that there is a strong positive linear relationship for the duration and cost which proves that 4D scheduling and 5D costing estimation models developed resulted in a better construction planning with no much variation in the estimated and the actual schedule and cost.

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.

C. Future Scope of the Study

BIM based scheduling can be used for quick or more detailed sequencing. A detailed BIM based schedule can be used for more precise visualization, improved construction planning and monitoring. Some of the challenges of the 4D BIM that needs further study are the synchronization of the updated models and schedules, the interoperability of BIM files, the generation of elements under resources based on specific locations such as rooms and the decomposition of the elements for better modeling.

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. However, these tools have some setbacks especially with interoperability which require further attention by the construction industry. Advanced techniques like Artificial Neural Network, Genetic algorithms may be used for better optimization of time and cost of the project.

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