Application of BIM Tools for Quantity Takeoff of Public Works Project Case Study: Anganwadi (Courtyard Shelter)

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Abstract— Since construction projects are large and complex, it is important to provide concurrent construction process to BIM models with construction automation. The Quantity Take-Off (QTO) estimation on the BIM models is a strategy, which can be used to support decision making, because 70–80% of construction costs are determined by designer's decisions in design stage itself. For this Master's thesis focus is on Quantity Take-off (QTO) processes applied during bidding stage of construction projects in India and use of BIM in material quantity extraction during the planning stage. It has been decided to make an overview of existing bidding practice in Anganwadi (Courtyard Shelter), to identify problems in preparation of bid material quantity, and to determine the situation of BIM technology and related issues with it in bidding process. Based on this information some suggestions on how this existing bidding process could be improved using BIM tools will be provided.

Key words: QTO-Quantity Take-off, AEC-Architecture, Engineering, Construction, BIM-Building Information Modeling, IFC-Industry Foundation Classes

I. INTRODUCTION

A. *Importance of BIM in Construction*

Building Information Modelling (BIM) has been in talk among all the construction managers. Does BIM mean the same thing to all architects and engineers, construction managers, owners, to facility maintenance personnel? BIM is a process offering noteworthy benefits for a construction project and the project owner: quicker delivery, advanced quality, cost certainty, lesser risk, and more efficient operation.

B. *BIM Quantity Take-off*

Since construction projects are large and complex, it is especially important to provide synchronized construction process to BIM models with construction automation. The schematic Quantity Take-Off (QTO) estimation on the BIM models is a strategy, which can be used to assist decision making in just minutes, because majority of construction costs are determined by designer's decisions in the early design stage. [1]

Resources required:

- Model-based estimating software
- Design authoring software
- Accurately built design model [2]

C. *BIM QTO Tools*

There are various open and registered BIM QTO tools available in the market. Most of them are proposed to be capable of handling IFC files. IFC is supported by about 150 software applications worldwide to enable improved work flows for the AEC industry. BIM QTO tools have the capability to extract required information from BIM like Revit and operate them within their API. Following are the famous BIM QTO tools:

- Innovaya Visual Quantity Take-off
- Vico 3D BIM Quantity Take-off
- Tocoman iLink [3]

D. *Aim*

The Aim of this research is to carry out the quantity take-off (QTO) of Aanganwadi, applying BIM as a tool; and comparing it with its bidding quantity.

E. *Objectives*

- Study BIM concept and benefits with respect to quantity & cost parameters
- Calculate Quantity Take-off of public works project (Anganwadi) applying BIM tools
- Comparative analysis of BIM estimated quantity and bidding quantity

F. *Scope of Work*

- The study area is focused solely on Anganwadi public works project located in Ahmedabad.
- Also this study is focused purely on calculating bidding stage material quantity take-off using BIM.
- Material quantity for steel could not be calculated because of unavailability of steel design, due to contractor's legal binding with the consultant.
- Quantity take-off by BIM will be calculated using Autodesk Revit software.

II. LITERATURE REVIEW

There are numerous benefits available to owners, designers, builders and facility managers through execution of BIM. Followers claim that BIM offers: Better visualization, Better productivity due to easy recovery of information, Increased management of construction documents, Inserting and linking of vigorous information such as vendors for specific materials, location of details and quantities required for estimation and tendering, Increased speed of delivery, Reduced costs, Accurate quantity estimation, etc. [4]

BIM has various applications, some of which are listed below: Visualization, Clash detection, Surveying and machine guidance, Model-based quantity take-off, Model-based scheduling, etc. [5]

BIM is divided into seven dimensions: 3D-Three dimensional model is prepared with the help of Autodesk Revit, 3D Max or any other software capable for improved visualization. 4D-Scheduling of a project relates to scheduling information, when will an element be built! With this information you can enable just-in-time (JIT) delivery of materials to site. This in turn has an impact on transportation, making it more efficient, and reduces storage issues as materials are delivered and immediately installed. 5D-Estimation in a project relates to the estimating quantity

and cost aspects of the building. Each element within the building model has a cost associated with it. This allows for detailed analysis to be done regarding budgets. It also allows the delivery team to make accurate predictions regarding how much needs to be done at any given time in order to meet the construction targets. 6D-Sustainability of a project covers the sustainability targets for a building allowing information such as energy use, sustainability from a materials and management point of view to be understood and leadership in Energy and Environmental Design (LEED) tracking to be performed. 7D-Facility management of a project is the "as-built" BIM model which is important as part of the handover process to the building owner. This model is a fundamental part of the ROI for BIM as it provide accurate Facilities Management (FM) and Asset Management (AM). Each part within the building will have a lifespan and in the event of replacement, the easy identification of parts ensures that these processes may be performed efficiently.

III. METHODOLOGY

This chapter discusses about the method adopted to reach the desired goals in this project. The goal of this project is to examine the uses and benefits of BIM for construction managers and analyze BIM based quantity.

So first the literature review included the definition and the use of BIM and its tools. There is a case study presented in this project to explain QTO using BIM. The case study of Anganwadi, Ahmedabad Municipal Corporation (AMC) project, was used to compare manually estimated quantity and quantity estimated using BIM as a tool. Overall, the literature review and case study provided an insight on the benefits of using BIM and its applications.

A. Work Flowchart

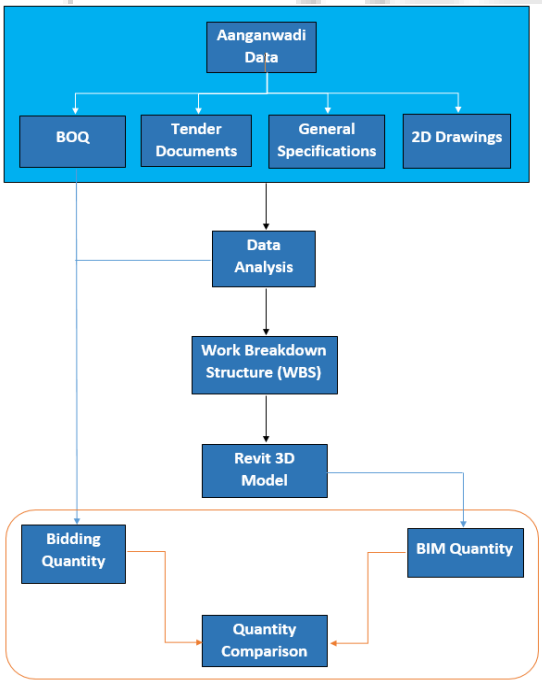

Fig. 1: Methodology Flowchart

For this case study 4 different types of data for anganwadi will be taken from AMC contractor. 1) BOQ, 2) Tender documents, 3) General specifications, and 4) 2D drawings. Data analysis will be performed for all these four types of data and to make the work easy and more understandable, basic work breakdown will be done. A 3D model will be prepared based on the general specifications for anganwadi, 2D drawings and the work breakdown. From that 3D model prepared in revit, direct QTO will be done within revit. At last quantities extracted from revit will be compared with the B.O.Q. of anganwadi given by the contractor. Methodology flowchart prepared for this case study is shown below in figure 1.

B. Modeling Design & Development

1) Walls

We know that walls form a major portion of any structure. Revit makes it very easy to calculate quantities of such high value elements. We can either create all the layers individually or we can make separate parts in a single layer and give them their desired properties like material, colour, thickness, etc.

2) Foundation Wall

Similarly like superstructure walls, one can create foundation walls in revit with utmost ease. Firstly levels are decided in the elevation from the project browser and then superstructure walls are formed above the ground level and similarly foundation walls are created below the ground level. But unlike superstructure walls, the foundation walls can be quite complex to create, because normally the superstructure walls have the same height, whereas foundation walls can vary in depth as per the ground conditions. So some walls might overlap with other walls as one wall's base might strike with other wall's steps at the same depth. This problem is eliminated inside revit.

3) Hollow Core Slab

Certain elements are preinstalled in the revit family while others can be created as per our specifications. For instance revit family only offers regular type slabs and not hollow care slabs. What it does offer is facility to create such elements. To create a hollow core slab, we just have to select a normal slab from revit family, go to edit type, and create changes in the element as per our requirement.

4) Joints

Just like we created a hollow core slab, we can create a joint used in between two precast walls.

5) Doors & Windows

The kind of detailing in revit is extraordinary. For instance if we want to form a window inside revit, we just have to give the window its height and length, and it will automatically assume its width based on the width of the wall on which it is placed. It will provide the window its frame, polish, glass, design, handles etc. Figure 2 below, shows the model of anganwadi prepared in revit.

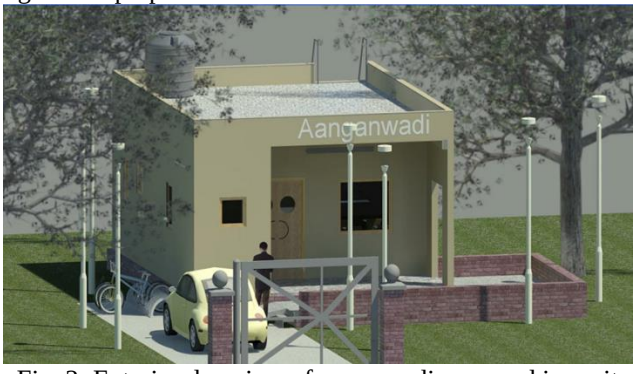

Fig. 2: Exterior day view of anganwadi prepared in revit

C. Quantity Take-Off in Revit

Quantity take-off can be a very complex process if not thoroughly understood. That's why a specialist in quantity surveyor is hired in any construction project to do this task effectively and accurately. But what if a person who is not an expert in taking out quantity want's to find out quantity of constructing a particular structure. Well revit makes this job very easy. If you know how to prepare a model in revit, some of the other tasks like sheet creation, scheduling, and material quantity take-off becomes very easy.

If someone wants to find out material quantity for doors in particular, then revit will filter out all other materials and will show quantity for all the doors that were used in that particular structure. This might not seem like a big deal when only total quantity of any structure is required. But this tool can be very useful when there are some changes in the structure later on in the execution stage. For example, initially there was a wall with a door, and later on it was decided that the door is to be removed and that part is to be kept as an opening in the wall. At that time one can simply go to the 3D model and delete that particular door, and necessary changes will be made in the quantity take-off for doors. Figure 3 below, shows a standard material take-off window in revit.

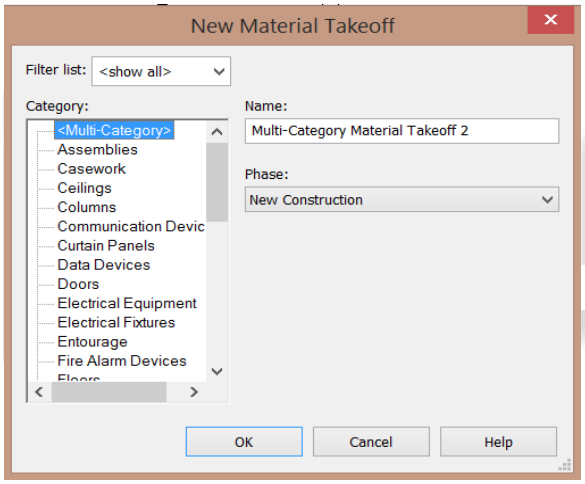

Fig. 3: Material take-off window

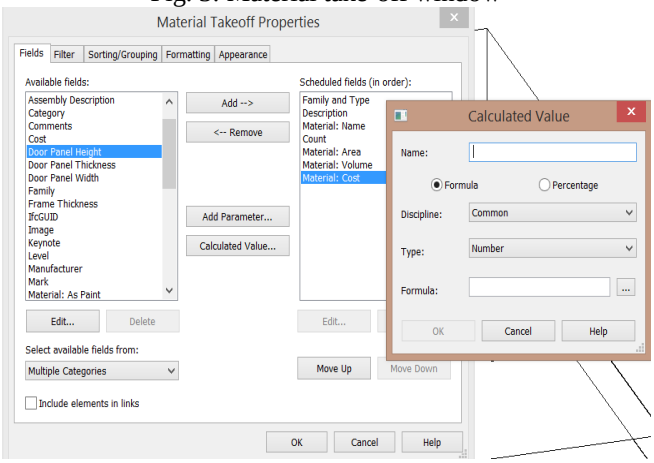

Fig. 4: Properties window

Revit also offers some other facilities while taking out material quantity take-off. There is an option called "sorting/grouping" in material take-off properties. This option allows you to sort material take-off on the basis of any category of your choice. Another option called "calculated value" allows you to apply any formulae to any field. This can be very useful when someone wants to add a separate parameter other than the ones offered by revit. Figure 4 below, shows material take-off properties window in revit, where abobe discussed facilities can be seen.

IV. DATA ANALYSIS

The standard estimation process followed for this case study consisted of 2D drawings and general specifications as an input, output being a fully finished product in the form of anganwadi structure.

But for this case study all the drawings were not available, and also the ones which were available were not highly accurate. So sometimes a proper assumption had to be made in order to get the work done. Also all the structures will vary according to their individual sites, so there will always be minor variations in the estimated quantity.

So the first step of analysis was to properly study all documents and drawings. Based on that a basic work breakdown structure was prepared in order to minimize the mistakes. Based on WBS, a step wise process will be followed to reach the end objective. The entire process was divided into 3 levels. First was the sub-structure level, then would come the super-structure, and at last would be the finishing work. The flowchart below in figure 5 shows WBS for the model prepared in revit.

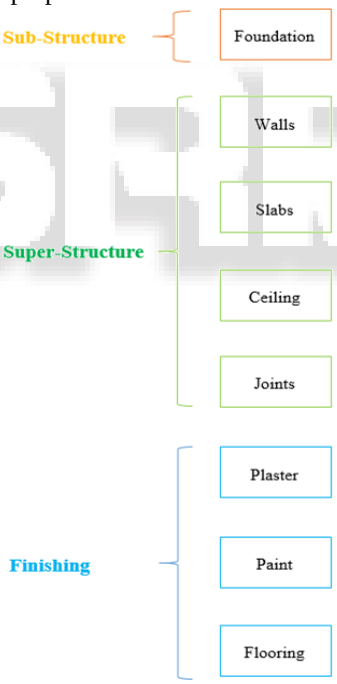

Fig. 5: WBS

V. RESULTS AND DISCUSSION

A. Results

After comparing the two costs, one obtained manually and other using revit, there was an observable difference of around Rs. 39,000 in the two costs, which incured for around 8% of the total project cost. One can do the math, for large projects costing crores of rupees, how much difference this can make to either parties. Figure 6 & figure 7 shows the quantity and cost comparison for some quantities with notable differences. It can be seen from figure 7 that there is no bar attached to the internal plaster field, this is because of

the fact that the contractor's B.O.Q. i.e the manual quantity did not include quantities for internal plaster, due to whatever reasons known to them.

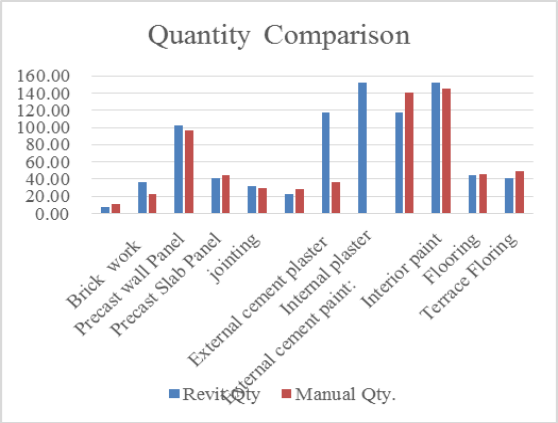

Fig. 6: Quantity Comparison

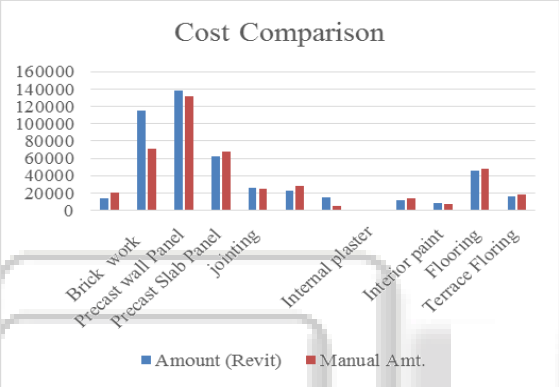

Fig. 7: Cost Comparison

B. Discussion

BIM is a very useful tool when it comes to estimating quantities. But it can be even more useful if used for the entire project, including coordinating different parties, scheduling, material ordering, value engineering, just in time, etc, i.e. BIM is most useful when used as the base of planning. Here BIM was used for a simple structure, but if it comes to using it for more complex structures like multi storeyed parking structures, high rise buildings, or water retaining structures, then more coordination would become necessary between different parties. It was found out that steel detailing is quite a complex process to involve in BIM modelling, so when it comes to designing a model for structures with high quantities of steel, only experts will be able to do such detailed work, and someone with basic knowledge in 3D modelling might not be enough. Also for accurate estimating purposes, it is quite necessary that all the documents and drawings are available to the modeller. A proper work breakdown structure is absolutely necessary, so that when the model is being designed, it is as per the requirements of the project, because final quantities also depend on the way the model is formed inside a software, and not just on the materials.

VI. Conclusion

The level of detailing in quantity take-off offered by revit is due to fact that it extracts quantities based on materials and not based on elements, i.e. a door is element and wood used to make that door is the material. It also consists of some other materials like a steel handle, sometimes a glass panel, etc. So revit will show quantity of each of these materials separately. This can be helpful is some cases whereas confusing in other cases. The type of quantity take-off required on the sites in construction industry is quite different from the one offered by revit. This problem might be solved by some of the other software's used primarily for quantity take-off only, which were mentioned in the fourth chapter.

One of the major advantages offered by BIM when it comes to quantity take-off is change detection. The way this works is, when any change is made in the 3D model, necessary changes will be made in the quantity take-off at the same time. Any changes at any time in a project can cause delay and account for major changes in the final cost. Especially in manual estimation this can mean hectic work for the estimator. Because a small change in one element can affect many other elements at the same time. This can also cause some errors from estimator's side.

Also BIM helps in making better coordination between different parties. This is because all the parties will deal with the same model, and as a result all will be aware about the quantities falling under others. For example the contractor knows the quantity of material to be ordered from the supplier and vice-versa.

From the results of case study shown in the last chapter, it has been found that BIM is pretty accurate in calculating quantities, and very a useful tool for pre-bidding estimations because of the ease with which one can extract quantities from it. Also a variation of around 8% in the final cost was observed which can result in huge loss to any one of the parties. Especially for small companies which are in their developing stage, such variations in estimate can finish a company's carrier in a single project itself. So BIM can be very useful to give a better idea about the overall cost of a project, and whether it would be profitable to bid within the tender price or not.

VII. Future Scope

For this study due to some of the limitations, BIM was used to takeout quantities of materials excluding steel, but if someone can access steel designs of any structure along with other details, then a detailed quantity estimate can be prepared using BIM in the future. Apart from this if there is no restriction of time, someone can also use it for quantity take-off and scheduling, to use it for planning purposes. BIM offers a very important facility of Just In Time (JIT), so someone can show how useful BIM is when it comes to ordering of materials. If someone has a knowledge on how to apply BIM for sustainability, than it could be very useful for future projects of energy sustainability and eco-friendly structures. BIM is not only applicable to structures under construction, but also for maintenance purposes. So to show the effectiveness of BIM in the maintenance field, someone can undertake a project for use of BIM in maintenance. Above all if someone has detailed knowledge of BIM or knows someone of that kind, than a thesis on BIM applying all its 7 dimensions on a structure can be adopted, in order to show full extent of BIM in the construction field.

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