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Use of Software for Estimation of RCC Buildings

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ABSTRACT: Early stage cost estimate plays a significant role in the success of any construction project. All parties involved in the construction of a project; owners, contractors, and donors are in need of reliable information about the cost in the early stages of the project, where very limited drawings and details are available during this stage. Construction cost estimating is a cumbersome process. It takes a long time for an estimator to complete an accurate estimate and construction contractors must prepare cost estimates quite often in order to prepare bids for new projects. This presents a challenge to an estimator who has to prepare several estimates in a short period of time. In recent years, computers and estimating software have reduced the amount of manual work necessary for preparing an estimate by organizing and providing fast access to latest labor, material and equipment costs, quickly performing calculations and generating reports. There is room to improve the estimating process even more. This can be accomplished by using the latest CAD and visualization technologies. Improvements can be made in how information is transferred from design files to estimating applications and in visually matching CAD elements with estimating database assemblies.

KEYWORDS: 3DCAD, Estimation, Construction, Digitizing Tablets

I. INTRODUCTION

1.1 GENERAL

Cost estimating is an essential task for budgeting and bid preparation for any construction project. A good estimate depends on many factors including time given to the estimator, estimator's experience, and a wide range of assumptions regarding the project (Jrade and Alkass, 2007). Construction cost estimating involves collecting, analyzing, and summarizing all available data for a project (Holm et al., 2005). This chapter will focus on detailed estimates, the information needed for a detailed estimate and an example illustrating how the information is used to make an estimate. Today's detailed estimating technologies and the difficulties associated with detailed estimates are also reviewed.

1.2 2.3 DETAILED COST ESTIMATES AND THE ESTIMATING PROCESS

Detailed cost estimating is a time-consuming process. It is prepared when all documents of the construction project have been completed. Creativity and knowledge are essential for preparing a construction cost estimate. Different contractors use different processes, methods, and technologies during construction. Therefore, estimators need knowledge, creativity, and experience to execute the estimating task successfully. Detailed cost estimating consists of two important steps: quantity estimate, also known as quantity takeoff, and pricing.

In a detailed cost estimate, the estimator divides the project into individual work items and estimates the quantities of materials for each work item. This is also known as quantity takeoff. Labor, equipment, and material needed for executing a work item are then determined based on the specification and the construction method.

After the element has been selected for cost estimating, the estimator must select work items necessary for the element. Construction of a building element may consist of a number of work items. For example, a concrete slab element may consist of several work items such as forming, reinforcing, concrete pouring, finishing, and curing.

1.3 TODAY'S TECHNOLOGIES FOR DETAILED COST ESTIMATE

As one can see, detailed cost estimating is a cumbersome process that involves a lot of data and calculations. Any technology that could assist the process of construction cost estimating would help reduce estimator's work load. Computers are considered to be effective tools for assisting estimators during the construction cost estimating process. Computers provide many benefits including reducing estimation errors and the time needed to produce an estimate. Today's estimating technologies include, but are not limited to, spreadsheets, cost estimating software, digitizing tablets, on-screen digitizing systems, and the yet to be matured 3-D CAD parametric estimating software.

1.3.1 Spreadsheet Estimating

A spreadsheet is a computer application that simulates a paper worksheet. It provides the user with cells that are compiled into rows and columns. Each cell can contain either text, numerical values, or formula can be defined in cells to obtain calculated value from the related cells. Complicated mathematical calculations can be automated with a change of a single cell with the use of formula in the spreadsheet. Contractors use worksheets to accelerate the estimating process. The estimator can set up a template with saved formula in the spreadsheet. Estimator can also perform quantity takeoff calculations within a spreadsheet. Although a spreadsheet requires a lot of input from the estimator, it eliminates the cumbersome and error prone manual calculations during the quantity takeoff and pricing.

1.3.2 Construction Cost Estimating Software Packages

Various software packages are available to assist the estimator during the detailed cost estimating process. The capabilities of software packages vary greatly. Some include labor, equipment, and material cost databases, which facilitates the estimating process after the database is set up. In order to perform a quantity takeoff, estimating software packages include technologies such as digitizing tablets, on-screen digitizing systems, and 3D CAD models.

1.3.3 Digitizing Tablets

A digitizing tablet is a computer input device that uses a stylus and a tracking surface to capture the drawing on to the computer system. The drawing traced on the tracking surface transfers point coordinates to a computer, thus it can be used for many different purposes including construction cost estimating. Digitizing tablets' purpose in construction cost estimating is to digitize the paper-based blueprints provided by the owner of the project or the designer. For example, the estimator can get the length, perimeter, or area out of the drawing by the scale provided in the blueprints. These parameters are available when using the digitizing tablet via software package. The software package may also include estimating software. After the paper blueprints have been digitized and the quantities for all work items have been determined, the estimator can use those quantities to estimate the prices of items.

1.3.4 3-D CAD

3-D computer aided drawing (CAD) models help estimators visualize what is going to be built in the 3-D environment. The ability to digitally extract and transfer data can speed up cost estimating process. A building model can be seen in many different views, where details of elements, including their dimensions can be extracted and transferred to the estimating software. A software company named Innovaya (Innovaya Website, 2009) has already attempted construction cost estimating using 3-D CAD; however, it is still a work in progress. Innovaya uses the estimating engine from Timberline (Timberline Website, 2009) or MC2 ICE (MC2 ICE Website, 2009).

Today, detailed cost estimating is done using computer-assisted technologies, which includes spreadsheets and estimating software. However, error prone and time consuming processes are a few difficulties that could arise during the estimating process. Although, the process of estimating has been improved, a solution to these difficulties could ease the estimator's task of construction project cost estimating. 3-D CAD and visualization can provide the estimator with a tool necessary to cope with the ever increasing complications in design.

II. BUILDING INFORMATION MODELING

2.1 INTRODUCTION TO CAD AND BIM

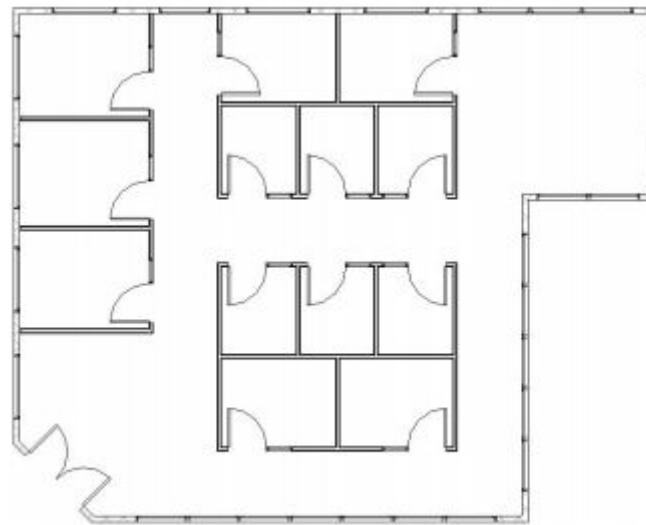
A cost estimate for a construction project can be prepared at any phase of the construction project. However, detailed cost estimates require a complete set of plans and specifications. Although most plans and specifications today are in 2D CAD format, advanced technologies have changed the way drawings are prepared, and 3D CAD drawings are playing a bigger role in documenting design intent. Building information modeling (BIM) is another technology that is

making an impact and becoming popular throughout the architecture, engineering, and construction (AEC) industries. The use of BIM enables architect to improve design efficiency. Structural designs can be optimized by the engineer and contractors can improve the planning for the construction of the project. This chapter will discuss in more detail CAD, BIM, the differences between the two technologies, BIM's applications, and the future of the construction industry with BIM technology.

2.2 COMPUTER-AIDED DRAWINGS

Computer-aided drawings (CAD) have been a significant tool helping architects and engineers in the engineering and design process (Jrade and Alkass, 2007). The basic function of CAD software is to allow the user to prepare drawings by manipulating lines, circles, rectangles, and text interactively on the computer screen. Some types of architectural specific software offer graphical libraries of commonly used building elements such as doors and windows. Creating a drawing is not the main advantage of using CAD because it could be done on a paper-based medium; however, the main advantage of CAD is its ability to easily edit a design (Sun and Howard, 2004). CAD allows users to delete, move, copy, rotate, scale, and mirror design elements with ease. CAD also has the functions to create repetitive design components, create elements at equal distance on a line, a circle, or on a grid, extending lines, trimming lines, and fillet any corners of an edge. These tasks are not easily carried out on the paper based drafting. CAD allows designers to concentrate on the creative aspects of the design instead of being distracted from unproductive activities (Bazjanac, 1975). CAD can be divided into two major categories: two dimensional (2D CAD) and three dimensional (3D CAD).

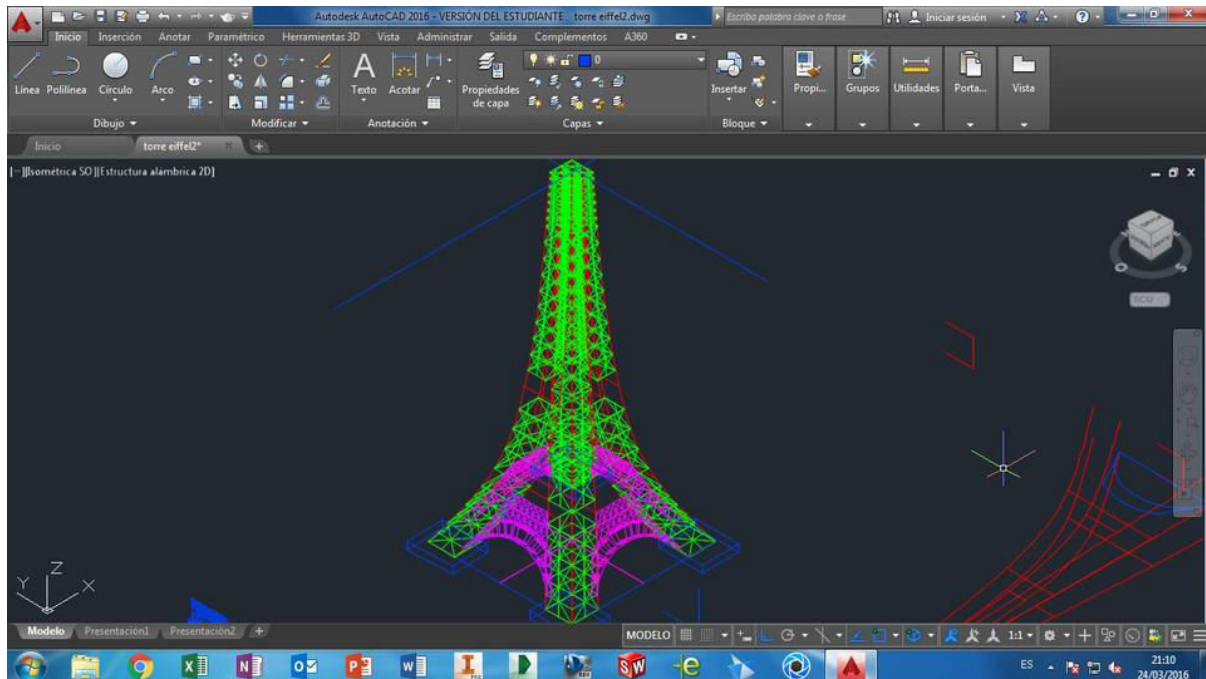
2D CAD is considered to be fast and easy to use. It is the most popular method of drafting in today's construction industry (Sun and Howard, 2004). A 2D CAD drawing, as shown in Figure 2.1, is a vector-based display of a project.



(FIGURE 2-1: A 2D CAD Drawing)

Although it is fast and easy to use, 2D CAD uses lines to draw components instead of the actual elements. Viewing of 2D drawings does not provide designer with different angles of the design. 3D CAD is an alternative to 2D CAD, allowing views from different angles and potential virtual environment capabilities of walking through or flying through the structure.

3D CAD can be created from 2D CAD by adding depth and elevation to the design. 3D CAD models are three dimensional drawings which represent objects in the X, Y, and Z axis (Reffat, 2002). The benefit of 3D CAD is the ability to visualize the building; designers can determine spaces available, thus improving the design. 3D CAD can also be turned into animation and visualization system where clients can experience the design at various settings of the project from different angles and views (Dzambazova, Demchak, and Krygiel, 2008; Vince, 2004; Sun and Howard, 2004).



(FIGURE 2-2: 3D CAD Wire Frame Model)

Different types of views, such as a wire 3D or a solid provided by the 3D CAD model, can be used extensively for different purposes. For example, wire 3D model, as shown in Figure 2-2, can be used to evaluate the structural integrity of the design. Solid model, as shown in Figure 2-3, can be used to see if the design will fit in the surrounding environment.



(FIGURE 2 -3: Rendered 3D CAD Model)

2.3 BUILDING INFORMATION MODELING

Although 3D CAD helps visualize the proposed structure during the design process, building information modeling or BIM can provide a better alternative. The process of BIM could help improve many aspects of the construction project.

Building Information Modeling (BIM) is one of the most promising developments in the Architecture, Engineering, and Construction (AEC) industries (Azhar et al., 2008).

According to Khemlani, BIM is a revolutionary technology that goes well beyond the design phase to impact construction and lifecycle management of the project (AECbytes Website, 2009). BIM is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility (AGC, 2005). Information provided by BIM includes, but is not limited to, dimensions, coordinates, properties, and other element details for the building. BIM technology would provide the potential for improving communication between participants involved in the construction project, improving the quality of information, the quality of services delivered, and reducing cost at every stage in the life cycle of a building (Smith and Tardif, 2009).

As today's technology grows more complex, building design has become more complicated. The involvement of the computer technology at the earliest phase of the design process is becoming more common. Difficulties of the design associated with the complexity of the building could provide many problems to not only the designer but also the engineers and the contractors who build it. BIM provides the ability for the designer to design the building with the modeling tool that creates object elements instead of different types of lines connected to make up a model. The 3D parametric model that BIM provides does not only provide the visualization of the model in three dimensions, but it also stores information about the elements that make up the building. This information includes its physical characteristics such as dimensions, locations, and texture of the objects. Functional characteristics could also be found in the parametric model, including the information about manufacturers and operating and maintenance procedures (Azhar et al., 2008).

Contractors can also benefit from BIM. It provides many features that help contractors avoid costly errors during construction of the project. Element clashes can be detected before the construction has started, saving contractors' time and money. Complexity of the construction or the design of the building could also provide many difficulties during the preparation of plans and specifications. With an integrated parametric 3D model, it's possible to detect spatial clashes between the multitudes of systems in the building (Dzambazova, Demchak, and Krygiel, 2008). Computer analytical systems could support design decision making by enabling designers to test and evaluate design alternatives rapidly in the search for an optimum solution (Bazjanac, 1975). Ambiguities in the design can also be highlighted by any team member and resolved before the design has been finalized. Constructability issues can be raised and debated among the parties involved (Levy, 2006). Time that is normally spent manually checking all the drawings by the design consultants and by the contractor and their subcontractors will be reduced considerably. This allows all parties to be more productive on other tasks such as project management or quality control.

III. COST ESTIMATING DATABASES

Construction cost estimating requires a lot of data on building elements, material, equipment, labor, and other related information. These data need to be organized in a way that they can be easily accessed. One way to solve the problem is to use a database for storage of the data. A database is a storage facility or a collection of related records or documents. Databases are designed, built, and populated with data for a specific purpose and has an intended group of users and some applications in which these users are interested (Retik and Langford, 2001). The estimating software designed for visual estimating adopts database technology to store all the information necessary for estimating. The cost estimating database will also be used to store new estimate information. This chapter will discuss why databases are used, database models especially the relational model, and how the estimating database used in this study was designed.

Estimating requires the input of data from many sources. The ability to integrate this data into the estimating process would be beneficial during an estimate. A cost estimating database was developed to store all the data required for the estimating application developed in this study. The application is named Visual Estimating Application. This section will present what should be stored in the cost estimating database, how the database was designed using the relational database model, and how the estimating data are related to each other. The cost of a building element is the sum of the costs of the work items necessary for the construction of the element. The data needed for estimating include labor, equipment, material costs and productivities. Figure 5.4 shows the schema of the database developed for storing the necessary data.

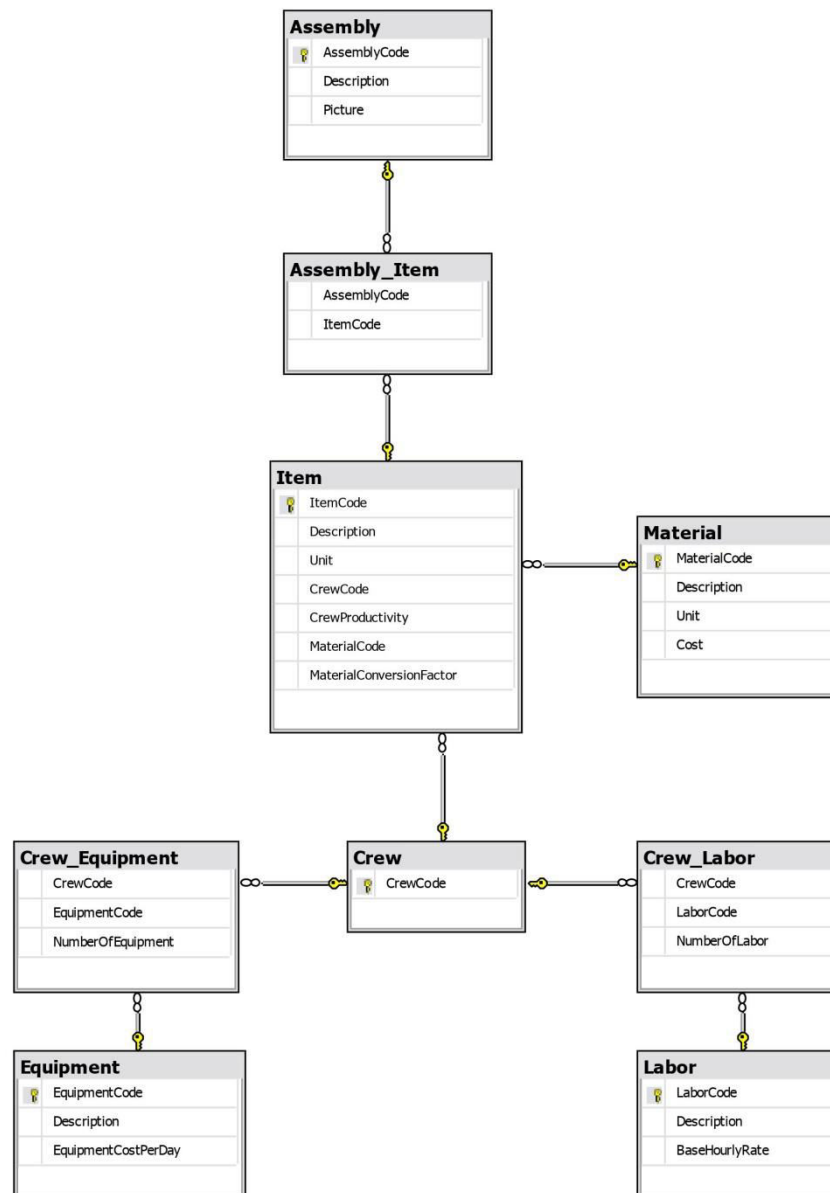


FIGURE 5-4: Cost Estimating Database Schema

IV. CASE STUDY

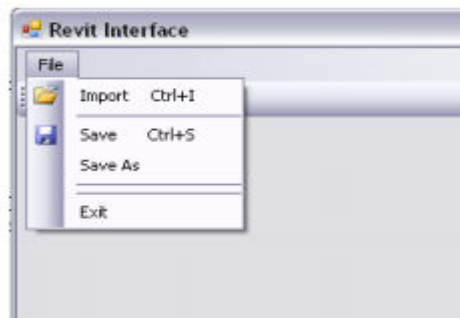
4.1 BASIC COMPONENTS OF THE GRAPHICAL USER INTERFACE

The Visual Estimating Application allows an estimator to visually select elements from a 3D model and estimate their costs. The application was developed based on how human brain perceives and processes information; therefore, minimizing the load on the estimator's long-term memory while preparing an estimate. Access and use of the

application's Revit element extractor, 3D visualization system, database management module, and cost estimating module.

4.1.1 Revit Element Extractor

Revit element extractor (as shown in Figure 4-1) interfaces with Autodesk Revit to extract all Revit elements from a 3D CAD model. The user must create a directory and save the extracted project element information in a file. After extraction, the user does not need the parent software (Revit Architecture) and the Revit model file.



(FIGURE 7-1: Revit Element Extractor)

4.1.2 Visualization System

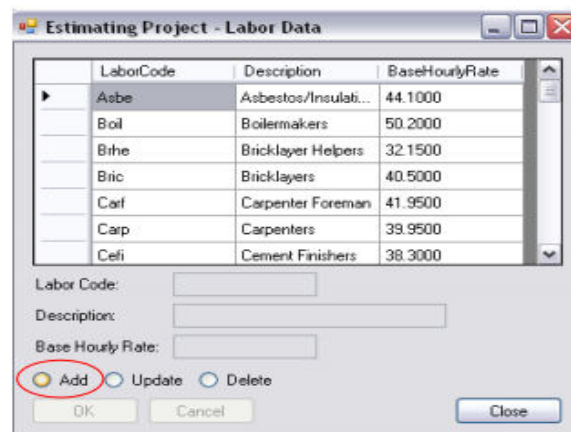
The visualization system interface allows users to visually interact with the 3D model and estimate a building element. The main functions of this interface are discussed below. Navigation: Navigation inside a 3D model is done by using the mouse and the keyboard. To move forward, the right key is pressed. To look around the building, the left key is pressed and the mouse is moved around to the desired direction. To look up and down, both left and right keys must be pressed together. Element Selection: A building element can be selected for estimating by changing the interface state from "Navigate" to "Select". This enables users to select any element in a 3D model to be estimated. An element is highlighted after it has been selected.

4.2 DESCRIPTION OF DATABASE MANAGEMENT SYSTEM

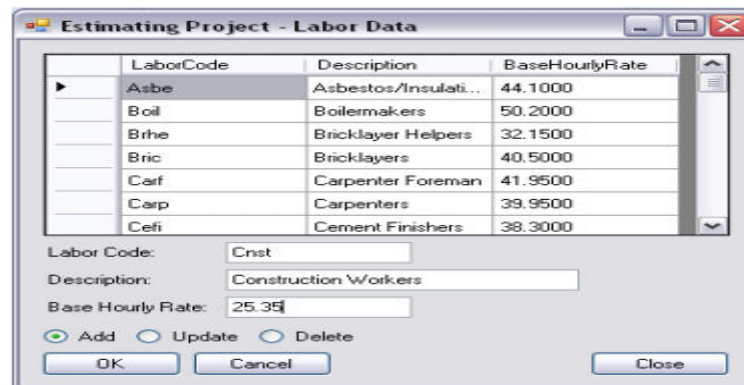
This section provides a step-by-step description for managing the cost estimating database. Users can choose whether to add, edit, or delete data from different tables in the cost estimating database. Since each table has its own dialog box, one can select the table that he/she wants to view and adjust any data necessary for that table.

Adding Data:

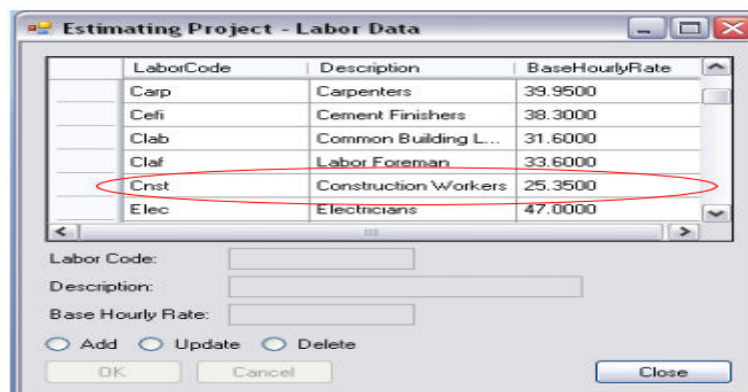
To add new data, the user can select "Add" radio button; as illustrated in Figure 7- 5 for the Labor table dialog box. After the button is clicked, textboxes are enabled for the user to input data into the database as can be seen in Figure 7- 6. After the necessary data have been entered, the estimator can click "OK" to add the data into the estimating database, or the estimator can click "Cancel" to abort data entry. Figure 7-7 shows databases' data grid view after an update with the latest data entry.



(FIGURE 7-5: "Add" Radio Button in the Labor Table Dialog Box)



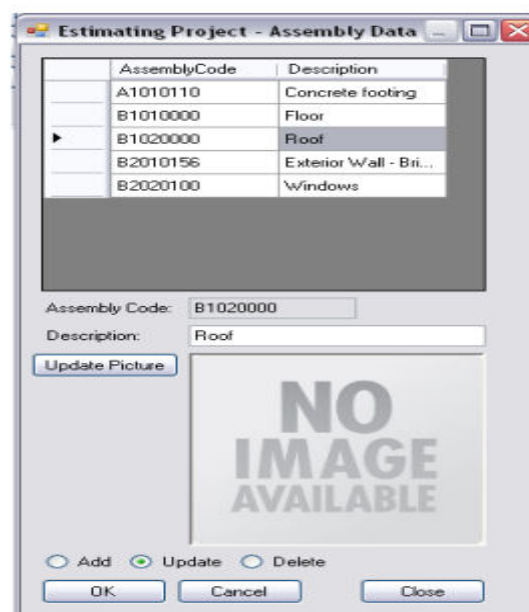
(FIGURE 7-6: After the “add” button is clicked, textboxes, “OK”, and “Cancel” buttons are enabled)



(FIGURE 7-7: After the estimator has clicked “OK” and the list will be updated automatically.)

Editing or Updating Data:

To edit or update data in the estimating database, data has to be selected first. The selection can be done using the data grid view that shows content from the database. Selected data and its attributes are then shown in textboxes. Figure 7-8 illustrates that “Roof” has been selected for update. The description for “Roof” will be changed to “Asphalt Roof” and a picture will be added to this assembly.



(FIGURE 7-8: Roof is selected and the update button is clicked.)

To update the picture, the “Update Picture” button has to be selected. A dialog box will appear, as shown in Figure 7-9. Figure 7-10 shows the Assembly table dialog box after the “Asphalt Roof” has been updated to the database.



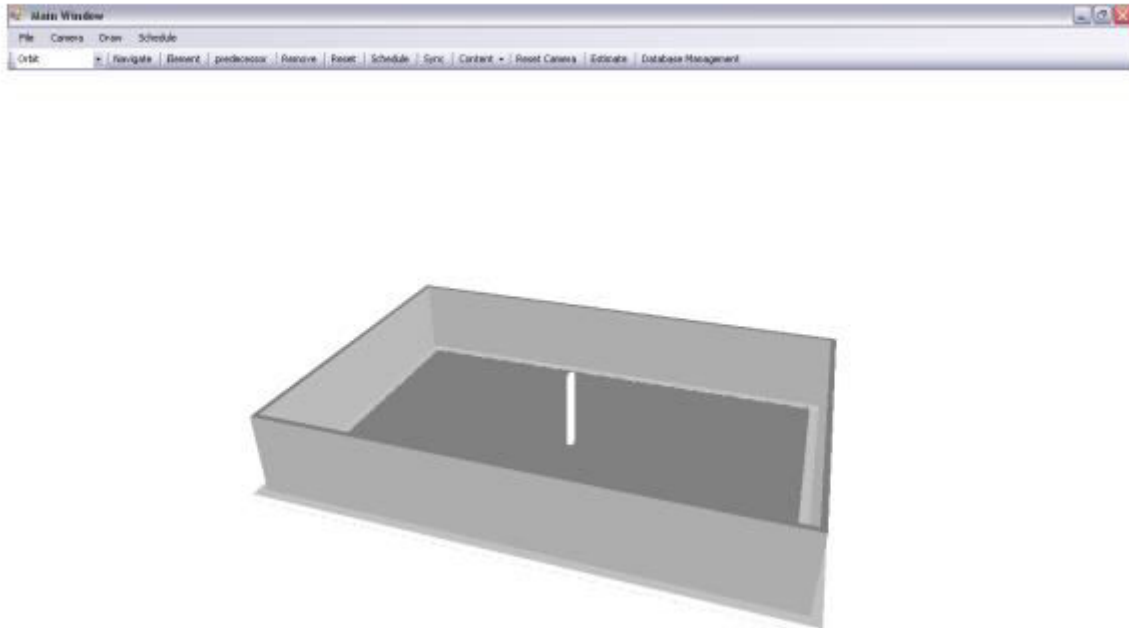
(FIGURE 7-9: Update picture dialog box. Asphalt roof picture was selected.)



(FIGURE 7-10: After “Roof” has been updated to “Asphalt Roof”. A picture was also added.)

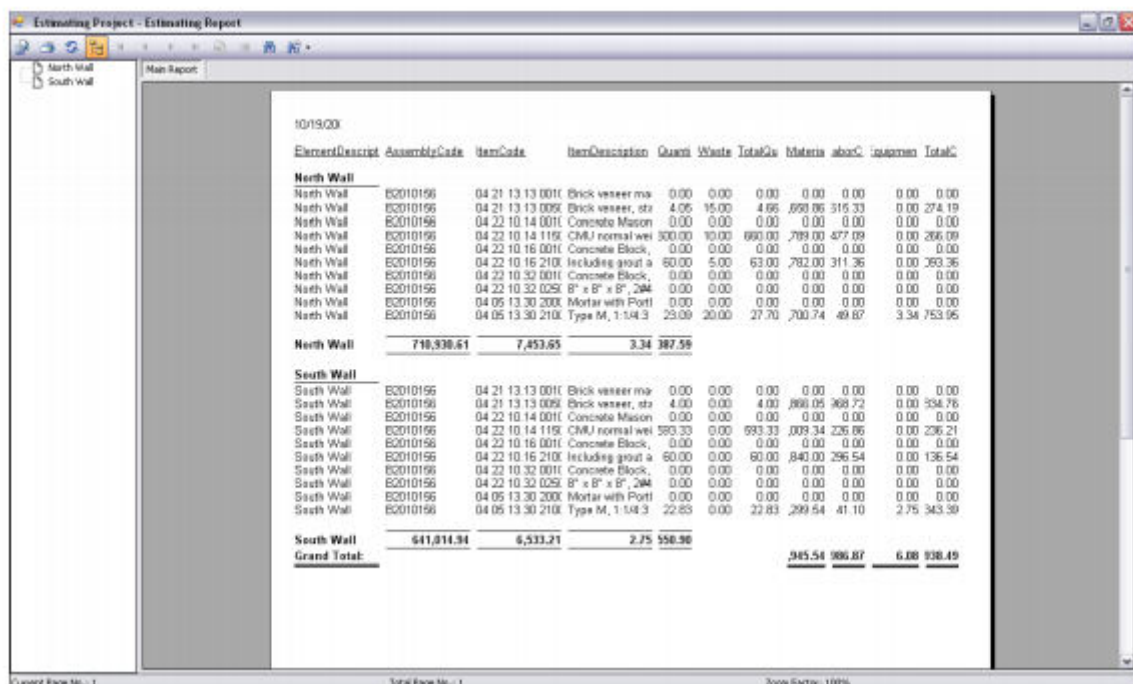
3D Model in the Visualization System:

Users can create a 3D model in the visualization system using the element properties extracted from the CAD model. Figure 7-13 shows a few elements drawn in the visualization system.



(FIGURE 7-13: Model shown in the visualization system module.)

Figure 7-18 shows an estimate report. Estimate reports can be saved in PDF file format for future use.



Element/Description	Assembly Code	Item Code	Item Description	Quant	Waste	Total Q	Material	labor	equipment	Total C
North Wall										
North Wall	E2010156	04 21 13 13 0011	Brick veneer ma	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Wall	E2010156	04 21 13 13 0055	Brick veneer, sta	4.00	15.00	4.00	,698.05	315.33	0.00	0.00
North Wall	E2010156	04 22 10 14 0011	Concrete Mason	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Wall	E2010156	04 22 10 14 1155	CMU normal wei	300.00	10.00	690.00	,789.00	477.09	0.00	0.00
North Wall	E2010156	04 22 10 16 0011	Concrete Block,	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Wall	E2010156	04 22 10 16 2101	Including grout a	60.00	5.00	63.00	,782.00	311.36	0.00	0.00
North Wall	E2010156	04 22 10 32 0011	Concrete Block,	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Wall	E2010156	04 22 10 32 0251	8" x 8" x 8", 2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Wall	E2010156	04 05 13 30 2001	Mortar with Portl	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Wall	E2010156	04 05 13 30 2101	Type M, 1:1/4:3	23.00	20.00	27.70	,700.74	49.87	3.34	753.95
North Wall				710,930.61			7,453.65		3.34	387.59
South Wall										
South Wall	E2010156	04 21 13 13 0011	Brick veneer ma	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Wall	E2010156	04 21 13 13 0055	Brick veneer, sta	4.00	0.00	4.00	,698.05	369.72	0.00	0.00
South Wall	E2010156	04 22 10 14 0011	Concrete Mason	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Wall	E2010156	04 22 10 14 1155	CMU normal wei	593.33	0.00	593.33	,009.34	236.06	0.00	0.00
South Wall	E2010156	04 22 10 16 0011	Concrete Block,	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Wall	E2010156	04 22 10 16 2101	Including grout a	60.00	0.00	60.00	,840.00	296.54	0.00	0.00
South Wall	E2010156	04 22 10 32 0011	Concrete Block,	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Wall	E2010156	04 22 10 32 0251	8" x 8" x 8", 2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Wall	E2010156	04 05 13 30 2001	Mortar with Portl	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Wall	E2010156	04 05 13 30 2101	Type M, 1:1/4:3	22.83	0.00	22.83	,269.54	41.10	2.75	343.39
South Wall				641,814.34			6,533.21		2.75	558.98
Grand Total:							,945.56	,986.87		6.08

(FIGURE 7-18: Estimating report created by the Visual Estimating Application)

V. CONCLUSION

The goal of this research was to make the process of construction cost estimating simpler and more intuitive. It also introduced the use of visualization in estimating. The developed application digitally transfers project information from a BIM model to the estimating application; this reduces the manual data entry which is a very time consuming process.

This study provided a visual approach for estimating that allows an estimator to walk inside a virtual building and select elements for estimating interactively.

The developed Visual Estimating Application helps ease the estimating process by utilizing 3D CAD models and information extracted from a 3D CAD model. A visualization module is used to help the estimator navigate and interact with the model. A cost estimating database is used to store cost data for the Visual Estimating Application. Although several database models can be used for storing cost data, the relational database model was adopted in this study. The developed visualization module interfaces with Revit Architecture using Revit API via C# programming language. The visualization module extracts from a Revit model not only a building element's geometry, but also element material properties. The visualization module uses Microsoft DirectX graphical library to generate a virtual prototype of the project.

The Visual Estimating Application matches an element extracted from a Revit model to an assembly from the cost estimating database for preparing an estimate. An estimate report could also be generated. Although some of the tedious estimating tasks have been eliminated, the estimator input is still a must. Different project has different methods of construction and circumstances. Even though computers can assist some process during estimating, it could only do so much while judgment and experience of estimator is also needed.

FUTURE SCOPE

- Elements from the 3D CAD model have to be matched to an assembly from the cost estimating database. Automating this process could provide the estimator with an easier task of searching for an assembly in the database.
- Since cost of equipments and materials changes on a regular basis. Cost estimating database should be updated automatically from remote resources such as suppliers' web sites. This would help save time by not having to update individual entries in the cost estimating database.
- Computer network capability can be added to facilitate collaboration among estimators. For example, an estimator can work on project walls while another estimator works on footings.

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