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Challenges in Cost Estimating with Building Information Modeling

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Abstract

As a visual database of building components, BIM can provide accurate and automated quantification, and assist in significantly reducing variability in cost estimates.

Exchanging data is a challenging aspect of AEC information technology. BIM applications are evolving and standard formats to organize and share building information are far from fully mature as well.

Overview

Building Information Modeling (BIM) offers a potentially transformational technology through its capability to provide a shared digital resource for all participants in a building's lifecycle management, from preliminary design through facilities management. As a visual database of building components, BIM can provide accurate and automated quantification, and assist in significantly reducing variability in cost estimates.

Exchanging data is a challenging aspect of AEC information technology. BIM applications are evolving and standard formats to organize and share building information are far from fully mature as well. Software applications can employ several methods for exchanging data – XML, APIs, ODBC among them. The method used depends on the phase of the project, detail required, and type of interaction needed between BIM and an external application.

Costing exercises can be conducted throughout the project lifecycle with BIM. The level of detail in the model will vary depending on the project phase. Firms employing BIM will need to develop methods and standards for object development that support the level of detail required for useful estimates, as well as provide a framework for providing consistent information for the BIM components tallied by cost estimators.

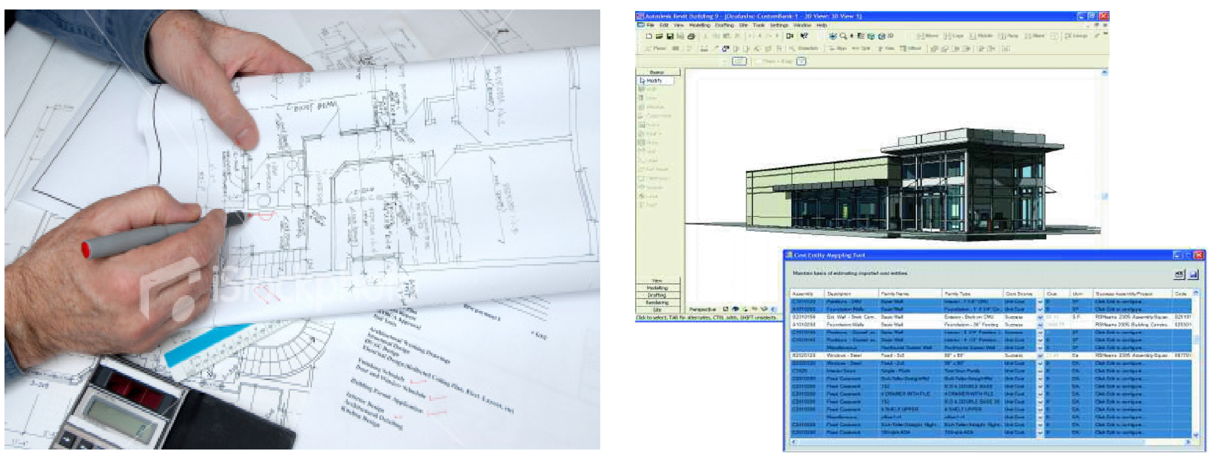

Figure 1: Traditional cost estimating take-off vs. BIM-based quantification[1]

BIM, Cost Estimates and Project Phasing

Cost estimation for building projects traditionally starts with quantification – a time-intensive process of tallying components from printed drawing sets, or more recently - CAD drawings. From these quantities, estimators utilize methods from spreadsheets to costing applications to produce the project cost estimate. This process is prone to human error and tends to propagate inaccuracies that creep into the tallies. Currently, quantification is also time-consuming – it can require 50% to 80% of a cost estimator's time on a project.[2]

BIM offers the capability to generate takeoffs, counts and measurements directly from a model. This provides a process where information stays consistent throughout the project and changes can be readily accommodated. Building information modeling supports the full project lifecycle and offers the capability to integrate costing efforts throughout all project phases. The information in a model and type

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[1] Screen shot from US Cost's Success Application and Autodesk Revit.

[2] *1-2-3 Revit: BIM and Cost Estimating*, Rick Rundell, Cadalyst Magazine, August and September 2006.

of cost estimate needed depends on the phase of the project – ranging from high level schematic models during preliminary phases, to detailed estimates as projects enter construction.

Preliminary Cost Estimates

During traditional (e.g. manual) project development, accurate, actionable costing information has been difficult to define during preliminary project phases. Greater project efficiencies and more accurate scheduling can be developed based on realistic costing feedback early on.

Architects typically do not provide cost estimates on projects as part of their standard services, but the native capability of BIM to quantify and calculate is changing the nature of project deliverables for all participants. Conceptual or "top-down" estimates are the first serious effort to predict the cost of a project and align decision-making with those estimates. Project information at these early stages is usually general and at a high level (e.g. number of occupants, gross square feet area, and enclosed volume).

Preliminary costing is generally based on templates from past project experience, or on standard square foot costs based on project type, region, or type of construction. Preliminary estimates, unlike those created during later stages, are prepared using concepts (e.g. "hospitals cost $ x/sq. ft." or "corporate space standards require x sq. ft. for this project"), and avoid counting of individual pieces.

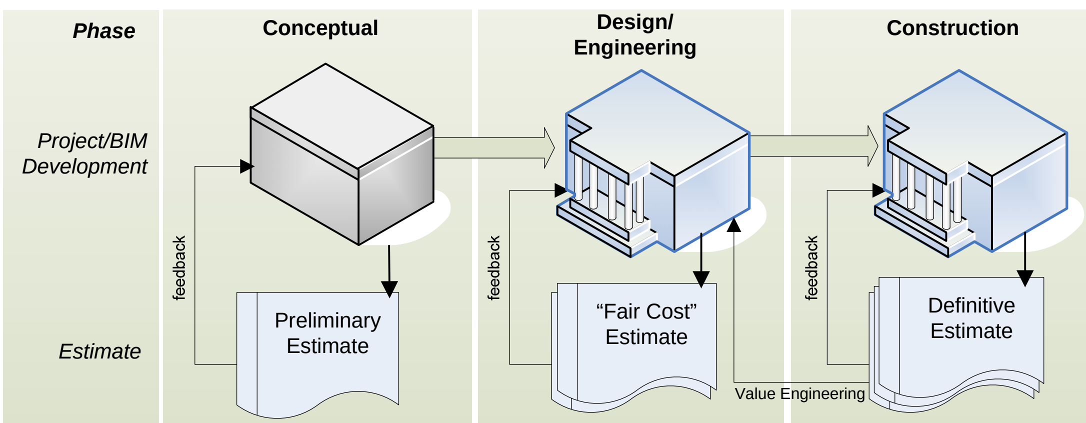


Figure 2: Project and Cost Estimating Process

Standard CAD, and now BIM, applications have the capability of modeling data far in excess of what is needed at preliminary project phases. Detailed modeling can confuse decision-making and scenario planning rather than assist it. Determining what the building information model "is" during the planning and schematic phases of a project involves delineating what information is required to support the decision-making processes at the early stages of a project.

Schematic BIM models are based on simple geometries and need to be flexible and lightweight enough to support many iterations and changes inherent in early project phases. Models at this project stage are generated from functional rules and programmatic requirements rather than geometry and specifications. Standard objects or assemblies ("cells" or "blocks" in CAD) at this phase are generic and less detailed in nature – to be replaced later in the project as the project develops through design development and construction document phases.

Software applications that develop preliminary building models and costing estimates may not necessarily be the same tools used to support the design development and documentation processes that follow (more typically thought of as “BIM”). The same process change that occurs now during project development will still exist in fully automated projects, but improved decision support tools are being developed to assist project professionals earlier on. Preliminary applications should have the capability to export developed information to full-fledged BIM modelers.

Detailed Cost Estimates

Detailed estimates, also known as bottom-up, fair-cost, or bid estimates, are prepared from well-defined design and engineering data. These estimates are generally carried out for bid evaluations, contract changes, work scoping, permits and approvals. As project development progresses from schematic design through contract documents, quantification and costing become dependent on developing objects in the building model in increasing levels of detail and complexity.

Estimate Phase	*Conceptual*		*Conceptual* / *Budget*	*Budget* / *Detailed*	*Detailed*
Estimate Class	5	4	3	2	1
Level of Project Definition *% of complete definition*	0% to 2%	1% to 15%	10% to 40%	30% to 70%	50% to 100%
End Usage *Typical purpose of estimate*	Screening or Feasibility	Concept Study or Feasibility	Budget, Authorization or Control	Control or Bid Tender	Check Estimate or Bid/Tender
Expecting Accuracy Range* *Typical variations in low and high ranges* — Hi:	+30% to +100%	+20% to +50%	+10% to +30%	+5% to +20%	+3% to +15%
Lo:	-20% to -50%	-15% to -30%	-10% to -20%	-5% to -15%	-3% to -10%
Preparation Effort *Typical degree of effort relative to least cost index of 1*	1	2 to 4	3 to 10	5 to 20	10 to 100

*The availability of applicable reference cost data can affect the range marketdly.

Figure 3: Cost Estimating Classification Matrix[3]

The level of detail encapsulated within a BIM object is a judgment area. BIM implementers need to develop standards for representing building elements (objects, families, assemblies) in a model – to what level of detail, at what phase of the project. Elements can be modeled in generic fashion (e.g. “Flush Door”) or to a well-defined level of detail (e.g. “5-Ply Particle Core WDMA Extra Heavy Duty PC-5 Flush Door”). AEC professionals need to develop graphic representations detailed enough to support their documentation effort, without creating a BIM model that is too cumbersome (“heavy”) to update and coordinate.

Objects and assemblies can be encoded with data in a building information model to some extent. Additional information can be affiliated with objects in an external database as well. Costing applications harvest information from BIM objects in various manners – either enhancing object definitions within the model, or using a unique identifier to link objects to more detailed information stored externally from the BIM application in a database such as Microsoft Access or Oracle.

[3] Adapted from *AACE Recommended Practice No. 17R-97: Cost Estimate Classification System*, AACE, Inc., 1997.

Costing efforts require a mechanism to cull component information from the building model for each item in the model - identifying information and quantities, and exporting this data to a costing application. Mechanisms to export information from BIM applications are discussed in the following section. Ideally, the exchange of data between the BIM and costing applications would be bi-directional, allowing evolving design models to retrieve information from costing exercises that result in the need for alternatives and substitutions. Currently, automated BIM costing applications do not accommodate bi-directionality.

Value-engineering efforts, typically undertaken during the construction documentation phase, would greatly benefit from the capability to automate substitutions in the building model from costing analyses. BIM costing exercises throughout the project have the promise of reducing the need for value engineering by supporting the decision-making process with more accurate information, earlier in the project.

Supporting Information Exchange BIM and Costing Applications

Building information modeling offers the promise of a common information repository for all project participants. Multiple parties can tap into a project BIM to derive component information for a range of tasks such as environmental compliance, energy analysis, as well as materials take-off and project costing. Several standard software methods are used by applications developers to facilitate this information exchange between BIM model s and external building analysis applications.

Application Program Interface

An Application Program Interface (API) is a set of routines, protocols, and tools for building software applications. Software vendors provide APIs to give third-party developers the building blocks to develop add-on applications. APIs are one mechanism that can be used to export information from within a BIM application for use by costing applications.

API routines allow costing applications to track the status of objects imported from a BIM model. This allows users to determine whether items or assemblies have been updated since they were last imported, and update costs accordingly.

At present, some developers are cautious about using API toolkits for applications since BIM software has been undergoing upgrades and development at a rapid pace (ergo, APIs are being enhanced and changed regularly, requiring developers to upgrade software based on API interchange more rapidly than other mediums such as ODBC or IFCs).

Open Database Connectivity

The Open Database Connectivity (ODBC) format is a standard database access method developed by Microsoft. Widely accepted, ODBC can be considered a type of API, offering a vendor-neutral mechanism for exchanging data between an application such as BIM and a relational database (RDBMS). ODBC inserts a middle layer, called a database driver, between a calling application (BIM) and the database application, which translates the BIM application's data queries into commands that the RDBMS understands. The goal of ODBC is to enable access to data from any application – BIM or others, regardless of the database management system used.

ODBC offers the advantage of not requiring any special programming or interfaces, as long as the calling application and the database software support ODBC. This simplifies and reduces the complexity of encoding data links to BIM elements. Storing data externally from the BIM applications keeps the model lightweight and allows a more expeditious access to external applications - like cost estimating, that need to use that information.

ODBC is limited by the fact that there is no real-time synchronization between an application such as BIM and the database (i.e. they are not tightly “wrapped”). The user must explicitly run a command to export data from the BIM application to the database. The database has no control over the BIM (i.e. changes in the database cannot drive changes in the building model).

Standardizing Data Models and Definitions

A prerequisite to the success of cost estimating will be consistent definitions and data formats for building objects and assemblies. There are significant efforts underway to develop consistent frameworks for data interoperability in the AEC-FM industry, proving common definitions in a common format for the many participants throughout the building process.

Industry Foundation Classes

The Industry Foundation Class (IFC) is a data model developed by the International Alliance for Interoperability (IAI). It aims to provide a single, internationally accepted framework to facilitate information exchange among participants in the building process, throughout the entire lifecycle.

The capabilities of building information models extend well beyond previous technologies of CAD and generic 3D models which were purely geometric in nature. Geometry is just one of the properties of building entities, but it serves as the primary interface to interact with a building database in BIM. Building information models track information on all of the components that comprise a building, and can range from the very generic to the fully detailed.

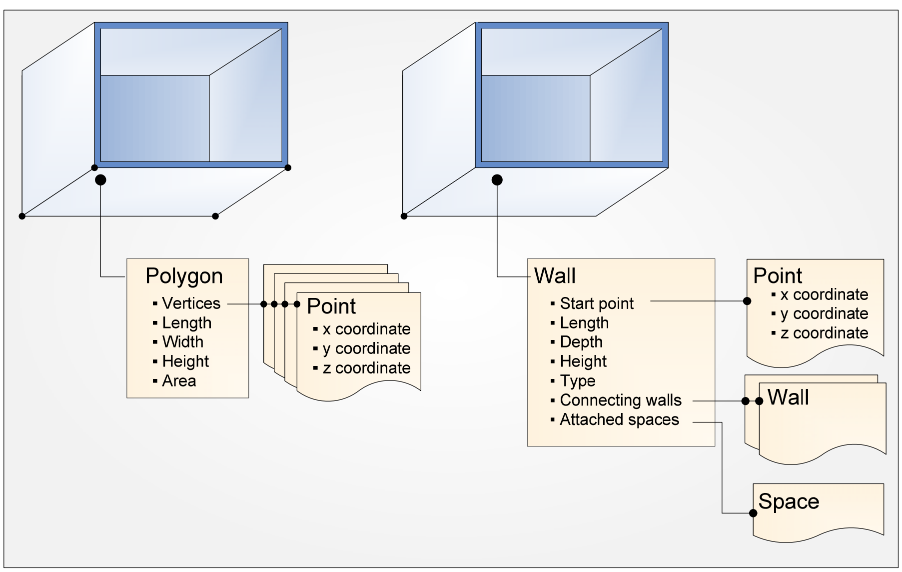


Figure 4: CAD (Geometric) vs. BIM Element Description

The IFC concept is a well-regarded collaboration faced with a complex goal. The effort is being developed by an all volunteer organization for a highly heterogeneous industry. At present, BIM software vendors have integrated IFC exporters within their applications, but the major success of these exports is with the 3D graphic elements. IFC exporting has less success to date exchanging non-graphical properties, complex geometries, or parametrically modeled components.

IFCs may never become *the* standalone unifying model or translation medium for BIM. However, they may have the greatest potential for standardizing BIM data exchange by providing a common set of terms and definitions. IFCs offer a framework for data description, but there will not be an off-the-shelf coverage of all the components needed for a detailed cost estimate in all cases. The usefulness of IFCs may be extended by being used in conjunction with more customized data structures and exchange formats for specific purposes, including cost estimating. At present, commercial cost estimating applications utilize IFCs, but not as the sole channel for information export.

Extensible Markup Language

A more general means of exchanging electronic information is offered through the Extensible Markup Language (XML) format. This is a text-based, platform-neutral superset of web's original HyperText Markup Language (HTML). Whereas IFCs provide a well-structured and detailed framework for building information, XML is a more general means of formatting information that is to be passed from one application to another.

One example of XML's use in a BIM application is to export quantity take-off information to a spreadsheet application. The XML format is used as an exchange medium for a range of building-related schemas. A few of these include gbXML (green building), AGCxml (construction-related data) and CityGML (urban 3d models). BIM data that is in IFC format can be exported via an XML framework, but the resulting files tend to get very large - perhaps prohibitively so (as shown in the example of a small piece of code below).

<table>
<tr><th>Original IFC definition</th><th>ifcXML schema</th></tr>
<tr><td><pre>ENTITY IfcProperty
   ABSTRACT SUPERTYPE OF (ONE OF
      (IfcComplexProperty
      ,IfcSimpleProperty));
      Name : IfcIdentifier;
      Description : OPTIONAL IfcText;
END_ENTITY;</pre></td><td><pre><xs:element name=”IfcProperty”
   type=”ifc:IfcProperty” abstract=”true”
   substitutionGroup=”ex:Entity” nillable=”true”/>

<xs:complexType name=”IfcProperty”
   abstract=”true”>
   <xs:complexContent>
      <xs:extension base=”ex:Entity”>
          <xs:sequence>
            <xs:element name=”Name”
               type=”IfcIfcIdentifier”/>
            <xs:element name=”Description”
               type=”ifc:IfcText” Nillable=”true”
               minOccurs=”0"/>
            </xs:sequence></pre></td></tr>
</table>

Figure 5: IFC definition and ifcXML schema[4]

Standard Taxonomies

[4] Adapted from: *ifcXML Implementation Guide*, N. Nisbet, T. Liebich ed.; February 9, 2005

Developing an automated cost estimate is dependent on using a consistent framework to organize the many components that constitute a building. Several taxonomies - techniques of classification, have been used for years in the AEC profession to organize building information. Methods chosen for use are very dependent on the project phase and detail required. Preliminary phases require a much more generalized organization than the detailed information required during the mature phases of a project cycle.

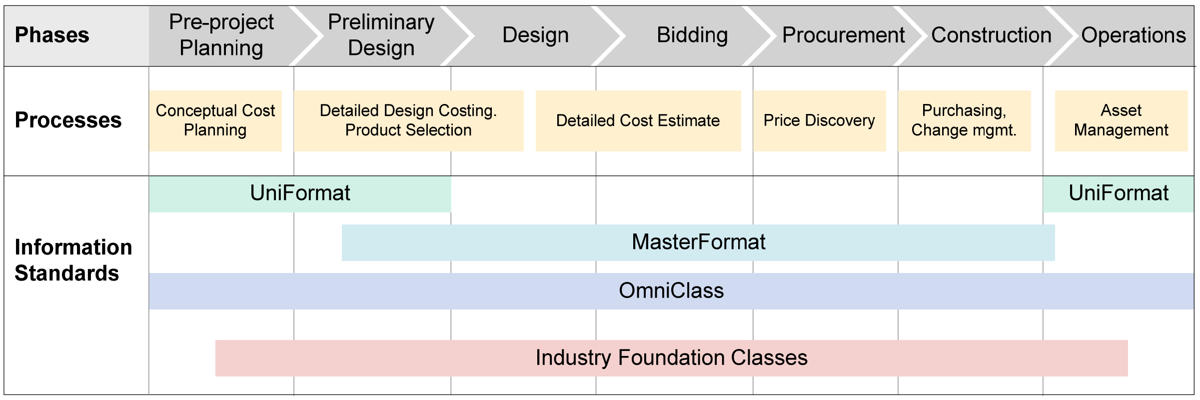
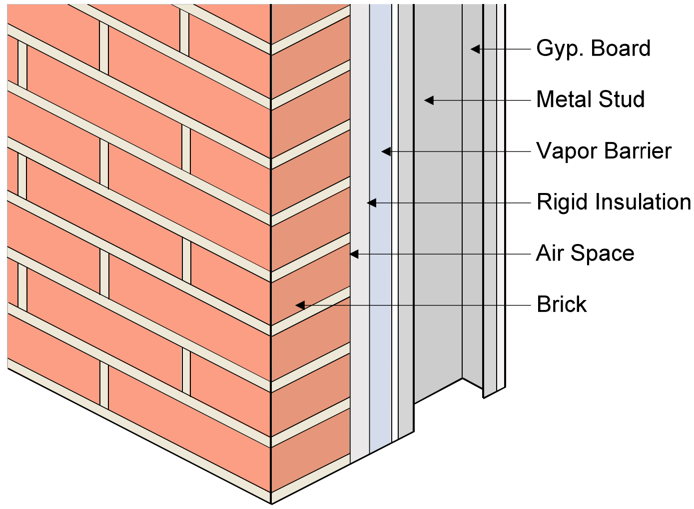


Figure 6: Construction Information Standards by Phase[5]

UniFormat was developed in the early seventies and enhanced in 1993 (by CSI, GSA, AACE, R.S. Means and others) to organize information for estimating and design costing analysis by a project's major components. This framework breaks building systems into categories such as foundation, superstructure, shell, and interior construction, and into subcategories - such as floor and roof construction and exterior walls and windows. The format is useful to cost estimates being generated in the preliminary phases of a project. BIM applications, such as Revit, use UniFormat for organizing their objects and assemblies. The format, by itself, will be too general to categorize components for detailed cost estimates (Figure 7).

MasterFormat is a specifications-writing standard developed by the Construction Specifications Institute (CSI) and has been in use for over forty years. This standard organizes information by construction requirements, products and activities (termed "work results"). This framework is generally used during the construction documentation phases of a building project, when detailed information is developed and organized.

[5] Adapted from: CSI Formats and Building Information Modeling, Roger Grant/CSI for Federal Facilities Council, Forum, October 31,2006



UniFormat	MasterFormat			
		Components	*Type*	*Size*
B2010				
	4210	Brick	Modular	
		Air Space		1"
	7210	Insulation	Rigid	1½"
	7260	Vapor Barrier	Felt	15#
	6160	Sheathing		5/8"
	5410	Metal Stud	Galvanized	3 ½"
	9250	Gyp. Board	Type 'X', WP	5/8"

Figure 7: Wall detail and classification by UniFormat and Master Format

OmniClass (OCCS) is a newly developed AEC industry-wide initiative led by the Construction Specifications Institute (CSI) and endorsed by the IAI. It is intended to be the most comprehensive classification format, essentially classifying the entire built environment for the North American market. Portions of the MasterFormat (for work results), UniFormat (for elements) and EPIC – Electronic Product Information Cooperation (for product) systems have been adapted into this framework.

OmniClass establishes a terminology library that can be used to explicitly identify objects and their parts by associating their names with the actions and resources that make them up. In the practice of building information modeling, objects that are associated with terms in an OmniClass library, inherit standard sets of properties and pre-defined relationships with other "concepts" in the OmniClass definition framework, by this association.

Building Information Models for the Project Lifecycle

Building Information Modeling offers the promise of a common repository for building information for all project participants. As an evolving technology, it remains to be seen whether BIM will consist of one consolidated model or a configuration of distributed, yet somehow affiliated, data models. The AEC industry is still a highly segmented business; participants have different functional requirements, deliverables vary in detail and purpose, and available technologies and standards are still evolving.

In current practice, different BIM models are often developed for different purposes, from planning to fabrication. A schematic model used for preliminary costing will be more of a massing or "stack and block" model, without detailed component definition. BIM models will need to be "light" enough to be responsive during project development and "generic" enough to facilitate change. Some commercially available software developers are addressing conceptual cost estimating, notably Trelligence's Affinity and Beck's Dprofiler applications.

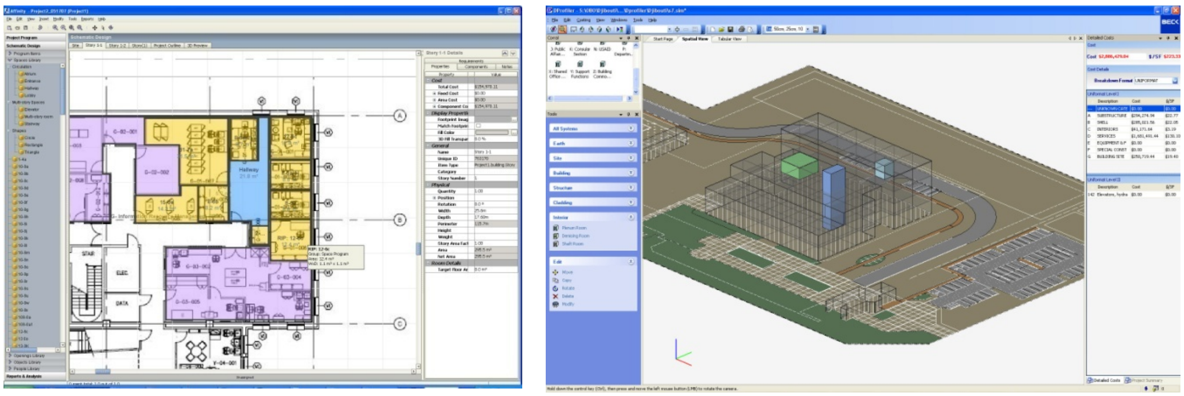


Figure 8: Preliminary costing applications Trelligence Affinity (left) and Beck Dprofiler (right)

Models developed to support one phase of the lifecycle will need to be passed along to the next, requiring the BIM user base to clearly delineate their processes and develop guidelines and standards (e.g. What information is included in a BIM model at each phase? When do generic objects in a model get replaced by more detailed objects? At what stage are cost estimates done and what is included in the product? Who has the responsibilities in the process for doing and overseeing these activities?).

BIM development processes need to support the different uses of the model in different project phases. This can be accommodated with the use of multiple object libraries for increasing levels of detail. For example - how costs calculations are derived from walls during the course of a project will vary. Estimates during earlier phases will use a more generalized cost per linear foot for a certain wall type. For that same wall, however, constructors will need to derive a total area for gypsum board, double area for finishes, framing, base molding and nail quantity. Accuracy of cost estimating will depend directly on how well developed assemblies and objects are in the model.

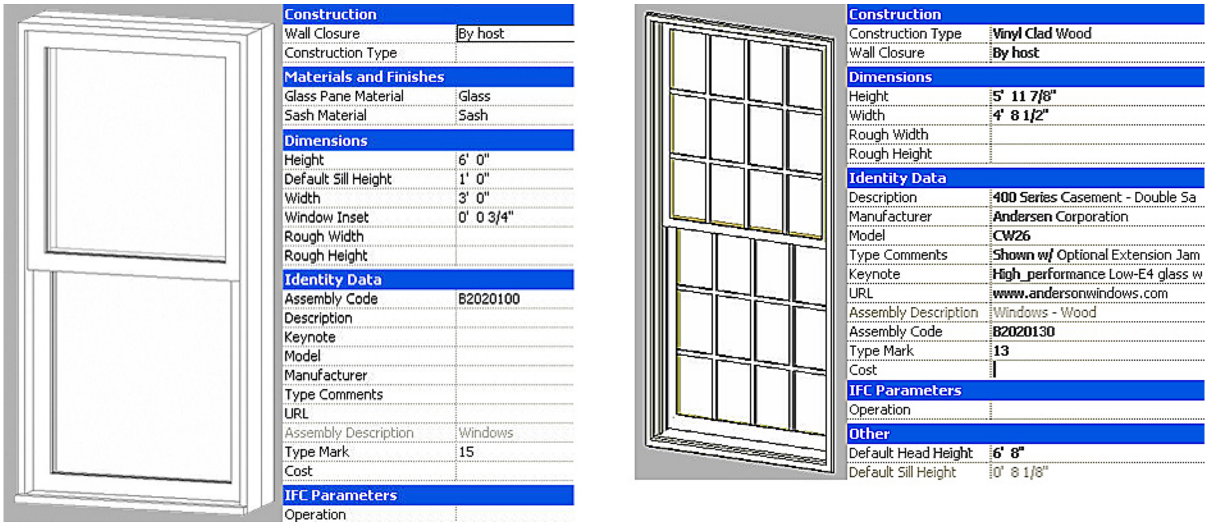


Figure 9: Object data for a generic window (left) and an Anderson Window (right)[6]

More sophisticated applications are being developed to enhance the BIM process for data-intensive uses such as cost estimating, environmental compliance, energy analysis, and component fabrication. How component data, such as costs and specifications, is to be associated with BIM components is a significant issue in right-sizing a BIM model's complexity (e.g. What data is stored in the BIM model? Is an external database being used for storing detailed data, and if so - how is that data structured and exchanged?).

During project development, objects in a BIM model need to be populated with sufficient data to allow a costing application to accurately classify the materials and assign costs. Developing detailed definitions for costing can take several paths. Large firms or organizations, such as the US Corps of Engineers (USACE), can develop detailed in-house standards for assemblies that comprise its building models. USACE is creating a detailed IFC-based format to be associated with objects in a model (enhancing the base IFC definitions with the detail required for standard components used in their projects).

Commercial BIM cost estimating applications work in various ways to enhance the detail associated with a BIM object in order to generate cost estimates, often enhancing object tags or text fields with detailed assembly or material descriptions. "Lightweight" models exported from the primary BIM applications are useful for a range of purposes, several current uses include: NavisWorks imports BIM models to its own format structure for clash detection and scheduling; Innovaya employs a lightweight model format to support its visual estimating application; Autodesk offers the DWF format for design review; and Solibri imports IFC models for rules-based analysis.

Monolithic, do-everything systems have yet to be a silver bullet in any arena. New information technologies in general, such as Web 2.0, Services Oriented Architecture, et al, are evolving to support integration and collaboration between applications through interoperability, aiming to ease the flow of information between silos.

[6] *from Autodesk Revit 2008*

Bi-directional Updating

The capability for BIM-generated cost estimating applications to update and change the original building model remains undeveloped. Costing exercises often result in the need to substitute components of the building design. Costing applications haven't yet developed the facilities to export these decisions back to BIM and automatically update the building model to reflect the changes. Current costing applications do have the ability to flag items that have either changed, or have been added to the original model, so that the estimator can modify the object base used for the estimate.

In fact, a two-way exchange ("round-tripping") of BIM geometry between formats (e.g. BIM out to IFC and back to BIM) is as of yet, problematic. A process that could exchange and updating geometry and integrate data-driven changes involves significant complexity beyond current BIM capabilities.

Importance of Visual Data Management

One of the most important features of BIM is its capability to explain building data through a 3D visual model. This representation gives its users a clearer understanding of a building project and reduces the chances for missing or misrepresenting components. Traditional costing applications by their nature have been text-oriented – listing, tabulating, and calculating lists of component assemblies.

In the current market, Innovaya's Visual Estimating application is an example of a BIM-based costing application that employs a robust interface for visual manipulating the model and its components for costing purposes. The BuildingExplorer application builds on Revit's visual interface to compose a graphic interface for interactive costing analysis.

The capability to visually select objects to quantify or display building components by user-defined groups (be it CSI formats, phase, or composition) with color coding offers the estimators a power tool to perform more informed decisions and investigate multiple what-if scenarios. Contrary to being replaced by technology, cost estimators will find their roles enhanced, freed from the tedium of quantifying with more time to perform higher level duties.

Figure 10 – Innovaya Visual Estimating application screen

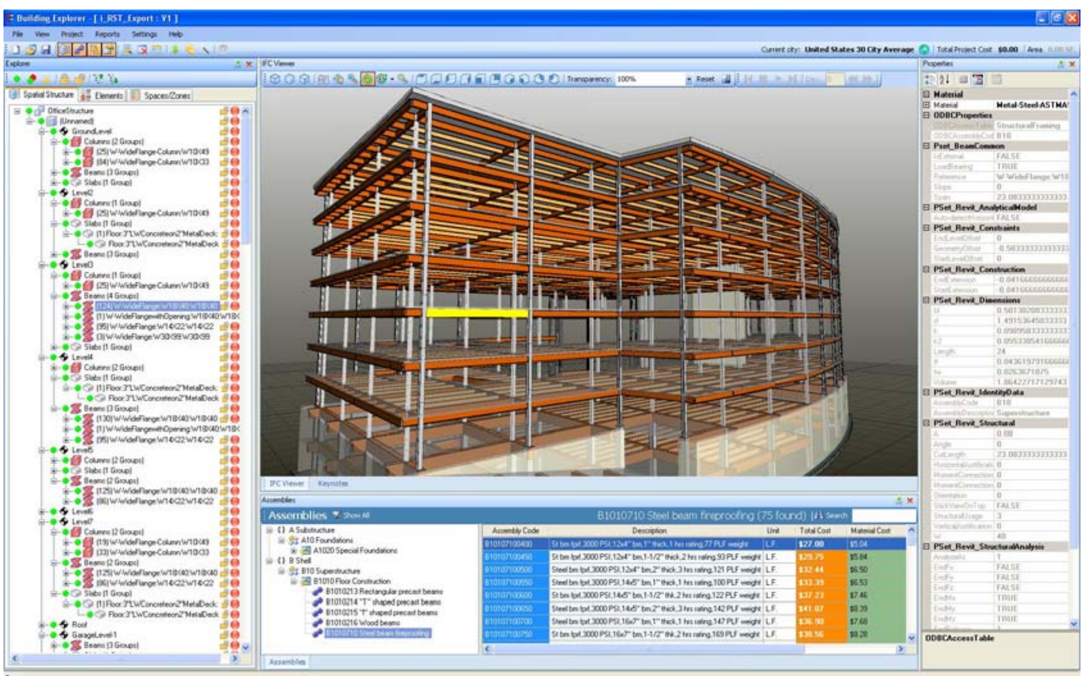


Figure 11: Structural component costing, BuildingExplorer application

Conclusion

Building Information Modeling offers the capability to develop project cost information with more accuracy throughout the entire building lifecycle. The key to successful use of BIM-based costing will be the development of processes and methods within organizations. The level of detail required in a building model will vary depending on project phases, from preliminary (macro) costing models to very detailed models required for micro costing activities during the construction phase

Data exchange between BIM and costing applications can be accomplished in several ways – APIs, ODBC and IFCs among them. The manner chosen will depend on the software developer's intent. Professionals using BIM costing applications will need to select a method depending on project phase and the detail required, and develop in-house standards and procedures for aligning their models with the estimating processes.

Industry standards for data exchange – IFCs in particular and frameworks for information classification (e.g. OmniClass, UniFormat) are integral to industry interoperability. As many standards are still developing, so are BIM applications. Professionals using BIM will have to adopt strategies to integrate and change as these technologies mature.

BIM offers the promise of a central detailed database for a range of project applications, and its visual capabilities for all of them should be a notable advantage when considering how professionals can change and manage building information throughout a project. As new technology, BIM assisted cost estimating will not obsolete estimators; rather, it promises to free them to focus on higher value task than counting, returning increased value to project processes.

References

Specifying and Cost Estimating with BIM, Robert Paul Dean, AIA, CSI, CCS, and Susan McClendon, RA, CSI, CCS. Archi-tech, April 2007

1-2-3 Revit: BIM and Cost Estimating, Rick Rundell, Cadalyst Magazine, August and September 2006.

New Tools Deliver BIM Data, H. Edward Goldberg, Cadalyst Magazine, December 2003

Preconstruction Management Software Trends and Strategy, Riverguide Inc., October 2006.

AACE Recommended Practice No. 17R-97: Cost Estimate Classification System, AACE, Inc., 1997.

A Different Approach to Using IFCs to Facilitate Interoperability in the Building Industry, Jim Forester and Ian Howell, AECbytes Viewpoint #15, April 13, 2005.

CSI Formats and Building Information Models, Roger J. Grant, AIA Edges, 2006. http://www.aia.org/nwsltr_tap.cfm?pagename=tap_a_200611_CSI_formats

Visual Estimating: Extending BIM to Construction. Lachmi Khemlani. AECbytes. March 21, 2006. http://www.aecbytes.com/buildingthefuture/2006/VisualEstimating.html

BIM Costing Applications:

Innovaya Visual Estimating	http://www.innovaya.com
Building Explorer	http://www.buildingexplorer.com
U.S. Cost Success Design Exchange	http://www.uscost.com
Trelligence Affinity	http://www.trelligence.com
Beck Dprofiler	http://www.dpearth.com

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Louise A. Sabol is a registered architect with more than 25 years of experience in the building and technology professions. At Design + Construction Strategies, LLC, Ms. Sabol serves as Director of Technology, providing overall technical planning for the firm's technology integration projects for organizations involved in complex capital projects.

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