# Rethinking the Cost Estimating Process through 5D BIM: a Case Study

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## ABSTRACT

This paper presents a comparative study of commercially available BIM-based estimating software, and an investigation of the changes in work practices and workflows incurred by the adoption of such software by a construction company. Due to the fragmentation of the construction industry and the linearity of the design process, cost estimating is typically performed at a time when the conceptual design is quite advanced or even completed, which is much too late in the design process to help the different stakeholders make informed decisions. Performing value engineering and cost estimation from the beginning of the design process would potentially enable a faster and more cost-effective project delivery process, higher quality buildings, and increased control and predictability for the owner. This research examines the changes in work practices and work flows within a construction company as they move towards adopting Building information Model (BIM) estimating process. To conduct this research, we: (1) tested several BIM-based cost estimating software tools to support different phases of design, (2) evaluated the benefits and challenges of working with this software, and (3) analyzed the work practices and workflows of a BIM-based estimating process within the firm. Finally, we propose a multi-stage technology adoption scenario.

## BACKGROUND

Due to the fragmentation of the construction industry and the linearity of the design process, cost estimating is typically performed at a time when the conceptual design is quite advanced or even completed, which is much too late in the design process to help the different stakeholders make informed decisions. Oftentimes, this cost feedback highlights potential budget concerns and a cost engineering process will be performed to reduce construction costs, often at the expense of building performance and construction quality. Performing value engineering and cost estimating from the beginning of the design process would potentially enable a faster

and more cost-effective project delivery process, higher quality buildings, and increased control and predictability for the owner. Although BIM-based cost estimating tools have been available for some time, only a handful of large construction firms have been able to fully leverage this functionality.

Nowadays, the AEC (Architecture-Engineering and Construction) industry is facing a technological change represented by the transition from CAD-based (Computer Aided Design) documentation to BIM (Building Information Modeling). Unlike the CAD drawings which were limited in information, BIM opens an expanded range of possibilities due to the immense amount of information which can be encapsulated and later extracted from the digital model.

This constructive research is a first step of a larger project to implement BIM in a large construction company. It is aimed at developing a concept of operation for implementing a BIM-based Cost Estimating process in one of their divisions. A main objective of this research was to test various workflows and to evaluate their applicability in this company's estimating departments.

This paper firstly presents the state of the art in BIM-based Cost Estimating. Secondly, it describes the methodology of research and the comparative studies of data and work flows. Thirdly, possible workflows for the new technology adoption at the studied General Contractor Company are proposed.

## Cost Estimating and BIM

Managing cost is an important priority in construction management. Since cost estimating is usually realized at the end of a project phase by different stakeholders using datasets and information that are heterogeneous, it is a highly fragmented, resource intensive and ineffective process especially on large or complex projects. According to literature, variation over 40% with the initial budget is frequent in these cases (Flyvbjerg, et al., 2003, Winch 2010).

One of the BIM promises is to tackle this problem by providing a unique source for cost estimating for the entire lifecycle of the project. According to Kahnzode et al (2007) a 3% cost accuracy could be achieved from front-end cost budgeting to building construction cost. However, the technological and work organization challenges of implementing BIM-based estimating into one of the key stakeholders of the supply chain, the general contractor, is little documented in the academic literature.

## On BIM-Based Cost Estimating

BIM conveys two concepts: the process of a shared development of the design and the collective object, the 3D virtual model produced using BIM enabled technologies. This model is composed of objects that represent the different elements of the building, and data related to each object. These data could be reused to simulate the construction of the building (4D BIM) or to provide quantities in real time for cost estimating (frequently referred to as 5D BIM).

Model-based cost estimating became possible after the implementation of object-based parametric modeling in the building-modeling software. BIM-enabling software programs use parameters and rules to determine the geometry, as well as non-geometric properties and features of objects (Eastman et al., 2011). Type and

cost of materials, cost of elements or assemblies are features which can be assigned to each object of a BIM (model). On the basis of the model, quantities and numbers can be extracted. But, according to Eastman et al. (2011, p. 220):

> "*No BIM tool provides the full capabilities of a spreadsheet or estimating package, so estimators must identify a method that works best for their specific estimating process. Three primary options are:*
> 1. *Export Building object quantities to estimating software*
> 2. *Use a BIM quantity take-off tool*."
> 3. *Link the BIM tool directly to the estimating software*

Options present different levels of interoperability. In the first two options, data are extracted from the model by exporting them using a format that could be read by a cost estimating software, or on the second case, the estimating software has the ability to map BIM objects with the cost database. These offer little or no interoperability capabilities to automate the exchange of data between the model and the BIM-based estimating.

**On the Technological Challenges of Implementing BIM-based Cost Estimating.**

Based on previous experiences (Forgues & Iordanova 2010), as well as on literature review (Tiwari et al. 2009, Eastman et al. 2011), we could conclude that BIM-based estimating technologies are not mature enough. The first challenge is the difficulty to select the right combination of cost-estimating BIM applications. A lot of applications are still mainly developed to address needs for a specific phase, purpose or speciality. For example, one application is dedicated to architects for conceptual estimating and will be of little use for quantity surveyor. There are also major problems of interoperability between software. There are issues in transferring data from these various applications. Another issue is that most of these applications rely on one or few specific external cost databases. Difficult choices have to be made between adopting an application compatible with the company legacy of cost databases and choosing the BIM-based software that best fit the needs.

Another challenge is the difficulty for a member of the construction supply chain to understand the differences and the specificities of each estimating software program offering and make the right choice. Judging from our previous experience (Forgues & Iordanova, 2010), it is unreasonable to rely only on the publicity and the white papers of software development companies because there very often some dimensions of the estimating process remain hidden or unclear. Moreover, there is the risk of interoperability problems related to the choices of BIM applications made by the other members of the supply chain for a specific project.

**On the Work Organization Challenges in adopting BIM-based cost estimating**

Notwithstanding the technological issues, there are also project management and work organization issues to be addressed. Project management theory and practices are based on a taylorist model in which the project is broken down into work package that are divided between resources or specialties (Koskela 2000). The first challenge is that BIM is a configurational technology, i.e. a collective tool around which work has to be reorganized around processes and workflows. A workflow is defined as a pattern of activity enabled by a systematic organization of

resources, defined roles and information flows, into a work process that can be documented and learned. Therefore, to use 5D BIM efficiently, boundaries and barriers created by the linear and fragmented project design and delivery have to be removed.

To achieve this new contractual arrangements have to be made, that promote a proper context for open collaboration and risk sharing in working on a shared model. Moreover, the role of project manager becomes obsolete. New skills, such as the ones associated to organizational architects, may be required to devise and integrate the members of the supply chain processes, workflows and data flows (Forgues, Lejeune in press).

A second challenge relies on the lack of maturity in the development and integration of the BIM-based cost estimating tools. They are difficult to "tune" and time consuming at first use. Tiwari et al. (2009) elaborate on the challenges of model-based estimating, pointing out that the more difficult part of this process is the cultural shift and training required. According to this author, "estimators must be thoroughly trained in the software and run test cases to make sure that the information coming out of the model is accurate and can be trusted".

A third challenge is the organization and integration of the workflows between 3D, 4D and 5D applications. Extracting data from 3D model could be misleading. Elements could be missing or there could be anomalies in the 3D model that will alter the quality of the estimate. Temporary structure and equipment are also not taken in account in the 3D model, so they will not be accounted for in the quantity take-off.

Most companies using CAD design their workflow in a way to match the use of this technology. A change in technology involves a major challenge since it will influence all business processes in depth. In order to take advantage from the BIM-modeling, a coherent dataflow has to be established. It can depend on the project context as well as on the company's expertise in modeling and cost estimating.

The application of BIM in the estimation process is often called "5D BIM." Some authors, though, find that a 5D model can only be built on the basis of a 4D one including time and constructability analysis (Staub-French & Khanzode 2007). In the context of this article, the time component is not studied, but only taken into consideration as absolutely necessary for precise cost estimating

## METHODOLOGY

This is a constructive research approach (Lurka, 2000) with qualitative methodology similar to action-research. A theory is defined and validated within one or more case studies. This approach is quite popular in information technology and is used for research in construction in Finland (Rekola et al. 2010). The core principle is that the researcher is intervening on the existing practices with the aim of transforming it based on the supporting theory. Koskela's (2000) TFV (Transformation-Flow-Value generation) theory is used for this case.

The case study was realized with one of the largest construction company of one of the Canadian provinces. The firm's business lines include building and infrastructure projects. Their aim is to implement BIM in their company practice in order to expand their market reach.

This research is a pilot project to examine the changes in work practices and work flows within this company as they move towards adopting a BIM-based estimating process. To conduct this research, we: (1) assessed company existing practices in estimating and compared them to BIM, recommended processes derived from literature (Eastman et al 2011), tested several BIM-based cost estimating software tools to support different phases of design; (2) evaluated the benefits and challenges of working with this software; and (3) analyzed the work practices and workflows of a BIM-based estimating process within the firm (data was collected through semi-structured interviews).

## BUILDING THE BIM-BASED ESTIMATING CONCEPT OF OPERATION

Developing a concept of operation through the mapping of existing and desired process is a common approach in information technology. The mapping of existing processes outlines a complexity rarely addressed in literature is the influence of the procurement mode on the estimating process, as illustrated in Figure 1.

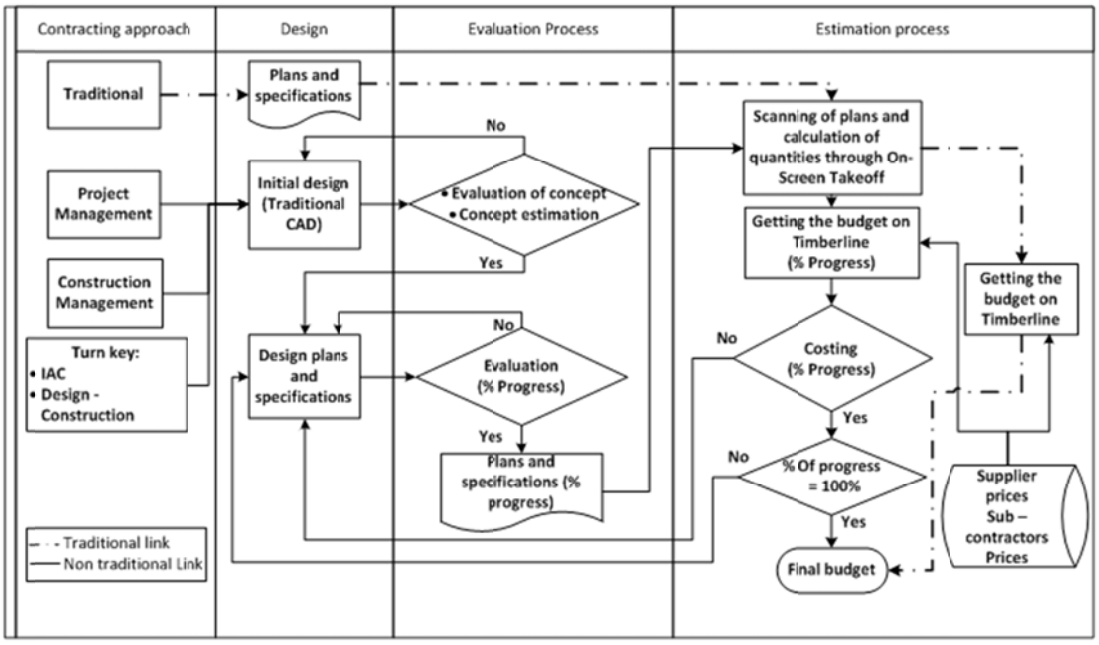


**Figure 1. Cost estimating workflow at the construction company**

In the traditional design-build-build procurement mode, the estimating process is quite straightforward and unsophisticated. Bidding documents are still paper-based and prescriptive. Documents are scanned for on-screen take-off, then quantity data is loaded into the cost estimating software to generate the project budget for validation of the sub-trades and supplier prices. Integrated procurement modes open the door for a more sophisticated process, which includes iterative constructability and cost validations or verifications during the design phase.

An exploration and analysis of various BIM-5D applications on a sample project confirmed observations in the literature that there is still no perfect application

that could meet the need to automate both core cost estimating workflows. To define the desired 5D-BIM state, we evaluated two types of BIM-based cost estimating applications in the design phase. First, at the preliminary design stage, before any models of the building are available – at this stage, 5D BIM tools provide parametric models with default values according to the type of construction; these models serve mainly to compare alternatives, their tools (DProfiler, Smart BIM QTO) are user friendly, and can be used by architect. Second, at a more advanced stage a precise estimation (using Autodesk QTO, Innovaya, Vico, Tocoman) can be made based on a the model – at this stage, cost estimating should also be linked to clash detection, constructability analysis and construction scheduling.

To select the software for the concept of operation, one of the key requirement to be able to exchange with the Company's Timberline database legacy. Figure 1 illustrates the proposed dataflow between applications that address issues related to the existing workflow.

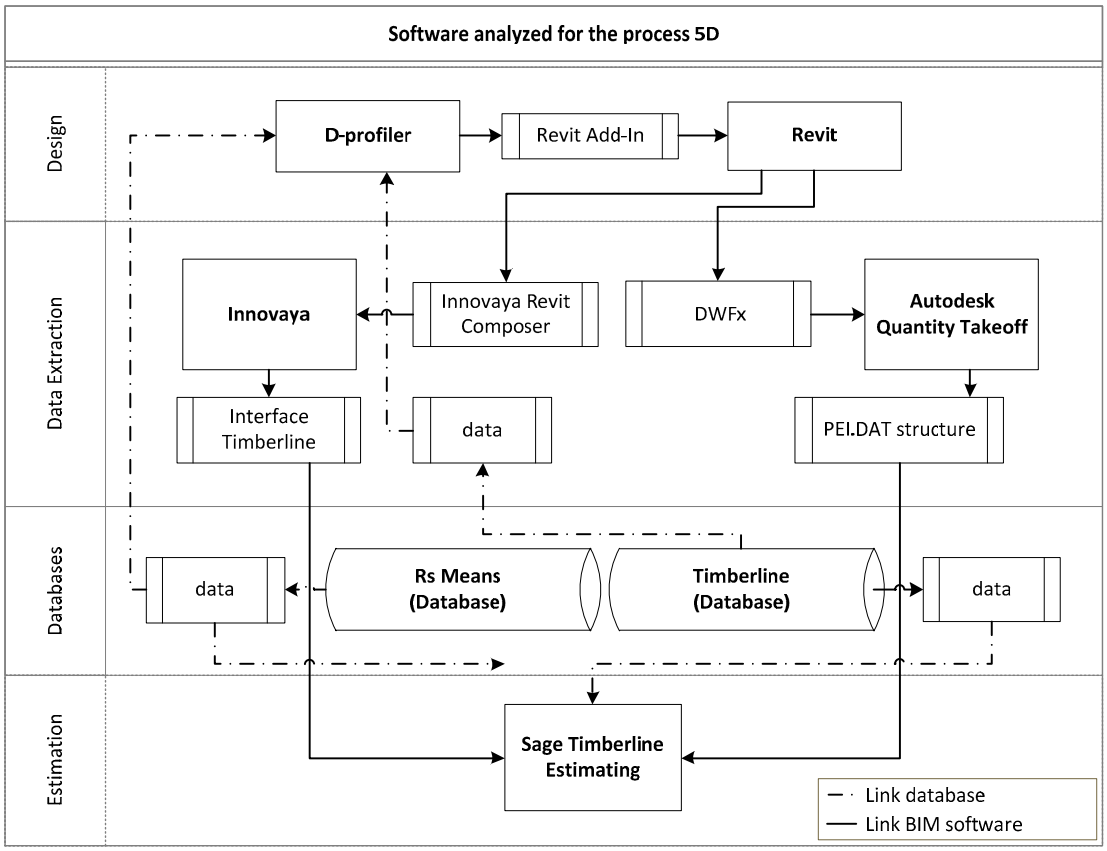


**Figure 2. Interoperability and workflow between BIM 3D, 5D and cost estimating**

Figure 2 presents the BIM-based estimating workflows tested during the case study:

- During the schematic design stage: starting from a D-Profiler parametric schematic model and importing it into Revit.

- During the conceptual and development phases: Data is extracted from the Revit model in two ways: using Innovaya or through Autodesk Quantity Take-off

The links to databases are also shown. In all cases, the estimating is done in Sage Timberline (at the client's request). Several possible workflows were created and evaluated according to the following criteria: the depth of the changes they imply for the company organization; the ability to preserve and assure the future use of the company's know how; the learning curve of the new software versus the features they offer; and the expected productivity improvements. Figure 3 presents the final step of the transition from the initial state presented in Figure 1.

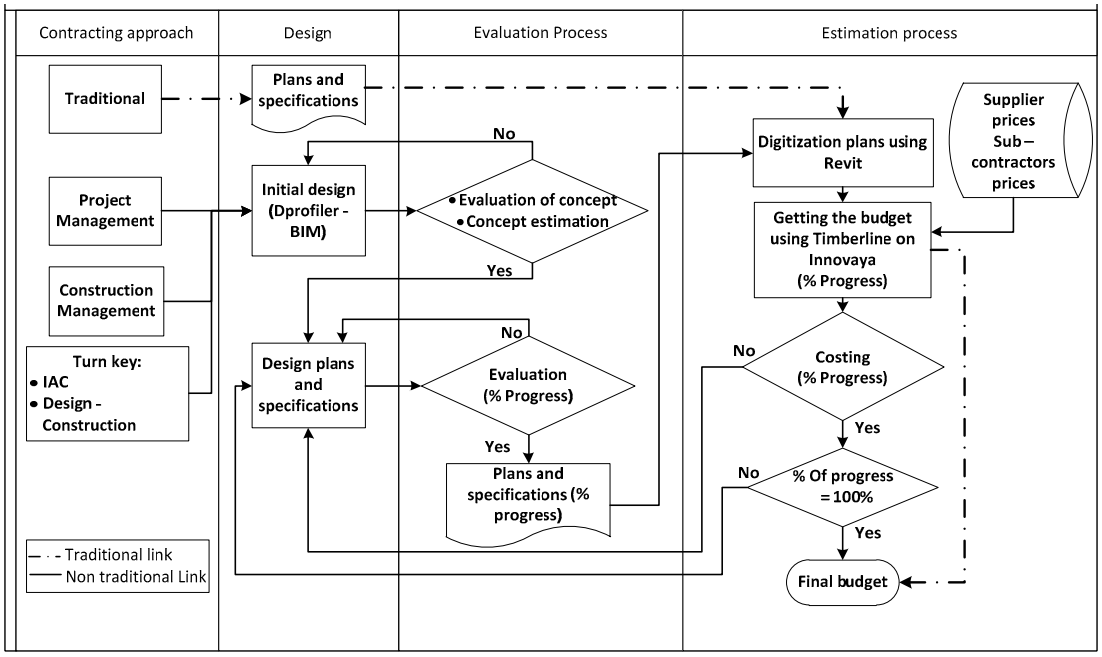


**Figure 3. Proposed cost estimating process**

As shown in the Figure, there are little changes in the existing workflow. A 5D-BIM was selected for the overall estimating process because of its ability to interoperate with 3D software and the firm's cost database legacy. A 5D-BIM application for conceptual cost estimating is proposed for scenario analysis at the project front-end.

## DISCUSSION AND CONCLUSION

The paper presents a first step in a constructive research undertaken with a large construction company with the aim to cogenerate new knowledge of practices regarding the implementation and use of a new set of technologies that are redefining existing practices. This step focuses on a strategic element of the success of such organization: the cost estimating process. It contributes to knowledge by the application of a new research approach derived from other disciplines better adapted to the co-generation of new practice knowledge. It also shed light to practical challenges in implementing advanced BIM capabilities within a construction firm. As

suggested in constructive research theory, the best validation is the endorsement from the industrial to follow suit with the recommendations which was confirmed following the presentation of our results to their board.

As suggested by BIM literature (Recola et al. 2010, Eastman et al. 2011), there are many challenges with automating many aspects of the building estimating process which cannot be described in details in this paper. For example it is very important to understand that we must change the Timberline database based on the parameters of Revit objects and not the other. It is necessary to check for collisions during the creation of the model because the 5D BIM software tools do not detect all the collisions. The use of BIM 4D software (Innovaya 4D, Solibri or Navisworks) can solve this problem. The creation or modification of objects must be made according to construction methods deployed in reality. Although there are many potential benefits to BIM-based cost estimating, there are also certain considerations for estimating at the different phases of design. For example, for the preliminary design stage, an export of the model to another modeling software is needed in order to continue the design from there – which is not available yet with the necessary quality. For the more advanced stage, an import of the building model (including all specialities: architecture, MEP, Structure, Civil) for Quantity Take-off or a direct link to the BIM software is needed. Mapping through rules and formula, visual interaction with the elements and clash detection are essential.

An important challenge is the organizational change provoked by introduction of the BIM technology – a change which should support the systemic adoption of BIM in the whole organisation. At the moment of BIM introduction, as Recola et al. (2010) states: "implementation of BIM creates challenges to the project management as there are many new BIM-enabled options for improved communication, analysis and design coordination but not yet mechanisms, tools or rules-of-thumb for selecting what to exploit, and when, in the most beneficial and cost-efficient way". A process of auto observation, analysis and learning should be set-up in the company in order to guide and control the BIM adoption process.

There are also opportunities to apply principles derived from TFV theory regarding Lean Construction, as explored by Sacks et al. (2010). Some possibilities to automate some elements for the control of the production control were explored and presented. However, it was not possible to go much further in the scope of this four months research project, since considerable practitioner input is needed to set up the software and cost estimating database(s), extract information from the building model in a format that is aligned with the structure of the cost database, and finally to tune the cost estimate according to the specific context of the construction project.

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