A Web-Based Virtual Reality Model for Preliminary Estimates of Hi-Rise Building Projects

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ABSTRACT

Cost estimating of a construction project at its early stage is considered to be very important task since it will be used as a base to commit or otherwise not to commit funds to that project. Preparation of a reliable and realistic preliminary estimate to aid the decision makers to commit funds for a specific project is a complicated assignment. Traditional methods and operations produced unsatisfactory aid due to lack of accuracy especially in the pre-design stage of a project. This participates in the increase of percentage of bankruptcy in the construction industry, which has dramatically climbed up and ranked as 15 percent of the whole bankruptcies claimed in Canada (Statistic Canada 1998). This paper presents a methodology for developing and a Web-based model to automate preliminary cost estimates for hi-rise buildings. This is achieved by integrating a database with design drawings in a Virtual Reality (VR) environment. The model will automatically generate preliminary estimates after modifying a 3D CAD drawing. It provides the user the option to visualize and simulate the drawing and its cost data through VR environment. Having done that, it will allow owners, architects and cost engineers to view a constructed building project, change its geometric objects and shapes, and accordingly generate a new conceptual cost estimate.

1 INTRODUCTION

Usually the preparation of a construction cost estimate starts by breaking down the project into packages or components, then taking off the quantities of the elements of each package and next pricing them all. Finally, by summing up the prices the direct construction cost is computed. This process is long and complex but the most complicated part of it is the quantity take off. Consequently, computers are considered to be effective tools in cost estimating, due to their capability of doing complex calculations and storing huge amount of data for future use.

Any decision concerning the construction of a project that has been or to be executed is based on one type of estimates, which are preliminary estimates. Despite their moderate level of accuracy owner, engineer and contractor consider them as the first choice estimates because they are inexpensive and fast to generate. Owner uses them to decide whether constructing a project is feasible and to evaluate contractors bids, while engineer to design within owner's budget and considering alternatives, and the contractor to know if bidding on a project is profitable or not. Consequently, in the proposed

methodology the concentration is on the preliminary construction cost estimates with the emphasis on a computer model as an avail tool for estimators.

Preliminary cost estimates are carried out prior to starting the design process of a project. At this stage, data from similar previously executed projects, if available, own experience and wide imagination administer the preparation of these estimates. This is a time consuming process because normally this data is not available or at most it is incomplete. Furthermore, errors occurrence and inaccurate estimates generation are likely to happen. To overcome these problems, researchers have been working on developing management tools in a form of decision support systems to assist in improving the construction process. This is done through the application of computer-modeling techniques to construction related problems in order to improve quality, increase efficiency and to reduce time and cost. Such management tools would improve the efficiency and accuracy of the entire construction process by integrating different types of information within computer-based environment. This process is valuable during cost estimating that converts design information into construction information, which is a core among the whole information related to construction projects [4]. Construction integration has been addressed through several efforts and developments varying from: integration at the application level (i.e. project repository of information), geometrical integration at level of CAD packages, knowledge-based integration between applications and databases, and object-oriented models integrating product and process information to promote collaboration among AEC (Architecture / Engineering / Construction) agents [7].

The benefits of using computer simulation technologies during the design and development of projects start to be realized in the construction industry. The purpose of simulation is to better understand the prospective creation or changes before the physical implementation through various mechanisms. Virtual Reality (VR) technology provides promising characteristics [2]. Virtual Reality Modeling Language (VRML) is an open standard that offers the possibility of accessing many types of construction project information using readily available and well-accepted graphical user interfaces based on 3D visualization of a model rather than paper [5]. Many studies have been conducted in recent years recommending the use of integration and VR/3D technologies to simulate and model construction processes [1].

In the construction industry, geometric building data is stored in CAD systems, such as AutoCAD. While it is possible to develop VR models within VR packages, it is widely agreed that transfer of the geometrical building data from CAD is desirable for application of VR within the industry. The reason for this is to reduce repetition and data redundancy [6].

This paper aims at modeling the preparation of conceptual cost estimate within the Virtual Reality (VR) environment in conjunction with Computer Integrated Construction (CIC). The model is designed to benefit from the web technology.

2 PROPOSED MODEL: SYSTEM COMPONENTS AND ARCHITECTURE

The proposed model is a web-based integration of 3D CAD drawings and databases in a VR environment. The development can be achieved through three stages. The first stage involve integrating AutoCAD drawings with an External Relational Databases in an attempt to automate the preparation of conceptual cost estimates. The second stage deals with creating a dynamic link between CAD and Virtual Reality Modeling Language in order to transfer data from CAD to VR. The third stage involves the development of the necessary components and procedures to post the developed model on the web.

The models' architecture is illustrated in Figure1. All the modules share a database system, which contains three databases assigned to preliminary cost estimate, imperial parametric cost estimate and metric parametric cost estimate; and managed by a database management system. The functions performed within each of the systems components and their local development are described in coming paragraphs.

Based on the user's input, the system will guide the user throughout the estimating process. The imperial parametric estimate module, which integrates the imperial parametric database, assists the user in adjusting the costs of previously executed projects based on the Masterformat or the Uniformat according to the city index and the inflation rate. The user can quickly prepare an approximate estimate for any similar project listed in the supplied database all in the imperial units. Similarly, the metric parametric estimate module integrating the metric parametric database provides the same information and results except in the metric units.

The systems databases based on both the Masterformat (67 projects) and the Uniformat (35 projects) Work Breakdown Structure (WBS) to be used for generating parametric estimates. Furthermore, another database that include published cost data (R.S. Means) based on the Masterformat WBS in both units is designed and implemented for preliminary estimates.

The methodology followed in designing this stage was based on providing the user with reliable data where needed to include the following features [3]:

1. For parametric estimates, employ previously executed projects cost data as historical data (100 projects in both WBS).
2. Adjust this historical data according to city indices, inflation, size, height and perimeter if needed.
3. Provide built-in cost data for preliminary estimates based on published cost data (R.S. Means), which can be modified and enhanced according to the user needs.
4. Generate graphical, tabulated, and organized take off list output reports.
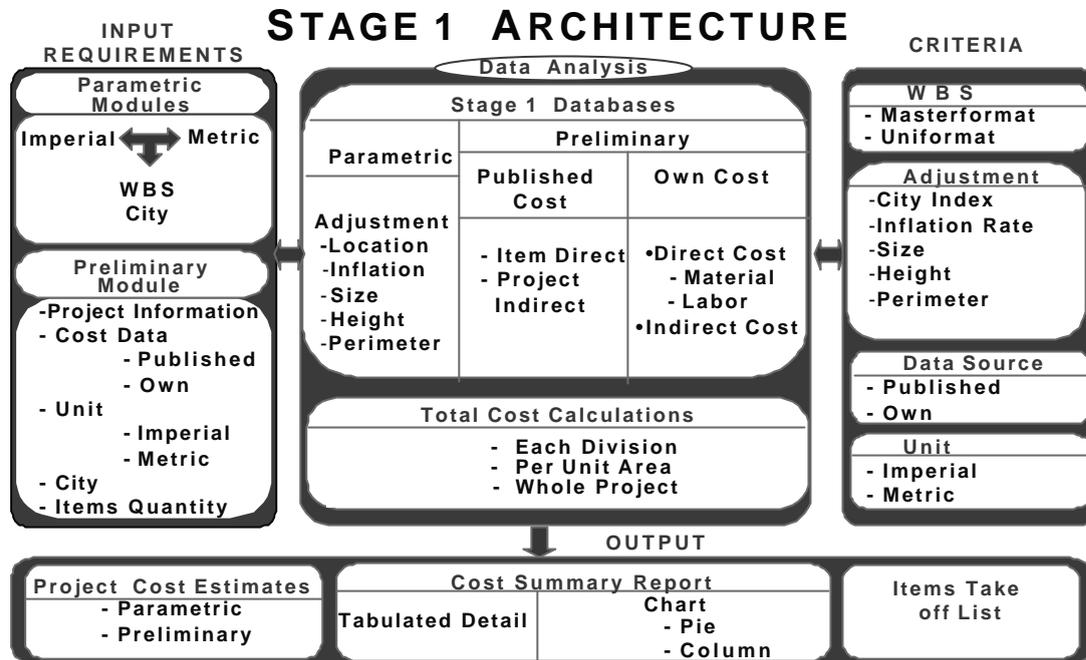
STAGE 1 ARCHITECTURE

INPUT REQUIREMENTS

CRITERIA

Data Analysis

Parametric Modules

Imperial ⬌ Metric

WBS
City

Stage 1 Databases

Parametric	Preliminary	
	Published Cost	**Own Cost**
Adjustment -Location -Inflation -Size -Height -Perimeter	- Item Direct - Project Indirect	•Direct Cost - Material - Labor •Indirect Cost

WBS
- Masterformat
- Uniformat

Adjustment
-City Index
-Inflation Rate
-Size
-Height
-Perimeter

Preliminary Module
-Project Information
- Cost Data
      - Published
      - Own
- Unit
      - Imperial
      - Metric
- City
- Items Quantity

Total Cost Calculations
- Each Division
- Per Unit Area
- Whole Project

Data Source
- Published
- Own

Unit
- Imperial
- Metric

OUTPUT

Project Cost Estimates	Cost Summary Report		Items Take off List
- Parametric - Preliminary	Tabulated Detail	Chart - Pie - Column	

Figure 1**: System Architecture**

As shown is shown in Figure 1, the process starts with the user selecting the estimate type. In case of preliminary estimate, the user enters project information, selects the cost data type, unit, city and items quantity. Thereafter output reports are produced as cost summary either tabulated or graphical, as well as a take off items list. It is to be noted that this type of estimates presently is not associated with CAD drawings.

For parametric estimate selecting unit, WBS, and city allows the user to adjust data for selected project for inflation, size, height and perimeter whenever required. Each previously executed project included in the database is to be associated with a 3D CAD drawing showing its external envelops, which consists the second stage of design. Figure 3 shows these components. The two first stages are combined in an integration environment using AutoCAD's Visual Basic for Application (VBA). Once the user makes changes to a drawing, the module reads the new areas of all floors that exist in that drawing workspace. By default, AutoCAD assigns for each area a unique number, which is used by the module to read the areas one at a time and write them to an external database. Subsequently the total area is calculated and accordingly a new parametric estimate is generated based on the modified drawing.

Figure 3 shows stage 3 integrated components. This stage comprises the animation of the modified 3D CAD drawing using Virtual Reality (VR) environment. The process of translation from CAD into VR is normally a one-way direction.
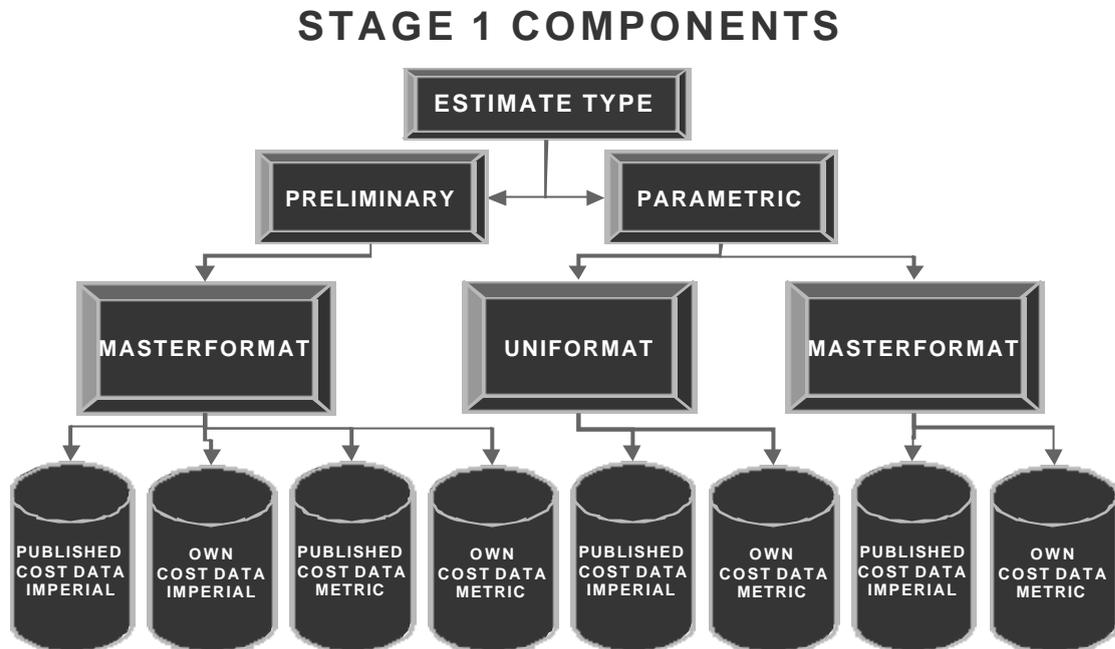
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STAGE 1 COMPONENTS

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                        ┌──────────────────┐
                        │  ESTIMATE TYPE   │
                        └──────────────────┘
              ┌──────────────┐        ┌──────────────┐
              │ PRELIMINARY  │◄──────►│  PARAMETRIC  │
              └──────────────┘        └──────────────┘
        ┌────────────────┐   ┌──────────────┐   ┌────────────────┐
        │ MASTERFORMAT   │   │  UNIFORMAT   │   │ MASTERFORMAT   │
        └────────────────┘   └──────────────┘   └────────────────┘
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| PUBLISHED COST DATA IMPERIAL | OWN COST DATA IMPERIAL | PUBLISHED COST DATA METRIC | OWN COST DATA METRIC | PUBLISHED COST DATA IMPERIAL | OWN COST DATA METRIC | PUBLISHED COST DATA IMPERIAL | OWN COST DATA METRIC |

Figure 2: **System Components**

A CAD model is translated into VR, either directly, or through the intermediate stage of a rendering package [6].

The whole 3D model can be simulated after writing long programming lines using VRML 2.0, however, this is out of the scope of this paper. At present the 3D CAD model, which has (.dwg) file format, is manually exported to 3D Studio Max 3.0 for rendering and from there will be exported with VR (.wrl) format. Figure 4 illustrates this process. Finally the model can be implemented in the web through a Virtual Reality browser. The outlook is to automate the data transfer from 3D CAD to VR without passing through 3D Studio Max.

VRML 2.0 is to be integrated with the Object-Oriented programming language JAVA due to its ability to provide a mechanism for enabling objects and to perform calculations when needed. Implementing stages one and two, the procedure is finalized by grouping them together, using CIC and VR environment in one single model.
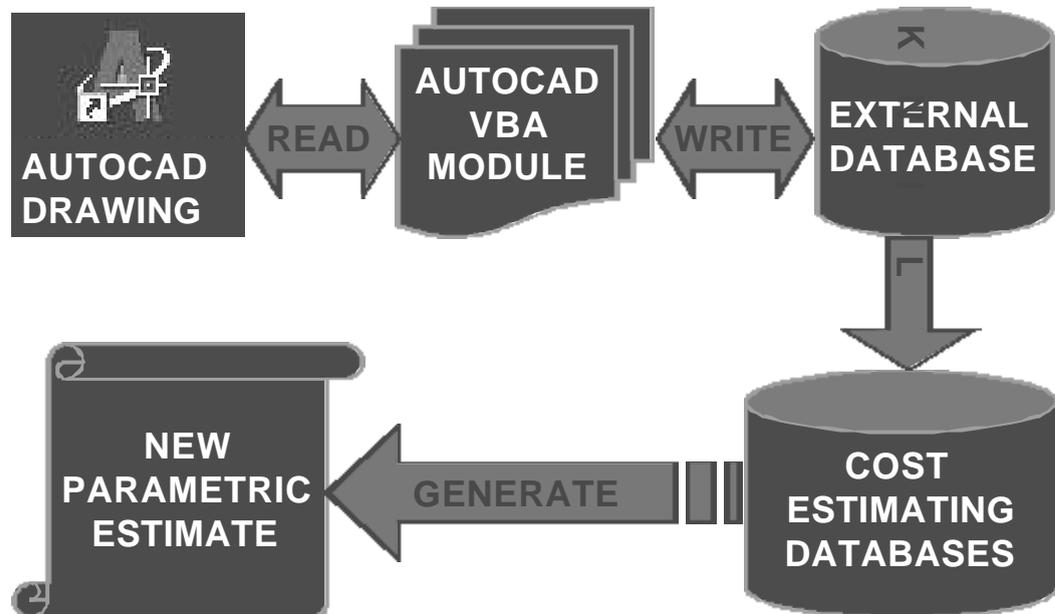
STAGE 3 INTEGRATED COMPONENTS

Figure 3**: Stage - 3 Integrated Components**

3 CONCLUSIONS

A computer system for preliminary estimates for hi-rise buildings has been introduced. The methodology followed to develop a Virtual 3D Conceptual Cost Estimating Model, that provides owners, architects, and cost engineers with a tool to perform conceptual cost estimate, animate, model and modify its associated drawings was described. Two types of estimates are established depending on the available information of the project.

Based on the model operation, the system has several useful features as follows:

- The system is designed in a manner that allows future expansions and enhancements.
- User friendly, easy to use, efficient, and fast calculations.
- Ability to easy edit, add and modify the available data of the entire database.
- Professional output reports that can be used for bidding purposes, and the ability to graphically visualize and print these reports either as pie or histogram chart.
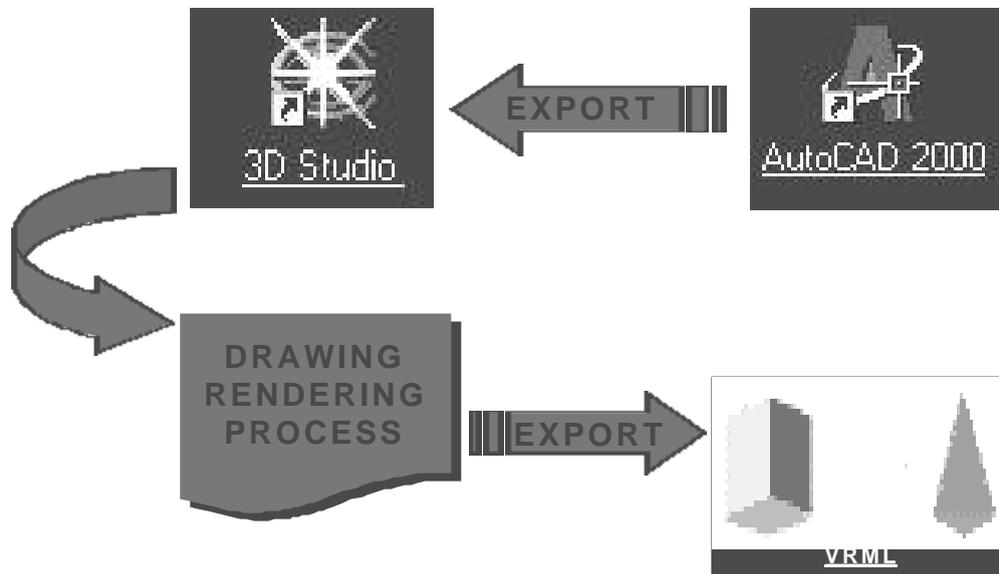
PHASE 2 EXPROTING PROCESS

Figure 4**: Exporting Process**

- Exporting the generated estimates to a spreadsheet and a word processing document.

The system will assist in producing quick and cost effective estimates. Moreover, the perspective of the model is to be simple, user-friendly, flexible, and allows users modifications whenever necessary.

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