BIM-based estimating and its applications in support of cost estimation and cost planning

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Abstract

For construction estimators, Building Information Modeling (BIM) is currently a trend that presents challenges and opportunities, particularly in the area of quantity take-offs, cost estimating and planning. BIM's capability of automating measurements through extracting quantities directly from digital models represents the key benefit for estimators. As industry has started to adopt BIM-based estimating, cost estimators are yet to integrate the comprehensive use of BIM into their practices. The process is slow and not standardized, due to multiple software packages and many existing industry practices. The paper review and analyzes BIM and its potential applications to quantity takeoffs and cost estimation. The investigation will ponder on various software packages to support the cost estimating processes for budgeting purposes including Solibri Model Checker, Autodesk Revit QTO, Autodesk Navisworks Manage and briefly reviews of others. It is concluded that the project stakeholders must agree on a set of requirements which is defined from cost estimating standpoint to enable the quantity take-off professionals to use BIM more effectively.

Keywords

BIM-based estimating, quantity takeoffs, cost estimating, cost planning, software packages

Introduction and Background Information

While implementation of Building Information Modeling (BIM) has been a major industry focus of recent years, the construction industry vision is shifting and looking at the broader vision of Virtual Design, Construction, and Operations (VDCO) and high-level metrics. The construction industry should bring all the strategies, tools, and technologies together to profoundly reduce waste, significantly improve productivity, reduce total cost of ownership, and create a sustainable environment for continuous future improvement, all of which will make the needed changes attractive to investors to accomplish rapidly. This paper is intended to identify challenges in the critical area of cost estimating with the BIM applications for its use toward a more efficient estimation process and to support cost planning. The dedicated issue of this manuscript is to meet these ends on the perspective that industry must dedicate and create a framework to assist practitioners in the standardizing a BIM-based cost planning and estimating process.

Various computer-aided-design (CAD) vendors have been promoting their 3D modeling software as though it is synonymous with BIM. However, it is important to recognize that they are not the same thing, although a BIM could certainly include the data comprising a 3D CAD

model. Conceptually, a BIM would include all sorts of additional data about a building that goes well beyond the graphic information needed to generate a 3D CAD model. Ideally, a BIM would include specifications and cost data for each building element, as well as ongoing maintenance data that would be useful during the life-cycle of the building.

BIM's capability of automating measurements through extracting quantities directly from digital models represents the key benefit for quantity and cost estimators to speed up the traditional estimating process. In order to measure progress and improvement, the practitioners are in advantage if they are able to adopt a set of high-level metrics. Comprising a 3D model of a building would be expanded to include all sorts of additional non-graphic data about the building, and all the data would be contained and maintained in a single database. According to this concept, the BIM would include all the quantities of all the materials and products needed for the building, so if the cost of each material were added to the data, the BIM could be queried for a detailed cost estimate. In similar fashion, all the necessary specifications data would be attached to the respective building elements in the BIM, allowing a complete set of specifications to be generated on demand. In theory, the advantages of a single-package BIM would be considerable, including greater efficiency because of the elimination of data duplication. BIM modelers may be asked by cost estimators the followings:

1. Could specification documents and cost estimates as we currently understand them be eliminated and replaced by new functionality in a well-developed 3D model?

2. If not, is it possible for estimators to add enough data to a 3D model to effectively generate the specifications and cost estimate documents?

Unfortunately, the author's opinion of the answer to the first question is negative. Because a 3D model contains objects representing building products with attributes that define their properties, there could be sufficient information in the model to eliminate the need for specifications and a detailed cost estimate. However, there are many other factors to consider in both applications. Specifications cannot be eliminated as long as construction contracts require human-readable documents that establish legal requirements governing the obligations of the parties to the respective contract. A formal cost estimate might be eliminated by the owners initially, but it is difficult to believe how they would propose to eliminate the need for a detailed and accurate cost estimate prepared by the contractor that results in a formal proposal or bid and subsequently generates a schedule of values for payments. P.A. Zhao and C. C. Wang[1] analyzed the effectiveness of various working methods by comparing traditional and BIM-assisted cost control methods through a case study in China, and then explored how to utilize BIM to better facilitate construction cost control process.

Aim and Objectives

This paper key objectives are to review the BIM in general and its application to cost estimating and quantity take-off generation from building objects. Also, the intent of the author was to examine the measuring standards that may be adopted for both cost estimating and conceptual cost planning for construction companies that use a parallel process along with traditional process in estimating. In this sense, developing and understanding information requirements for BIM models in support of cost estimation and cost planning is becoming critical. The paper is addressing a review of technical features for major BIM-based software tools that support rules

of measuring order of cost estimating. The investigation on various software packages of BIM tools to support the estimating processes, cost estimating and cost planning for budgeting purposes will look into features related to these areas, specifically software tools to be investigated include Solibri Model Checker, Autodesk Revit QTO, Autodesk Navisworks Manage and briefly review Modelogix within Vico software (Trimble Buildings).

Solibri Model Checker

The main features of Solibri Model Checker (SMC) are making this software quite unique to the market and especially to the estimators. The followings present these features with their peculiarities[2]:

- *Advance clash detection and management*: automatically analyze and group clashes according to severity. Clashes are determined between structural elements and other components of systems within buildings. Relevant problems can be quickly and easily found; therefore the quality of the BIM files can be investigated.
- *Deficiency detection:* Preventing issues in advance. User can relate for SMC to its logical reasoning rules in order to search for components and materials missing from the model.
- *Verify matching elements in architectural and structural designs:* Use SMC to locate flaws and exceptions in models made by different design teams. Expensive rework by knowing both models match can be avoided.
- *Managing change orders or design versions:* Manage and track changes between two design versions of the same model. Easy visualization and verification of model changes can save time (example in Figure 1).
- *Instant BIM data mining*: The user is assured on the quality of information in BIM designs. Then SMC is used for easy and instant information takeoff. Multiple report templates may be used that best suit the user role. SMC is capable of measuring spaces and materials on the fly and share this information with others.

Solibri Model Checker (SMC) helps find and visualize issues and problems before and during construction. It also provides a wealth of information that can be taken off throughout the building's life-cycle and utilized for needs that include area calculation, accessibility and building code compliance.

Regarding Takeoff and reporting, SMC is capable of generating the following information:

- Calculate basic quantities: dimensions, areas and volumes
- Customizing listing functionality
- Lists any properties for any set of components
- Listing is integrated with 3D view with visualization and zoom-in functionality
- Customizable report templates and possibility to use Excel functions with them

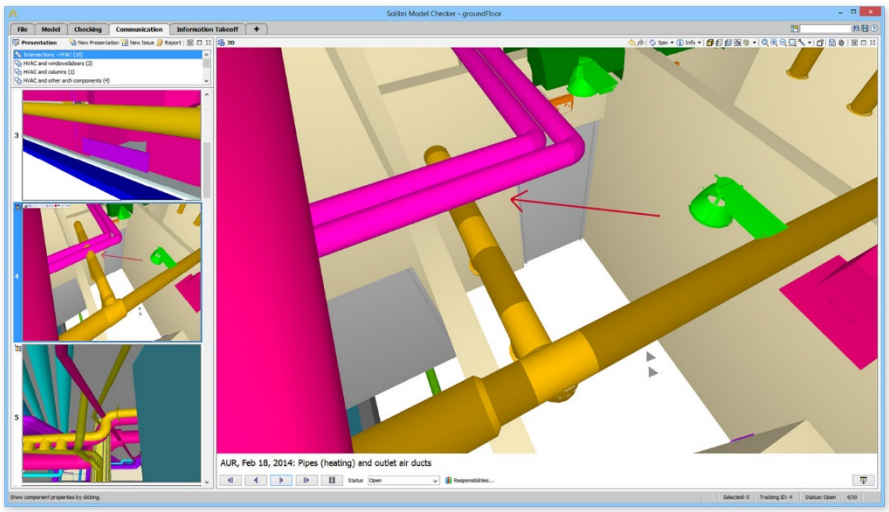

Figure 1. Easy visualization and verification for model changes

In order to make sure BIM model produced by architect or designer is up to the desired standards, SMC is an effective application to help cost estimators to perform checks first before the quantity takeoff process. Users of this program can either select from the range of parameters, rules and standards predefined in the application in order to perform checks to the model or customize the rules based on their preferences and purpose. In general, estimators are able to run quick checks to see if there are any missing components or information in the generated BIM model as well as discrepancies in the design suing the Quantity Take-off rule set in SMC. After identifying potential problems and errors, the estimator can later transfer the results to the designer to request the changes be implemented into the design. With this functionality the estimators can ensure that the quantity information to be produced is more reliable and accurate.

Autodesk Revit Quantity Takeoff and Autodesk QTO

Material Quantity Take-off's from Autodesk Revit 2016 allow users to create detailed material quantities directly from the building information model. To increase usability, material take-offs operate very much like schedules or quantities. Even though Autodesk Quantity Takeoff has been discontinued since 2014, Quantity Takeoffs have been incorporated into Navisworks Manage, and therefore works just as well. There is not a 2014 release of Autodesk Quantity Takeoff (QTO) software. Autodesk Navisworks Manage 2014 and Autodesk Navisworks Simulate 2014 software include new rich quantification features built on the trusted Navisworks platform. Customers with Autodesk® Building Design Suite Ultimate 2014 on active subscription can deploy Autodesk Building Design Suite Ultimate 2013 as a Previous Version entitlement through subscription, allowing access to Autodesk Quantity Takeoff 2013[3].

Some of the inabilities for Autodesk QTO software are not supporting the model walkthrough and section cutting, although it does not have a serious impact on quantity take-off process or estimating process in general. However, having these capabilities in place is effectively improving the accuracies of cost estimates by helping estimators to understand the internal components or other items which might have cost implications but are not modelled within the BIM design (Figure 2).

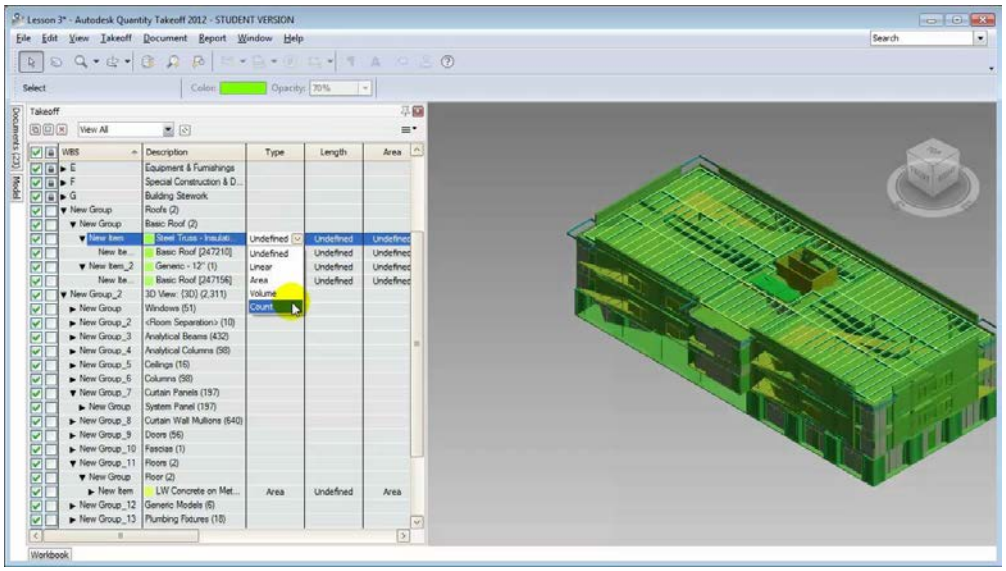

Figure 2. Autodesk Quantity Takeoff extraction for a commercial building

Known as the only cost estimating tool produced by Autodesk, the application is able to support great level of integration with Revit model. However, Autodesk QTO which only operates as cost estimating software does not contain any checking feature that helps the estimator to assess and examine the quality of information within the model. This application is also not able to detect any duplications or missing quantities in the BIM model.

Navisworks Manage and Navisworks Simulate are in the Autodesk Building Design Suite Premium and Ultimate editions, respectively, and include new rich quantification features built on the trusted Navisworks platform.

Autodesk Navisworks Manage

The Navisworks platform is the starting point for aggregated model-based workflows, and a natural place for users to focus on building an integrated set of quantification, coordination, planning, and project review tools. This strategy provides a strong platform to help address the customers' demands for 5D workflows.

Some of the new takeoff capabilities created in Navisworks Manage 2014 and Navisworks Simulate 2014 are explained in this section. In both Navisworks Manage and Navisworks Simulate 2014 releases, the estimator can bring quantities from an aggregated model into a project. The user can also mine quantities from model properties and create placeholders for non-modeled items. In addition, the user is capable of connecting quantification data to model objects without properties. This ability to go from high-level detailed models to virtually

no details and still allow for more accurate quantity takeoff supports the entire project team, from design to field execution. The Navisworks quantification feature functionality includes:

- Item and resource catalogs (Figure 3)
  - Import or create item and resource catalogs
  - Associate items with resources
  - Use formulas in catalogs
  - Export catalogs
- Model takeoff
  - Automated takeoff from object parameters
  - Manual takeoff for modeled objects
  - Virtual takeoff for non-modeled objects
- Workbook (Figure 3)
  - Quantification reporting
  - Export to Microsoft Excel spreadsheet software
- Change Analysis

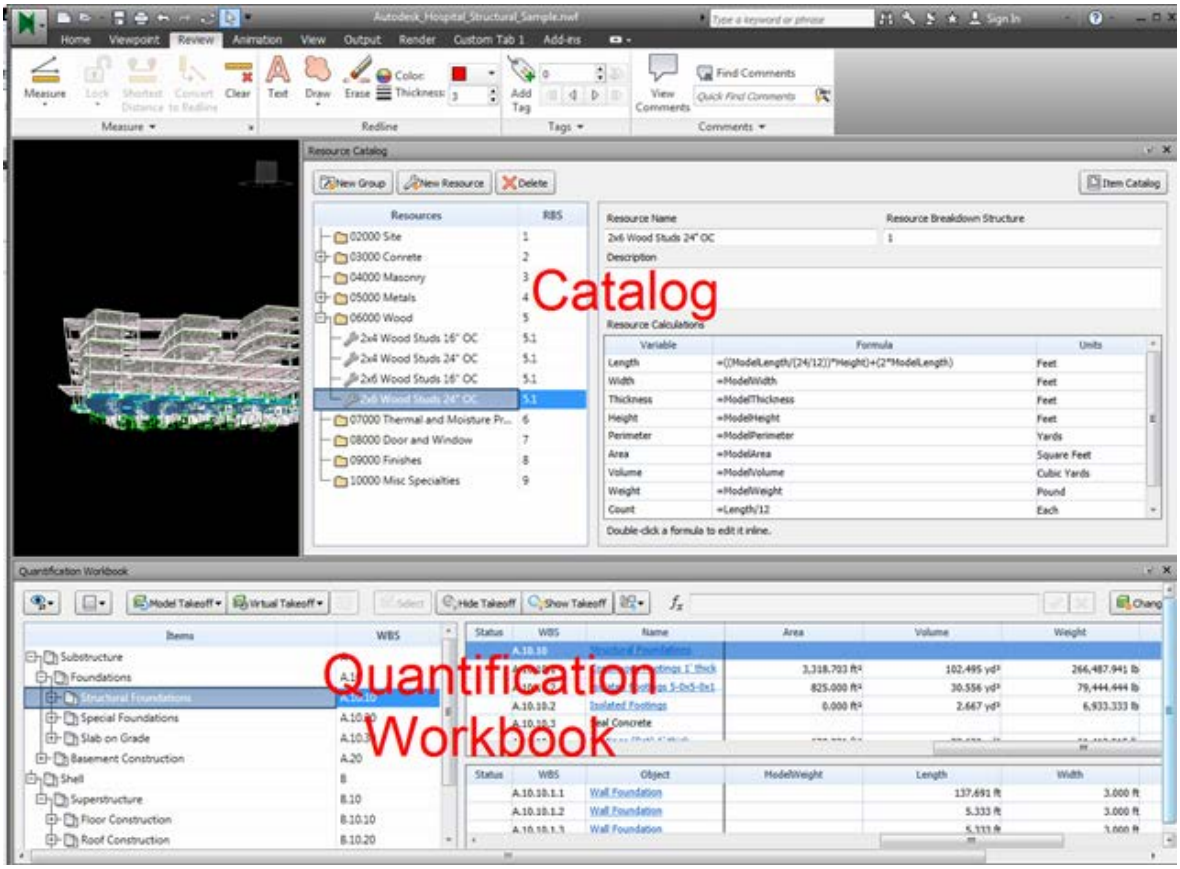

Figure 3. Quantification feature and its functionality in Navisworks

The quantification workflow is enabled by leveraging items and resource catalogs. These catalogs enable the creation, classification, and management of objects and their properties for detailed quantity take-offs. The items are associated with resources. Both items and resources can use formulas to add detailed quantities that leverage model properties, manual calculations,

or virtual quantities for things that are not modeled. A workbook is also included that creates a running report of all quantities in the model, aggregated according to the item and resource structure, which can be exported for downstream workflows including use in widely-used estimating applications. Lastly, the quantification capabilities also enable a change management workflow, where updates to models can be analyzed, compared and tracked to help see and take action on where designs or properties have changed quickly and easily for the purpose of quantification.

Comparing the quantification features in Navisworks with the one discontinued from Autodesk Quantity Takeoff, the users reported that Navisworks Manage and Navisworks Simulate 2014 releases include quantification features built from the ground up, based on intensive customer and user feedback and the experience gained with the Quantity Takeoff product[1]. These features enable more customers to bring quantities from an aggregated 3D model into a project. The Navisworks platform currently does not support 2D takeoff. However, quantity estimators recognize that 2D takeoff is still a very important part of a number of estimating practices and therefore Autodesk decided to continue to support Quantity Takeoff 2013 as a stand-alone product.

Regarding compatibility and interoperability users are able to integrate Autodesk Quantity Takeoff with third-party estimating software applications; Navisworks offers a comprehensive API (application program interface - a set of routines, protocols, and tools for building software applications) that supports integration with third-party software applications. Also, Autodesk Quantity Takeoff 2013 integrates with 2014 versions of Autodesk design products such as Autodesk AutoCAD, Autodesk Revit Architecture, and Autodesk AutoCAD Civil 3D software.

Modelogix

So many times the estimators are racing when a new bid is due. In the rush to get everything completed, they divide up the work and everyone pours over their section of the project, calling on assumptions made in dissimilar spreadsheets, recalling good and bad experiences alike with different subs, and dialing up years of experience in the market. As the deadline emerges, the estimators stitch the pieces together and organize the final estimate. Sometimes, there's time to spot check it, but most often there is not enough time. Then the questions arise: did they miss anything? Did they forget to consider something? Who double-checked that part on the estimate? Modelogix is proposing a different way of approaching each new estimate. The software capture all the rich experiences teams of estimators have had over the past years. It is capable of organizing all the past projects with their inaccuracies and the ones that won the bids. It is very helpful to an estimating team if they are able to create a composite estimate based on all similar past projects a company has delivered. Basically Modelogix is the missing link between your past projects and your new bids. Using past-project data, the estimators are able to create new cost models for feasibility budgets, benchmark new estimates and identify pricing variances, and even sanity-check a new budget to ensure that all scope is covered. By better understanding cost variances, company estimators can better identify project risk, suggest value engineering ideas, and even present multiple options to an Owner. And in bid situations, creating these helpful options illustrate your firm's knowledge, experience, and partnering capabilities.

Modelogix[4] is a stand-alone application with a MS SQL database engine. This means it works with every construction-estimating solution in the market: WinEst, Timberline, Vico Office, MC2, US Cost, and even with Microsoft Excel.

The following steps represent the way this software is working:

1. First Modelogix organizes the key past projects into a searchable database. And it doesn't matter if those estimates are in WinEst, MC2, Timberline, or even Excel – it can map the correct fields and values. The software is capable of handling information from a state-wide, nation-wide, world-wide project portfolio according to any number and combination of attributes. For example, it can show all the hospital projects completed over the last fifteen years with more than four hundred beds.

2. Secondly, Modelogix normalizes project data for geographic cost variances and even inflation variable. This means that every project is relevant and every project has valuable pieces to learn from. Therefore, estimators have a way to compare apples to apples to apples no matter the materials, labor, and equipment costs per region is.

3. The third step is to compare new estimate to the costs from these similar past projects. The estimator only has to be certain all the scope is covered, check for variance, run the quality assurance protocol, not a random spot check.

4. Finally, the software can output compelling reports that Owners may appreciate by creating side-by-side comparisons of similar projects, complete with easy-to-read charts and graphs in just a few hours[4]. (See Figure 4)

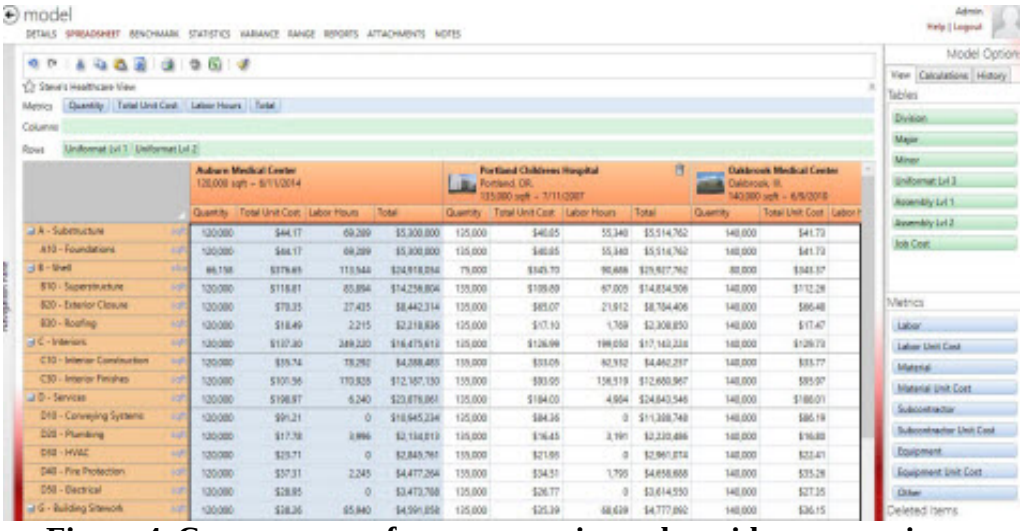

Figure 4. Compare costs from past projects alongside a new estimate.

Meaningful Interoperability through Standard Taxonomy

After reviewing all these software packages, it seems that what is missing from the market at the moment is an actual viable standard taxonomy that every construction software application could use as a template for mapping its own data. Such a standard taxonomy would have to include properties and values, in addition to product names and in order to achieve meaningful interoperability. Cost estimating procedures differ from company to company and most of the time it is proprietary information. It is not enough to know that an object is a door or even to know its dimensions. To specify it or estimate its cost, we need to know what it is made of and

how it is made. The material as wood or metal is making a definite difference. If the door is fire-rated or sound-rated is also important to know. Type of finish does it have is also another category of information that may affect directly the estimate.

The idea of meaningful interoperability does seem to hold a lot of promise and we can all imagine a near future in which an architect can design a building in three dimensions, assign properties to the various building elements as the design is developed, and then the cost estimator work with the same shared software to generate a detailed quantity takeoff of materials, produce a complete cost estimate, and print a finished set of specifications. This paper related here a few applications available today that have made a couple of steps toward true interoperability. It is now possible to query the comparative data for conflicts and then click on a conflict area to see the location of the mismatch within the affected application. Underlying the interoperable system should be a standard taxonomy of data that allows any building assembly or product to be classified, both by its name and its relevant properties. When such a system becomes available, the next challenge will be to change office practices to take advantage of the new technology.

Conclusions

The review of technical features of various software packages that have a quantity take-off and cost component for estimators on the types of measurements a BIM model can generate is valuable to the construction industry and to estimating departments within large or small scale companies. Because estimating procedures and their workflow vary from business to business, a couple of alternatives are provided and, therefore, this paper has reviewed the well-known tools in the United States market. Specific scenarios from a number of available scenarios must be analyzed and appropriate tools must be considered based on time savings generated with automatic performance and generation of cost reports and accuracies required in the bidding procedure. Some of the key benefits offered with this paper are increasing awareness of new BIM technology among estimating professionals and providing quick guidance to select an appropriate BIM technology. Another category in this industry that may be benefited are design professionals due to the fact that they may be better guided in their design process by information requirements generated from estimators' perspective. Also, software developers can be further guided by construction professionals and practitioners to improve their products in order to support more and more cost estimating and cost planning for general or specialty contractors.

As mentioned before, BIM-based estimating can be executed in three different ways: by exporting the measurements to spreadsheets, by directly linking modeling tools with estimating software plug-ins and by using specialized BIM estimating tools. To obtain greater accuracies for plans and specification development phase, BIM-based estimating tools rely so far on the fact that the project has been defined to the estimator, the quality of information included in the model and the details of the construction methods presented in the plans and specifications by the designer, contractor and/or architect. BIM may not be able to resolute on all quantification issues or support a comprehensive knowledge for taking-off all of the required quantities, however through a standard taxonomy for estimating it can enrich effectiveness and improve accuracy on the process. This research explored the information requirement of BIM-based models to support cost estimating and cost planning and it provided overall guidance for

experience estimators on how the quantity information extracted from a BIM model can be used effectively in cost estimating and planning.

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