

INTEGRATED COST BUDGETING AND COST ESTIMATION MODEL FOR BUILDING PROJECTS

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ABSTRACT

Integrated Cost Budgeting and Cost Estimation Model for Building Projects

Sarmad Al-Mashta

Concordia University, 2010

Cost estimation is an essential skill in the construction industry. For each stage in the project life cycle, conceptual design till decommissioning, there are particular techniques to perform cost estimation. Starting from the preliminary design stage, cost estimates progressively become more detailed and more challenging as a task that requires more man-hours. Consequently, it is not feasible to be performed repetitively. Considering this, detailed cost estimates are only performed at specific points during the design and at the bidding; leaving gaps where project cost can grow out of control.

This research proposes a methodology to develop an integrated cost budgeting and cost estimation model for building projects. The proposed model is implemented by integrating an automated quantity take-off system, with a relational database to generate cost estimate reports. The dynamic environment of the proposed model, streamlines the preparation of cost estimates in order to reflect, virtually instantly, the impact of changes in project scope on the cost. Accordingly, decision makers will be able to; venture various scenarios to meet the client budget without compromising the project quality, save tremendous

amount of resource-hours allocated to prepare cost estimates and cut down design process cost. The benefits of such a model can extend well beyond the doors of engineering offices to tremendously reduce the time required by contractors for preparing bidding estimates.

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To my late grandfather, Abdulwahab, I dedicate this

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NOMENCLATURE

BIM	Building Information Modeling
B.O.M.	Bill of Materials
B.O.Q.	Bill of Quantities
DB	Database
EWBS	Elemental Work Breakdown Structure
GAC	Global Assemblies Catalogue
ODBC	Open Database Connectivity
PCQ	Process Construction Quantities
PPQ	Procurement Process Quantities
RDBMS	Relational Database Management System
SCML	Systems' Components Master List
TWBS	Trade Work Breakdown Structure

CHAPTER 1

Introduction

1.1. General

Each construction project requires many cost estimates and re-estimates, based on the stage of project (Peurifoy and Oberlender 2002). Depending on the project complexity and the project phase, cost estimate preparation can become a very tedious and time consuming process. It is, in itself, one of the project expenses.

Cost estimate aims to validate the work to be executed; this can happen on a detail, phase or project level. The actual cost will remain always unknown awaiting the completion of that work. From this very nature of uncertainty comes the importance of reliable cost estimate, and the reason beyond contingency and risk allocations.

No matter how complex is the required cost estimate, it always follows a simple process; generate input data, process this data by applying appropriate method(s) (computation formulas) to obtain an output.

In a traditional context, the elements that dictate the accuracy of the estimate under preparation are; expertise of the project team, the used tools and methods, the amount of allocated time, and the particularity of the available information (Jrade 2000). The expertise and the experience of the estimator(s) are of highest significance as they play a major role in appropriate generation and selection of input data based on the available information, in the selection and

implementation of suitable method(s) to process that input, as well as to manage the allocated time to generate the output.

Due to the complexity and the large amount of data generated by the process of cost estimate, usually, the work is broken down into packages or components, then the required resources are assigned for each component, then cost is estimated for each resource. Finally, the total cost is calculated by aggregating the packages or components cost.

1.2. Research Objectives

The main objective of this research is to develop a methodology to automate the cost estimate process for building projects. It should be independent from quantity take-off mechanism and complying with Class 2 (Level 4) and/or Class 1 (Level 5) of AACE International Cost Estimation Classifications - 17R-97. (AACE International 1997)

Also the research holds the following sub-objectives:

- Evaluate current trends in quantity take-off process to explore the possibilities of integration and automation.
- Develop database model to store various cost sources to serve as global catalogue for cost estimate preparation.
- Develop a method for mapping between different formats of cost estimate work breakdown structures as required by the project phase or the project team needs. This will enable the proposed model to reduce tremendously the amount needed to generate a detailed quantity take-off.

- Integrate the different parts into one computer model that can accommodate the various sources and formats of quantity take-off and costing databases to streamline the cost estimate process.

1.3. Methodology

To meet the forth mentioned objectives of the present research the following procedures are executed:

1.3.1. Literature review

In-depth literature review is conducted in the areas of; cost estimation, building projects design and documentation software and database design.

1.3.2. Software review

A review of genres of available automated quantity take-off packages, presented by Izon-MTO developed by Archidata (based on 2D AutoCAD drawings) and Revit developed by AuoDesk (Based on BIM – Building Information Modelling)

1.3.3. Model development

The iterative and incremental model is followed for the development of proposed model. The proposed model is implemented by using Revit and Microsoft Access.

1.3.4. Validation of the Model

Once the system is developed it will be presented to experts, practitioners, cost estimators and architects to obtain their feedback, comments and evaluation.

1.4. Thesis organization

This chapter (chapter1) gave a prelude for the research subject as well it identified the outlines of this research.

Chapter 2 presents a literature review of present day methods, approaches and solutions for cost estimate.

Chapter 3 addresses the role of computer and IT in construction domain focusing on the cost estimate applications.

Chapter 4 explains the proposed model, which is developed based on the findings from previous chapters. Covering it is various components and the dataflow.

Chapter 5 describes the steps taken to implementing the proposed model into a working solution. As well as, databases structures and relations and the required inputs and the expected outputs.

Chapter 6 focuses on system performance by using it to generate automated cost estimate for a case study project.

Chapter 7 summarizes and concludes the thesis of this research. It mentions also prepositions for future expansions and extensions.

CHAPTER 2

Cost Estimation, Background

2.1. Introduction

Cost estimate is a central process for any construction project, or simply it “is the nuts and bolts of the construction industry” (Adrian 1993). Yet, it is not an exact science (Peurifoy and Oberlender 2002), it is an “art more than science” (Adrian 1993). Nevertheless, the cost estimate level of accuracy, aside from meaning the very existence of the project itself, it can mean as well the existence of the client, the architect(s)/engineer(s) as well as the contractor(s) in the business. The accuracy in itself depends on the method used, availability of cost data and level of project definition (Jrade 2000). Therefore, throughout the years engineers had developed many methods to improve the accuracy of the calculated cost estimate.

From management perspective, Project Management Institute (PMI) defines quality as “the degree to which a set of inherent characteristics fulfill requirements” and it is subject to three constrains; time, scope and cost (Figure 2.1). Quality differs from grade, which is a “category assigned to products or services having the same functional use but different technical characteristics” (Project Management Institute 2008). CSI (Construction Specification Institution) and CSC (Construction Specification Canada), and in accordance with PMI defines three factors that affect the project quality and delivery method (CSI and

CSC 2005). These are cost, time and extent (CSI/CSC). Consequently, project control processes target these factors to deliver the project as per defined quality. These factors are interrelated together, that any changes in any of them will incur changes in the other two. For instance, changes in cost (or budget) will require redefining the time (project schedule) and / or project scope to maintain the same quality.

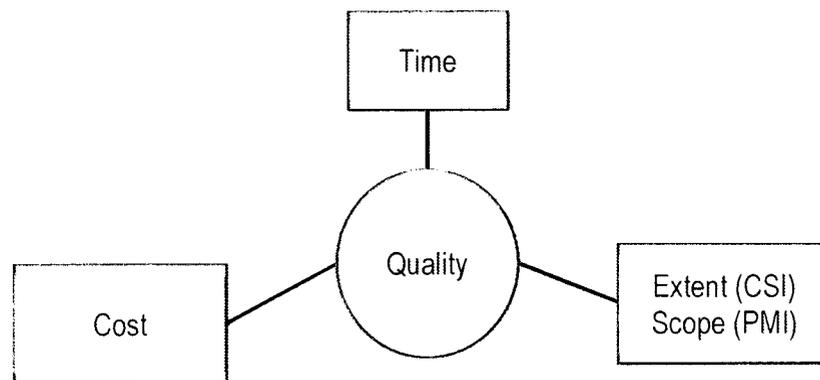


Figure 2.1: Factors / Constrains of Project Quality

On the other hand, the construction management process is characterized by the decrease of decision makers' ability to influence the total cost of the project as a function of time (CSI and CSC 2005) and (Project Management Institute 2008). In other words, the earlier decisions have a higher impact on determining the project cost in comparison with latter ones (Figure 2.2). the figure demonstrate that the curve starts with an easy slope between the Conception and Delivery Method, then slopes in a steep manner between the Schematic Design and Facility Management, where it starts to ease again toward the end of the project life cycle. Consequently, reliable cost estimates in those stages; Schematic Design, Design Development, Construction Documents and Bidding are of high

importance to support and inform the decision makers, as those stages constitute more than 50% of their capacity to impact the project cost.

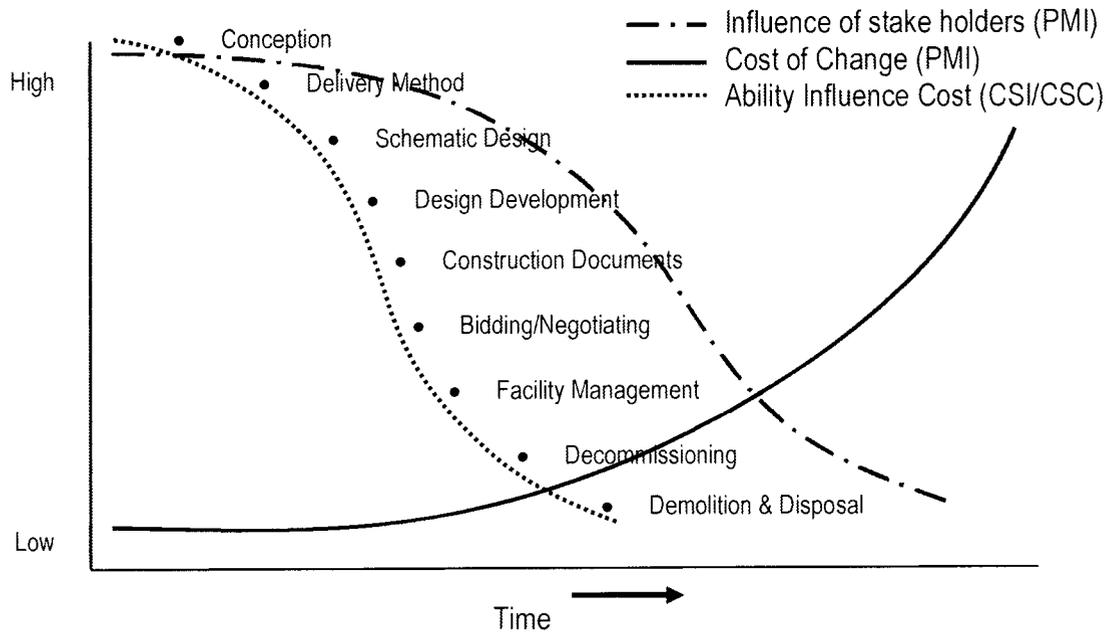


Figure 2.2: Change of Cost and Time
(Adapted from CSI and CSC 2005, and Project Management Institute)

In the coming parts, this chapter will present the types, methods and common practices of cost estimation procedures used in the building construction industry, as well as a brief review of different work breakdown structures; OmniClass, UniFormat and MasterFormat 2004 and their implementations.

2.2. Cost Estimate Definitions

According to Merriam Webster dictionary; “*Estimate*: to judge tentatively or approximately the value, worth, or significance of, to determine roughly the size, extent, or nature of, to produce a statement of the approximate cost of.”

Cost estimate can be viewed as the task of determining the quantities of work to be performed, with the productivity and cost of the resources required to perform that work (Adrian 1993). The Association for the Advancement of Cost Engineering (AACE) defines cost estimate as; “a predictive process used to quantify cost, and cost the resources required by the scope of an investment option, activity, or project” (AACE International 1990) or it is; “an elevation of all the costs of the elements of a project or effort as defined by an agreed-upon scope” (Aaron, et al. 1997). As well it is; “the process of looking into the future and trying to predict costs and resource requirements” (Halpin 1985). While PMI defines two terms: Cost Estimating is; “developing an approximation of the costs of the resources needed to complete project activities” and Cost Budgeting is; “aggregating the estimated costs of individual activities or work packages to establish a cost baseline”. Another definition is; “an A/E’s opinion of the probable cost of construction based on the cost of similar constructed projects; published cost data; input from construction participants; economic conditions prevailing at the proposed time of construction; and contingency for inestimable factors” (CSI and CSC 2005).

As a result, we find cost estimate definitions, although they differ from experts to expert and from researcher to another, they agree on the outline in describing the process of cost estimate as: A forecast of the most probable expected use or expenditure of the required resources to realize, complete or execute a; defined task, an activity, an element or a project during certain time range.

2.3. Uses of Cost Estimate

The use of cost estimate depends on the stage of the project, the audience that will evaluate it and its perspective. Generally speaking, for the owner(s); it means the feasibility of the project or cash flow schedule, for the architect and engineers; it is meeting the project budget assigned by the client and/or performing value engineering to augment the project quality or grade, as for the contractor; it represents the “flight plan” to be followed and to aid him in achieving profit (Halpin 1985).

2.4. Cost Estimates Types and Methods

Cost estimate references refer to estimate types and methods as separate topics. However, from this research point of view, it is more suitable to address them together as often an estimate type will be defined by the used method.

Project stages dictate the amount and nature of available information to prepare a cost estimate. This stipulation infers the available options at each stage in regards to which method(s) can be used to accomplish the estimate. Conversely, the selected method will characterize the estimate type. On the other hand, it should be noted that all the various estimate’s methods and types share the same single objective; that is to increase the estimate accuracy.

Based on the stage of the project two broad categories can be defined (Adrian 1993):

- Pre-Construction Design estimates; are estimates performed often by the architects and engineers for the feasibility studies and project cost

budgeting. Pre-construction design estimate can use one of the following methods which as well defines its type:

- Unit-Cost Estimate; is a function of the base element considered. A common unit-cost estimate is the *function estimate* using square-foot (or square-meter) unit. The estimate is obtained by multiplying the historical data of cost per quantifying unit by the number of units quantified in the new project. Then to apply adjustment factors and modifiers (RSMMeans 2008); e.g. location, inflation, project size modifier...etc.
- Parameter Estimating; instead of using one parameter (unit-cost per function) multiple parameters are considered to estimate the project cost. Historical data allocate lump-sum costs to trades or components systems, which each of them is linked to one parameter.
- Factor Estimating; is used where there is a predominant cost component. A typical case is process plants where the purchased equipment constitutes the dominant factor that influence the project cost.
- Range Estimating; this type of estimate implements the probability theory to establish a range for the estimated cost, by doing as such, the uncertain nature of estimate is being taken into consideration. As well, other information can be made available through this

method, e.g. critical work packages can be identified to help in the project control and management.

- Construction estimates; are the estimates performed by the contractor for bidding and project execution purposes. Basically it is an estimate prepared using detailed quantity take-off then apply one or the combination of two methods (Halpin 1985):
 - Unit Pricing; is the result of multiplying the quantity of work to be performed by historical data records then applying a qualitative correction factor(s). This method is sufficiently accurate for common items.
 - Resources Enumeration; when there is no historical data available, the cost is calculated by breaking the work item into subsets and enumerating the required resources for each item in the subsets. The sum of each required resource will constitute the cost of that work item.

In a traditional context the cost estimate is performed at four major milestones (updates can still occur during each stage at required intervals) of the project (Halpin 1985):

- Conceptual Estimate; is an estimate that happens before the initiation of the design, where very little is known about the project. Thus it relies on a comprehensive unit; like square foot, or number of seats...etc. and multiply it by the average obtained from historical data to get a gross estimate of the project.

- Preliminary Estimate; as the design process starts more information will be available. After the termination of the first of two design stages (preliminary design) another estimate is performed. A common time for this estimate is at 40% completion of the total design.
- Engineer's Estimate; as the second and final stage of design starts after preliminary design approval, more and more definitive information will be available, specification will be determined as well during this stage. At its completion another estimate will be performed to:
 - Insure that the design is within the project budget.
 - Establish a reference cost to evaluate the contractors' bids.
- Bid Estimate; using the project final design documentation the contractor will prepare his estimate, which require a greater level of efforts and much more man-hour to prepare.

The same milestones are pinned-out by (Peurifoy and Oberlender 2002), although they approve a different naming:

- Initial estimate; is the estimate prepared after the sponsor's study and before starting the preliminary engineering.
- Re-estimate; is the estimate prepared after preliminary engineering and before detailed engineering.
- Re-estimate; is the estimate prepared after detailed engineering and before procurement.
- Bid-estimate; is the estimate prepared after procurement and before the start of construction.

As for the National Institute of Standards and Technology, the cost estimate falls into two broad categories that depend on the cost breakdown structure instead of the project phase (Charette and Marshall 1999). However, each category is more suitable at different project stages:

- Construction product (Trade) estimate; that usually reference the CSI MasterFormat product classification that was initially developed for specifications. This breakdown structure is useful for specification development as well as assigning work packages for subcontractors.
- Elemental estimate; to facilitate design cost analysis and monitoring of costs from programming phase through the completion of construction documents. Which uses one or a combination of the following methods:
 - Elemental unit rate; is an application of unit-cost method, where the *function* is a variant that equals the building elements.
 - Assembly Costs; is the add up of multiple assemblies cost to sum the total cost of an element, then it is divided by the element quantifying unit to derive a unit rate that can be incorporated in historical data.
 - Component Costs; is similar to assemblies cost except that it handles the component cost as a lump-sum number for that component. This approach is most suitable for equipment (e.g. air handling units)

2.5. Classes of Cost Estimates

The naming conventions, as mentioned above, is the source of a lot of confusion (Aaron, et al. 1997), as it describes only a single characteristic of an estimate, while there is at least four characteristics that need to be addressed to identify an estimate correctly:

- End use of the estimate; changes from screening to control
- Accuracy range; changes from broad to narrow
- Estimate content and the used information to prepare it; changes from summary to detailed
- Calculation method; changes from stochastic to deterministic.

These characteristics represent the core of AACE Recommended Practice 17R-97 (AACE International 1997) to build generic cost estimate classification matrix (Table 2.1).

In brief, the classification depends on primary characteristic and secondary ones. The primary characteristic; Level of Project Definition is the percentage of the completed project definition defined by the set of deliverables for every stage, which functions, as well, as a driver of the secondary characteristics. It also dictates the available inputs to the estimating process. Regarding the secondary characteristics; End Usage is the reason behind performing the estimate; it defines as well how the estimate is analysed and evaluated. As for the two broad categories of methodology, a stochastic method feed the estimating algorithm with value(s), which are not the output of direct quantifying process. In

opposition, a deterministic method feed the estimating algorithm with a definitive quantifying of subject item. Finally, efforts and cost to prepare the estimate is defined as indexes as they can vary from industry to industry, even from a division to another within the same industry.

Estimate Class	Primary Characteristic	Secondary Characteristic			
	Level of Project Definition Expressed as % of complete definition	End Usage Typical purpose of estimate	Methodology Typical estimate method	Expected Accuracy Range Typical +/- range relative to best index of 1	Preparation Effort Typical degree of effort relative to least cost index of 1
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgement	4 to 20	1
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget, Authorization or Control	Mixed, but Primarily Stochastic	2 to 6	3 to 10
Class 2	30% to 70%	Control or Bid/Tender	Primarily Deterministic	1 to 3	5 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	1	10 to 100

Table 2.1: AACE Generic Cost Estimate Classification Matrix

2.6. Estimating Process

Similar to cost definition, the estimating process internal steps do not have a commonly adapted structure. Consequently, experts and researchers do not adhere to exact number of steps performed during the process. For instance; (Aaron, et al. 1997) set up eleven steps; starting with “*Project Initiation*” till “*Cost Feedback & Continual Improvements*” (Figure 2.3), while (Halpin 1985) defines

the estimating process with eight steps; starting with “*Study plans and specs*”, ending it with “*Revise estimate as required*” (Figure 2.4).

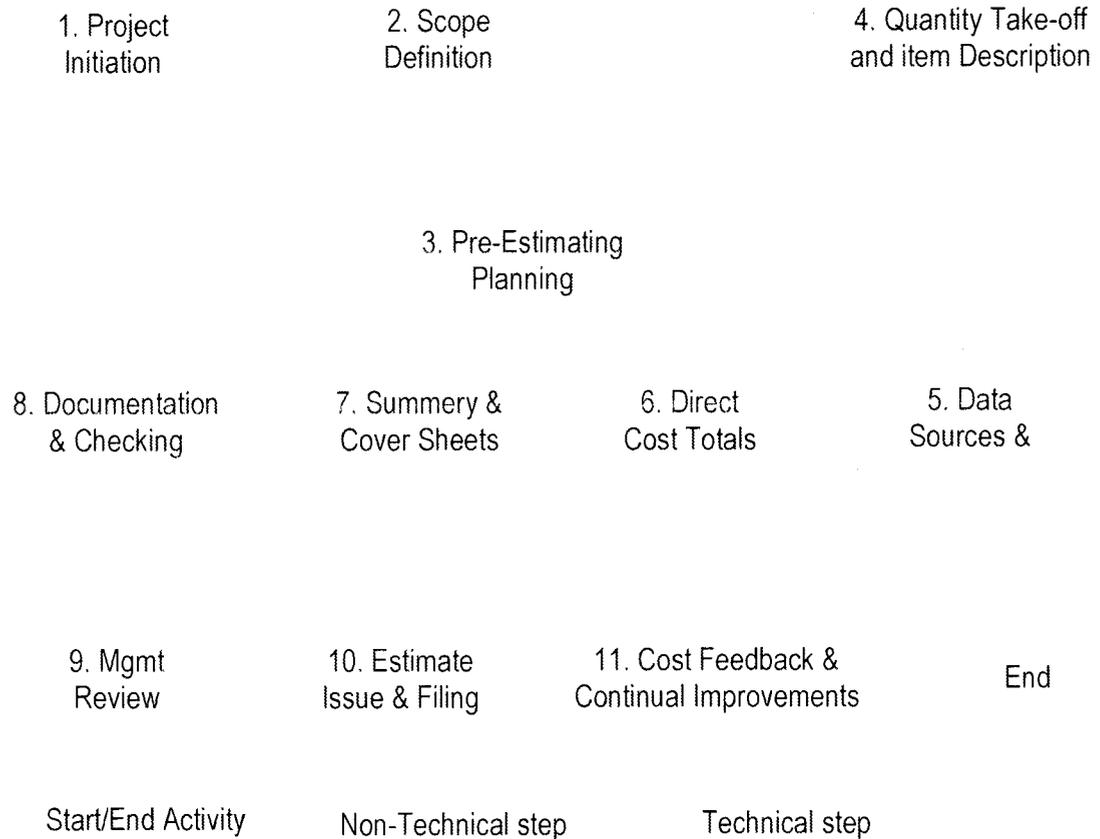


Figure 2.3: The 11 Step Cost Estimate Process

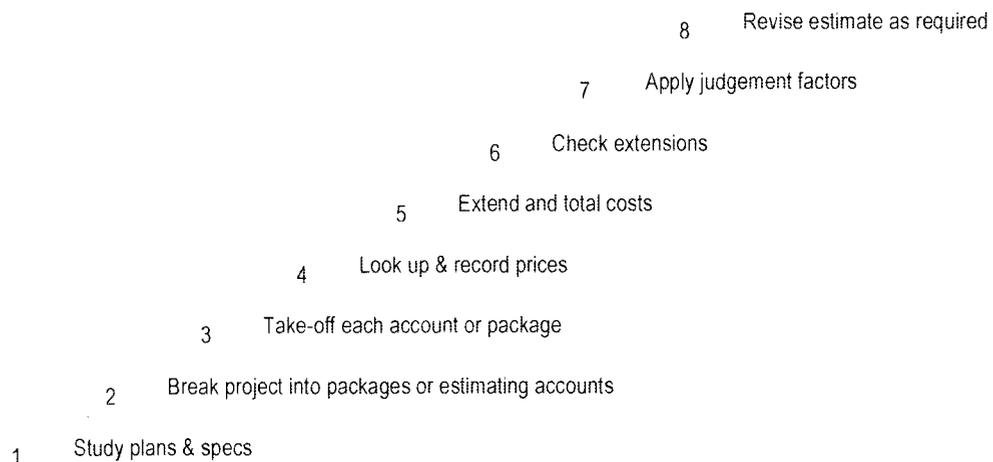


Figure 2.4: Steps in Estimate Process

However, no matter how many steps are defined by various experts and researchers, the preparation of cost estimate, in any phase of the project, can be simplified to four steps which belong to two stages (Figure 2.5):

- Data Preparation (Input Stage); this stage is a time consuming process and consists of two separate sub-processes that depends heavily on the expertise and knowledge of the estimation team
 - WBS; is breaking the project to subsets of items or packages. A suitable format should be selected depending on the end-use of the cost estimate.
 - Quantity take-off (including materials quantity, labour and equipment); there are various techniques that are applied during this sub-process if performed manually, mainly depending on the item that is being quantified.
 - Cost data collection; using the two methods mentioned earlier; unit-cost based on historical data or resource enumeration. Historical data can be collected from previously executed projects or obtained from third parties like manufacturers, subcontractors or database providers (e.g. RS Means in North America)
- Data Manipulation (output stage);
 - Computing; easy parts of cost estimate preparation (although it is prone to mistakes when done manually). In general it depends on simple mathematics

- Classification (cost reports generation); is a time consuming process, as each item has to be classified and sorted in meaningful breakdown structure. In others words, it is the way the estimate is presented. The format of the estimate presentation changes according to the project phase and to it is audience as well as it is purpose.

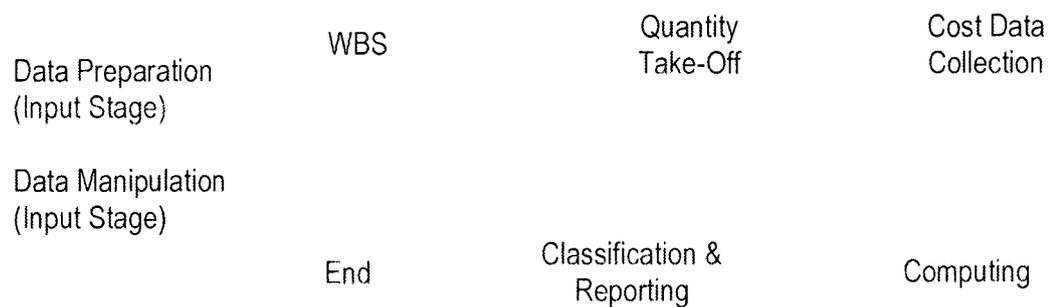


Figure 2.5: Cost Estimate Process

2.7. Different types of Costs

A project cost is not limited to the accumulative sum of costs of the used or spent resources in placing the elements of construction. Every project has many other costs that are associated with it directly or indirectly.

- Direct Cost; related to placing construction element and are traceable to a given project. It includes costs of material, labour and equipment.
- Indirect Costs (Overheads); are various costs other than direct costs, the included costs vary from project owner(s) point of view to the contractor point of view:

- Job Overheads; these are costs that are traceable to a project but cannot be associated with any specific segment of that project (Adrian 1993). Job overheads may vary from a project to another, although many of them are common to every project. From contractor point of view; it includes, enumerating a few; temporarily site installations, material storage, interest in case of construction loan...etc. From project owner(s) point of view, it includes various fees, to enumerate a few; permit fees, taxes, interest in case of construction loan, marketing expenses, design team fees and contractor (subcontractor) profit
- Administrative expenses; these are the costs that support the production process but is not directly associated with a specific one. For instance, general marketing expenses, expenses to maintain the home office...etc.

2.8. Direct Cost

Direct cost of a building projects is affected by main two parameters; building design and materials used (Mohamed and Celik 2002). These two parameters in addition to the contractor expertise in construction methods will determine the construction process and its execution. Those parameters must be considered during the generation of a detailed cost estimate. Shen and Issa divide detailed cost estimate quantities into two types; product /procurement quantities (PPQ) that are quantities of the physical design components and estimating process quantities (PCQ) that are specific to the construction process, while PPQ can be

considered fixed as long as the design do not change, PCQ varies according to construction process/construction method to implemented (Shen and Issa, Quantitative Evaluation of the BIM-Assisted Construction Detailed Cost Estimates 2010). To further explain how the PCQ can varies for a given design, an example of an L-shape Cast-in-Place Tilt-UP Concrete Panel with Brick Veneer is demonstrated below (Figure 2.6 and Table 2.2).

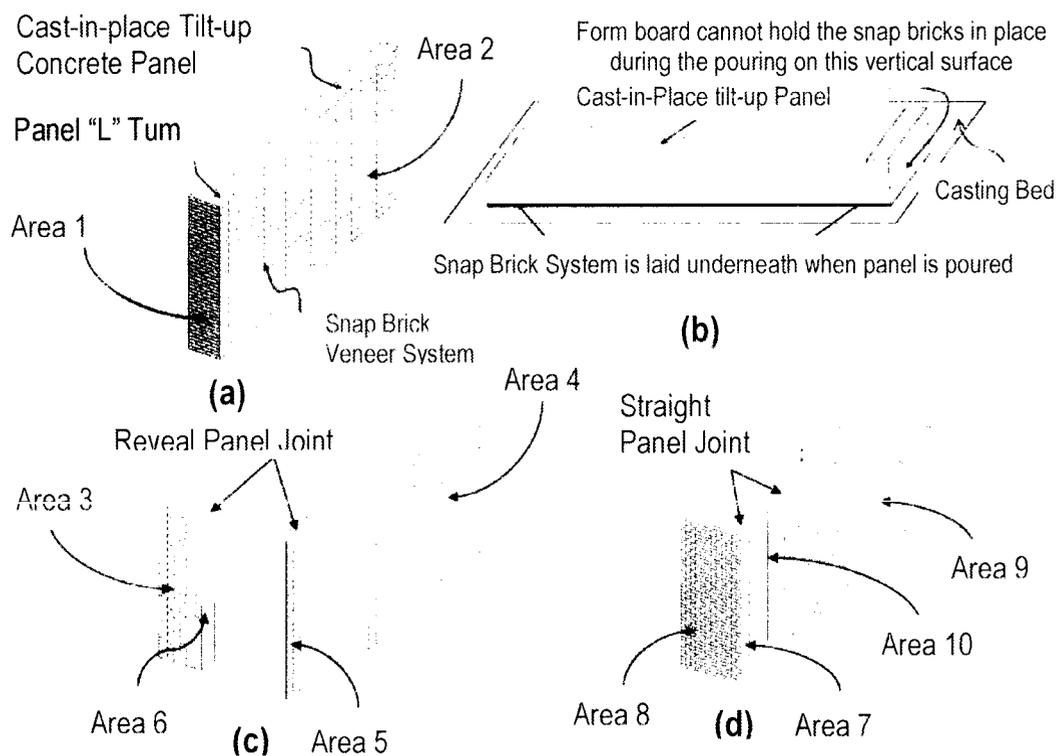


Figure 2.6: Three Construction Methods for an L-shape tilt Panel

Source (Shen and Issa 2010)

Depending on the contractor knowledge and expertise this panel will constructed according to one of the three methods. The selected method will generate various PCQ for the same design. It should be noted that the PPQ of the brick

veneer will be equal to summation of Areas of side A and Side B which will be the same quantity that is independent from the selected construction method.

Required PCQ Quantities for Calculating Labour Hours of Placing the Tilt-Up Panel				
Labour Hours Calculation method	Apply production rate for laying brick on the casting bed	Apply production rate for placing corner brick on the casting bed	Apply production rate for placing brick after the panel was tilted	Exclude
Method 1 (Fig. 2a)	Area 2	n/a	Area 1	n/a
Method 2 (Fig. 2a)	Area 3, 4, and 5	Area 5	n/a	Area 6
Method 3 (Fig. 2a)	Area 8 and 9	Area 7	n/a	Area 10

Table 2.2: Matrix of the construction methods and the corresponding PCQ
Source (Shen and Issa 2010)

2.9. Historical data

Historical data play very important role in cost estimate. It is used in all cost estimate methods mentioned previously except for resource enumeration. Historical data has two sources; 3rd parties (e.g. data providers) or from previously executed projects. In the latter case, it is an output from applying cost control functions. More specifically it is one of the outputs of the cost accounting process (Figure 2.7).

In brief, cost control is the process of monitoring the actual cost of a work item and compare it with the estimated cost considering the percentage of completion for the subject item, then if required apply corrective measures. This process requires logging material quantities as well as equipment and labour hours associated with the corresponding work item (Adrian 1993).

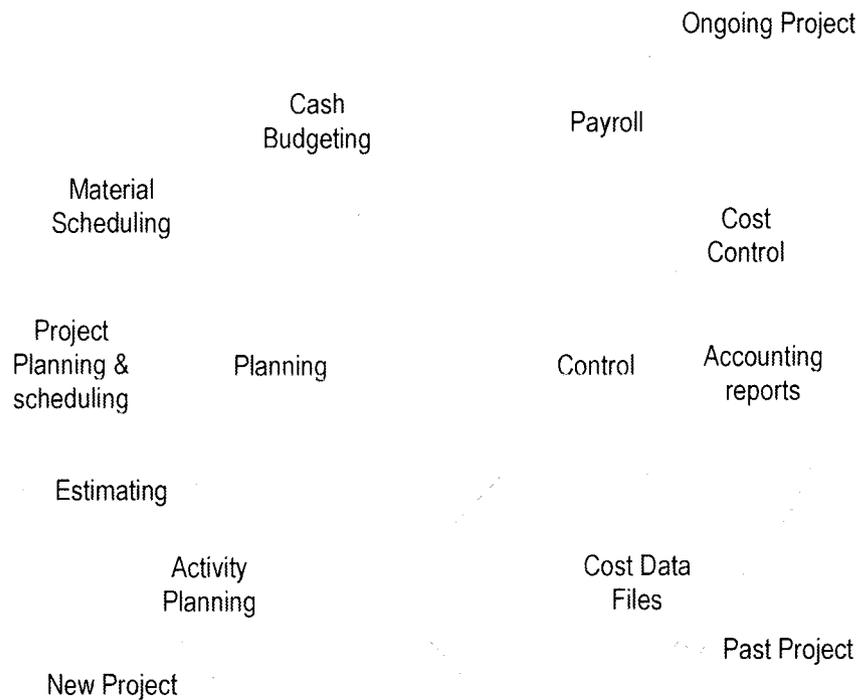


Figure 2.7: Overview of a Project Management System (Adrian 1993)

2.9.1. Cost Index

Historical data can be out-dated by definition due to multiple factors (e.g. inflation, changes in labour rates, materials cost...etc.). Therefore, it requires applying correction factors in order to adjust the cost input making the current estimate achieve the required level of accuracy.

A cost index provides a comparison of cost changes from year to year for a fixed quantity of work or service. It can be calculated by applying the following equation (Adrian 1993):

$$C_c = C_r \frac{(I_c)}{(I_r)}$$

Where C_c = present cost in dollars

$C_r = \text{original reference cost in dollars}$

$I_c = \text{Index Value at present time}$

$I_r = \text{Index Value at time reference cost was obtained}$

It should be noted that a variety of indexes available for construction including those published by *Engineering News Record* as well as Boeck and Marshal and Steven Indexes for building projects.

2.10. Work Breakdown Structure

The PMI sees the work break structure (WBS) as a “*deliverable-oriented hierarchy of decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables, with each descending level of the WBS representing an increasingly detailed definition of the project work*”. The results of the applying WBS is smaller more manageable components (Project Management Institute 2008). As far as cost estimation is concerned these smaller components will establish the cost items or the input for the estimating process.

Typically a detailed cost estimate can range from few hundred lines to multi-thousands, depending on the project size and complexity. In order to make sense of this enormous amount of data, it must be classified, grouped and summed into a format that is comprehensible by the audience. This grouping follows the same WBS.

2.10.1. Work Breakdown Structure Formats

CSI / CSC describe three formats for specs documents; MasterFormat, UniFormat and OmniClass™ (OCCS). UniFormat break the building into functional elements known as systems and assemblies. Consequently, UniFormat is employed majorly; in early design of a project, for preliminary project descriptions, for performance specifying, and, frequently, for cost estimating. Contrariwise, MasterFormat breaks the same information into groups of work results based on products and construction practices. As a result, MasterFormat is used at later design and construction stages of a project, and throughout the facility lifecycle. On the other hand, OCCS is a multiple tables system that aims to organize information used by the architectural, engineering, and construction industry. It is a basis for deriving relational applications, targeting supporting and empowering the transfer and use of information in the construction marketplace, in order to serve all participants involved in sustaining the built environment throughout the entire life cycle of a facility (CSI and CSC 2005).

2.10.1.1. Elemental Work Breakdown Structure (EWBS)

According to American Society for Testing and Materials (ASTM) UniFormat is a classification framework based on building element (physical parts – called “systems” and “assemblies”) which provides a consistent reference for the description, economics analysis and management during the different phases of a project life cycle (Charette and Marshall 1999). UniFormat consists of three levels (Figure 2.8). However, there are some initiatives to create level 4 (CSI

uses MasterFormat numbering, and ASTM uses same letters as level 1).but no standard has been established yet.

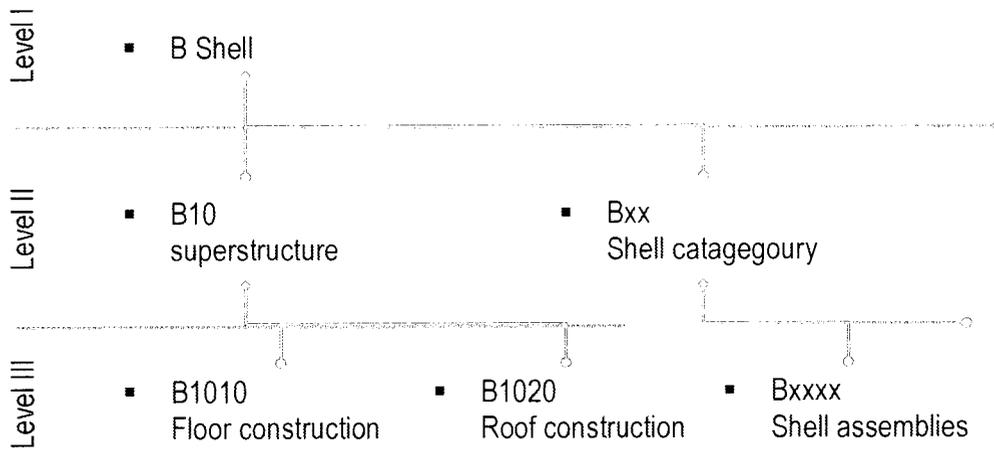


Figure 2.8: UniFormat Structure

2.10.1.2. Trade Work Breakdown Structure (TWBS)

According to Construction Specifications Institute – CSI and Construction Specifications Canada - CSC, MasterFormat is a master list which organizes construction requirements, products and activities into “Section”. These sections are arranged in “Levels” depending on their breadth of coverage. MasterFormat 2004 constitutes of 50 divisions made up of three levels and occasionally level 4 (Figure 2.9). The main purpose of MasterFormat is to organize the project manual, reference keynotes, specifications and detailed cost estimates.

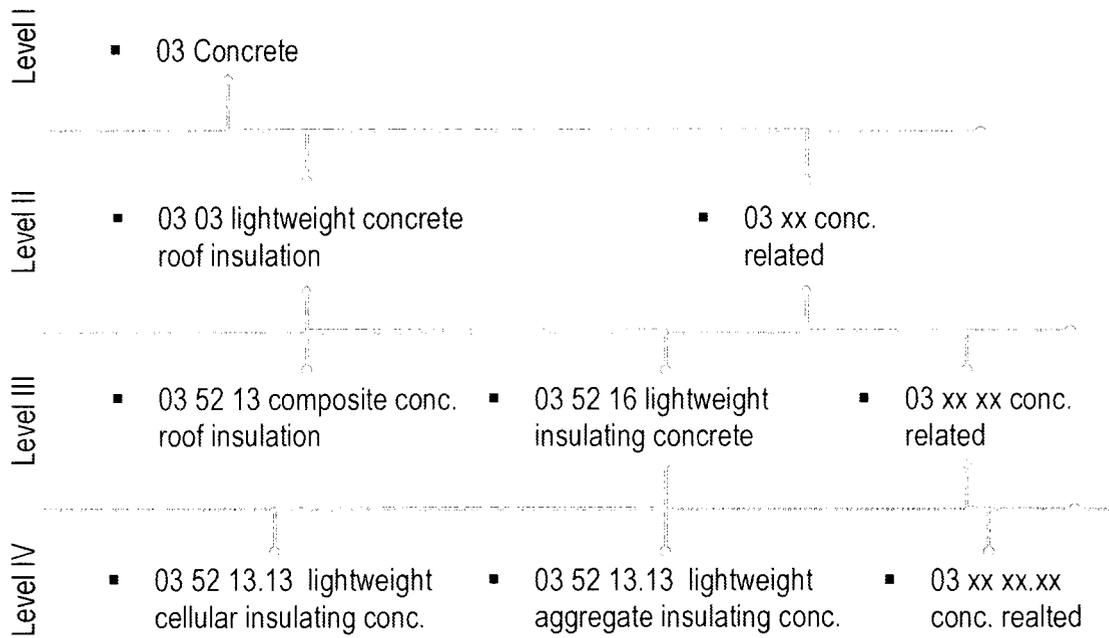


Figure 2.9: MasterFormat 2004 Structure

Although MasterFormat is very widely adapted in construction industry in North America, it is inconvenient for early design stages and/or to compare multiple design alternatives due to insufficient project definition level and the fact that preparing a cost estimate based on listing products and materials per item is time consuming and costly (Charette and Marshall 1999).

2.10.1.3. Relationship between the Formats

According to CSI and CSC, Even though UniFormat and MasterFormat were designed separately, they evolved to complement each other and not to replace each other (Figure 2.10), they are connected in a hierarchical relationship (CSI and CSC 2005).

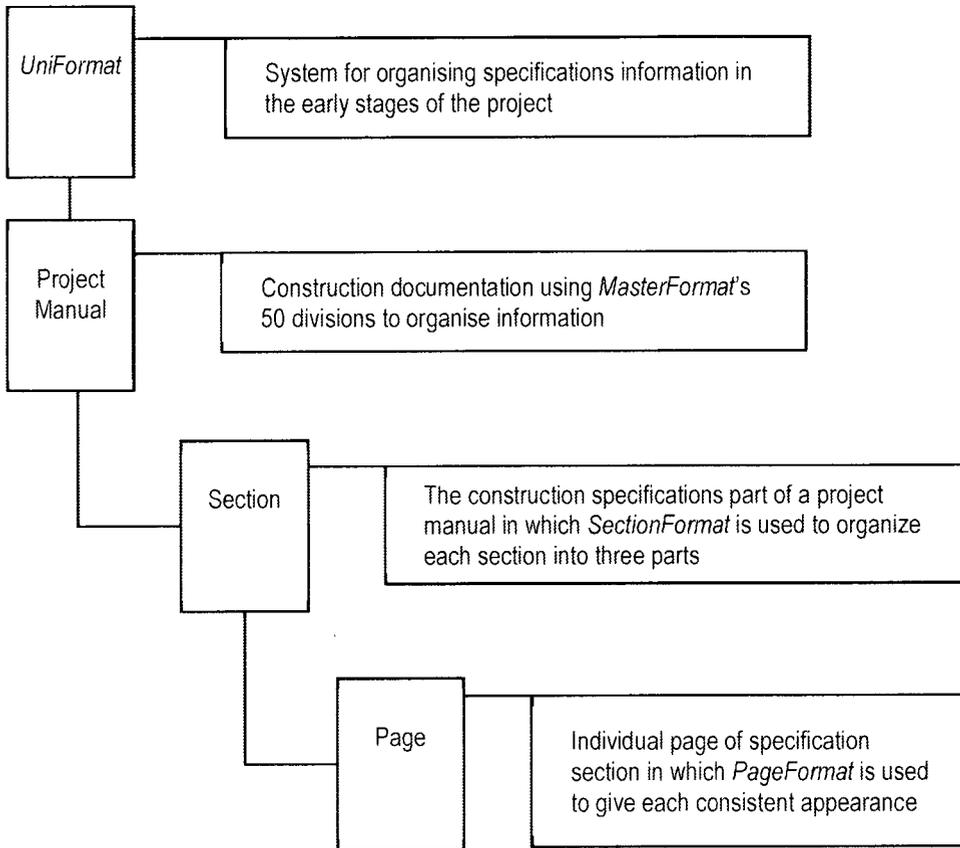


Figure 2.10: Hierarchy of the Formats

PROGRAM SPECIFICATIONS	DESIGN SPECIFICATIONS
TECHNICAL PROGRAM <ul style="list-style-type: none"> • Performance Specifications (UNIFORMAT™ II) • Technical Requirements (UNIFORMAT™ II) 	SCHEMATIC DESIGN <ul style="list-style-type: none"> • Preliminary Project Description (PPD) (UNIFORMAT™ II) DESIGN DEVELOPMENT <ul style="list-style-type: none"> • Outline Specifications (MasterFormat™ 95) CONSTRUCTION DOCUMENTS <ul style="list-style-type: none"> • Construction Specifications (MasterFormat™ 95)

Figure 2.11: Program and Design Specifications

This complementary nature is reflected clearly in common practice during various phases of the project, where Unifomat is used in early stages of the project and the WBS is switched to MasterFormat during Design Development (Charette and Marshall 1999) and used through the Construction Documents and the project execution (Figure 2.11).

Design UniFormat		Construction UCI	01 General requirements	02 Site Work	03 Concrete	04 Masonry	05 Metals	06 Wood / Plastic	07 Thermal & Moisture	08 Doors and Windows	09 Finishes	10 Specialities	11 Equipment	12 Furnishing	13 Special Constructions	14 Conveying Systems	15 Mechanical	16 Electrical	
Level 2	Level 3																		
01 Foundation	011 Standard Foundations																		
	012 Spec Foundation Cond.																		
02 Substructure	021 Slab On Grade																		
	022 Basement Excavations																		
	023 Basement Walls																		
03 Superstructure	031 Floor Construction																		
	032 Roof Construction																		
	033 Stair Construction																		
04 Ext. Closure	041 Exterior Walls																		
	042 Ext. Doors & Windows																		
05 Roofing																			
06 Int. Const.	061 Partitions																		
	062 Interior Finishes																		
	063 Specialities																		
07 Conveying Systems																			
08 Mechanical	081 Plumbing																		
	082 H.V.A.C																		
	083 Fire Protection																		
	084 Spec. Mech. Systems																		
09 Electrical	091 Services & Distribution																		
	092 Lighting & Power																		
	093 Spec. Elec. Systems																		
10 Gen. Cond. OH&P																			
11 Equipment	111 Fixed & Movable Equip.																		
	112 Furnishing																		
	113 Special Construction																		
12 Sitework	121 Site Preperation																		
	122 Site Improvement																		
	123 Site Utilities																		
	124 Off-Site Work																		

**Table 2.3: Relationship of UniFormat to Master Format
(The American Institute of Architects - AIA 1984)**

However, the transit process between the formats is not documented nor covered in the literature neither a systematic method of performing this transition has been established. On the other hand, a generic mapping grid has been established by the American Institute of Architects (AIA) that maps the Unifomat Levels to Construction UCI, which was superseded by MasterFormat 1995 (Table 2.3). This table has been updated and extended by Lewis R. McClain to cover MasterFormat 2004 (McClain 2007) and is included as appendix C.

2.10.2. OmniClass

OmniClass (OCCS) is a new standard that aims to provide comprehensive classification for the entire built environment (OmniClass - Introduction and User's Guide 2006). It consists of fifteen interrelated tables as of edition 1, 28-03-2006 release, these tables map to the suggested tables in Section 4 of ISO 12006-2. Each table can be used independently to classify a particular type of information, or entries on it can be combined with entries on other tables to classify more complex subjects. The information in each table is organized and based on a specific aspect or view of the total information that exists in the built environment.

OmniClass is a much broader classification system than MasterFormat 2004 and UniFormat. It attempts to classify the whole built environment. However it has two tables based on these classification systems;

- MasterFormat 2004 serving to inform Table 22 (Work Results) of the OmniClass Construction Classification System - OCCS (OmniClass - Introduction and User's Guide 2006).
- UniFormat is undergoing revisions by CSI and CSC, when the new version will become available it will serve as the source for Table 21 (Elements) of the OmniClass Construction Classification System (OCCS), similar to the current relationship between MasterFormat and Table 22 (OmniClass - Introduction and User's Guide 2006).

The tables that concern the research the most is Table 21 and Table 22. As of edition 1, 28-03-2006 release, the status of Table 21 is Conditional Draft. The OCCS Development Committee is waiting for the new release of UniFormat to finalise its release. On the other hand, table 22 status is released. These two tables are based on, and serve UniFormat and MasterFormat respectively.

The structure of OmniClass tables is similar to UniFormat and MasterFormat, as it is a hierarchical tree structure with five levels as illustrated in (Figure 2.12).

To maximize compatibility of OmniClass with existing classification systems, as well as to ease the migration process, the OCCS Development Committee adopted a guiding principle to *“Utilize existing systems and compatible initiatives to avoid duplication of effort.”* these include; Uniclass, MasterFormat™ , UniFormat™, EPIC (Electronic Product Information Cooperation), Portions of a few tables published by ASTM International, Selected resources provided by the

U.S. General Services Administration (GSA), U.S. Army Corps of Engineers, the International Code Council (ICC).

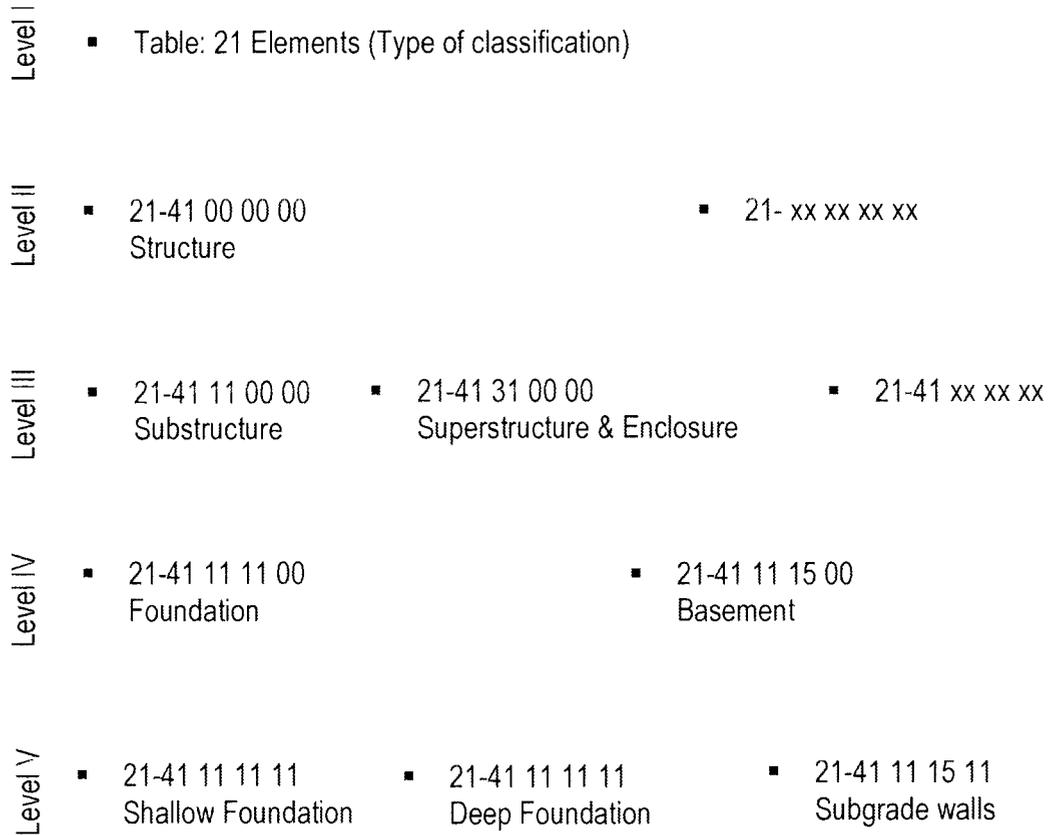


Figure 2.12: OmniClass Structure

2.11. Summary

This chapter covered a literature review of cost estimate in construction, in terms of definitions, classes, categories, types and methods, and its role in project management, its uses as well as its breakdown structures. The key findings of this chapter are:

- Although some experts define two sets of estimates, approximate and detailed (Peurifoy and Oberlender 2002, Jrade 2000) the estimate

accuracy is never known until the end of execution of the project, that springs from the nature and definition of the estimation process as there is always unknown factors in every project. Hence, even in detailed estimates there is the contingency allowance, which aims at addressing the project uncertainties and risks.

- Traditionally and in today practice, cost estimates happen at milestones of the project, leaving gaps in between those milestones where the cost is not under full monitoring due to the effort/cost required to prepare them in addition to the used methodologies. Therefore, in some cases the estimated cost can jump out of the project budget, while it was in good standing in the previous stage.
- Trade or work result breakdown structure MasterFormat is the most commonly used in North America (Wirahadikusumah 2007) is widely used among architects and engineers as it helps them to control the specification of the project. However, with more emphasis is placed on controlling the project cost during the design phases this breakdown structure falls short on achieving its objective (Charette and Marshall 1999).
- Elemental based breakdown structure (e.g. UniFormat) can be an extremely useful during design phases, as it offers architects and engineers a set of analytical views that starts from the programming phase through the completion of construction documentation. On the other hand, starting from the bidding phase till the completion of construction a trade

(product) breakdown structure is indispensable and elemental breakdown structure is of little use apart from providing historical data for next projects.

- UniFormat consist of three levels, which become insufficient when more detailed specifications are needed to be assigned to project elements. Yet, there is no established standard that addresses this issue.
- OmniClass (OCCS) is an ambitious standard the aims to provides comprehensive classification for the entire built environment

CHAPTER 3

Computers in Cost Estimation

3.1. Introduction

Construction industry represent in no way an exception to the fast growth of computer utilization. Hardware and Software packages have been developed to target specific tasks or multiple tasks as standalone solutions or in an integrated environment. Design, Drafting, planning and scheduling, management and cost estimation is few examples where the computers has become a standard tool that is used by architects, draft persons, structural engineers, planners, managers, cost estimators...etc. computers has introduced modern technology to the construction industry (Jrade 2000). However, the industry and people response rate to the advancements of computer technologies remains much slower, making construction a slowly changing industry (Haward 1998).

3.2. Computers in Building Design

Articles about computer-aided design can be traced all the way back to the sixties. More than twenty years before the spread of the personal computers. An article titled "Computer-Aided Design and Automated Drawings" appeared in *Architectural Record* October 1965 issue (Haward 1998).

Since then computers had transformed the construction industry and the parties involved in it. Drafting boards were replaced by personal computer stations, hand filled tables were replaced with spreadsheets application, manually drawn Gantt

charts had transformed into electronic and interactive ones, huge archives of piles of documents and accounting invoices were wiped by databases and electronic documents that fits on one disk... and so on, so forth. The common dominator of all these applications is the ease of retrieving historical data as well as reusing it to generate new documents, but most importantly is the ease of modification, saving a tremendous amount of man-hours in every project. The increased productivity allowed architects, engineers, project managers and other parties involved in the process to venture more design alternatives, optimize their tasks outputs. Conversely the industry response was tighter deadlines, more documentation of projects was required and higher performances from the buildings were expected leaving the pressure sustained if not increased.

3.2.1. Computer-Aided Design (CAD)

CAD software were developed relatively early to help with engineering tasks, starting with early computers. Though CAD stands for Computer Aided Design, the vast majority of CAD implementations are limited to alleviate the pressure of repetitive tasks like drafting, calculation...etc. rather than actual design, due the rapidly changing IT counterweighted by a much slower pace of the change in the construction industry mentality. In other words the construction industry has adapted new tools rather than new approaches (Haward 1998).

CAD as term can be interpreted in two ways; generic, for instance using a spreadsheet application to perform engineering calculation is an implementation of CAD. However, in construction industry realm, the term commonly refers more specifically to drafting software that is used to produce drawings.

CAD drawings in its essence is a collection of 2D shapes, and generic 3D solids and/or meshes, when 3D is supported, stored along with different properties, like color, height, width as well as many others. Moreover, those elements are stored without any relational interdependencies; thus in its totality, they are merely a visual representation of project plans, sections, elevations...etc., without any actual significance outside the human mind (Figure 3.1).

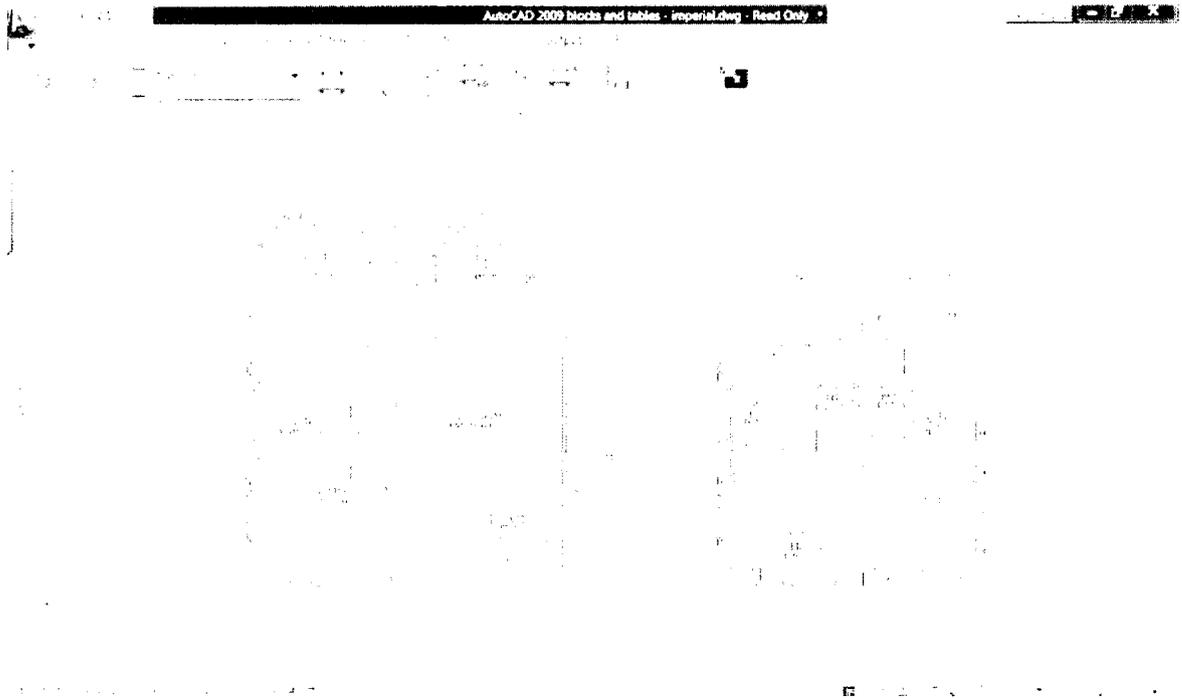


Figure 3.1: 2D CAD Drawing in AutoCAD 2009

As far as CAD market is concerned, it is dominated by AutoCAD from AutoDesk and Microstation by Bentley at this research time. Those packages appeared more than twenty years ago. They have been under development since then. More features, faster performance with more automation of minor repetitive tasks are injected in every new version benefiting from the growing computing power of the underlying hardware.

3.2.2. Building Information Modeling (BIM)

Once the construction industry started to absorb the potentials of the electronic medium along with the communication revolution that took place side by side with advancements of programming technologies and hardware, a new breed of software started to appear to address the growing needs of architects and engineers to close the gaps that were not filled by typical CAD software. This type of software is object oriented and tailored to the needs of the engineering discipline that it serves. For instance in the domain of construction, instead of having collection of shapes and generic geometry, a database of objects is developed containing real world objects; walls, doors, pipes, ducts, columns, circuits...etc. depending on the software field of speciality. In building construction, these software packages are commonly known as Building Information Modelling (BIM).

The underlying concept of BIM is, instead of having a collection of unlinked shapes presented over unlinked series of drawing, The user will built a virtual model of the building with interdependent real-life like objects. Then all the drawings will be generated automatically as “views” of this model by cutting the model vertically, horizontally or both at any desired points (Figure 3.2).

One of the first commercial software widely used by architects is ArchiCAD by Garphisoft. Later on, some developers, CAD companies and researchers started to develop BIM solutions as vertical expansion of existing CAD packages with open architecture and 3D support (Mainly AutoCAD and Microstation). AutoCAD Architecture, AutoCAD Electrical and AutoCAD Mechanical (developed by

AutoDesk with AutoCAD being the underlying engine) are just a few to mention. However, in recent years a very powerful BIM package appeared under the commercial name “Revit” that was originally developed by a German company which was acquired by AutoDesk. With the huge market share of AutoDesk, the unique features of Revit, and 3rd parties plug-ins that extend Revit functionality it has become one of the industry standards for BIM solution.

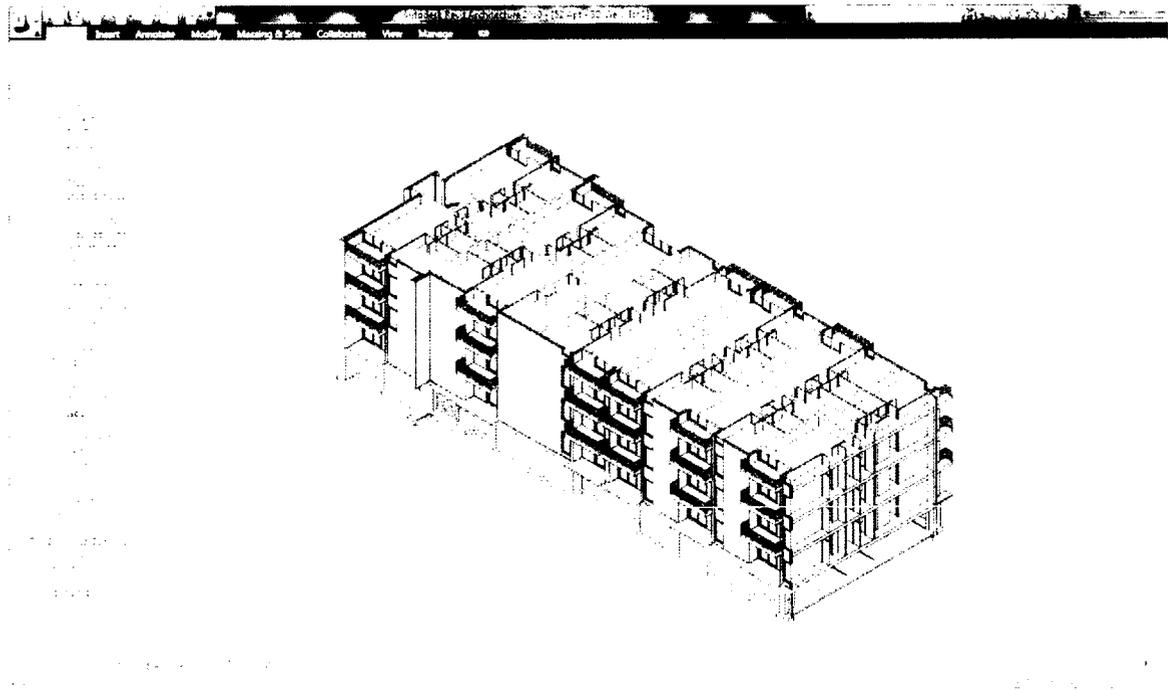


Figure 3.2: Architectural BIM Model in Revit

3.2.3. BIM vs. CAD

Building Information Modelling (BIM) differs from CAD programs majorly in two points:

- BIM software is object oriented. That means its objects based on real world building elements like walls, windows, doors...etc. on the other

hand CAD software is shape based, so its objects are lines, arcs, circles...etc.

- BIM software maintains relationships between objects, for example a floor slab is connected to supporting wall. Thus if the wall moved the slab will extend itself to maintain its relationship to the wall.

Since BIM is object oriented, it provide a more robust framework to perform engineering task that are extremely complex from a traditional CAD software point of view. For example, collision detection; to check if there are spatial intersections between ducts and other objects. Or, advise the user if there is a wall intersection with a window. As well it allows for unprecedented level of coordination between different disciplines during the various design phases, allowing architects and engineers to produce a much more precise documentation of the project with much less errors (Figure 3.3).

Beyond that BIM software nature lays the foundation for integrated design processes and project management processes. In the following example (Figure 3.4) BIM was used to illustrate the construction sequencing for a residential unit. Each step these sequences are able to produce the corresponding construction documentation, all from the same model, with minimal user interference.

On top of the mentioned above, the object oriented nature of BIM software holds within it the capacity to export quantity take-off accurately (depending on the model robustness) and without any extra efforts or input from the user.



Figure 3.3: Coordinating different disciplinary models.
 (Source: AEC Bytes, www.aecbytes.com, © M.A. Mortenson Company)

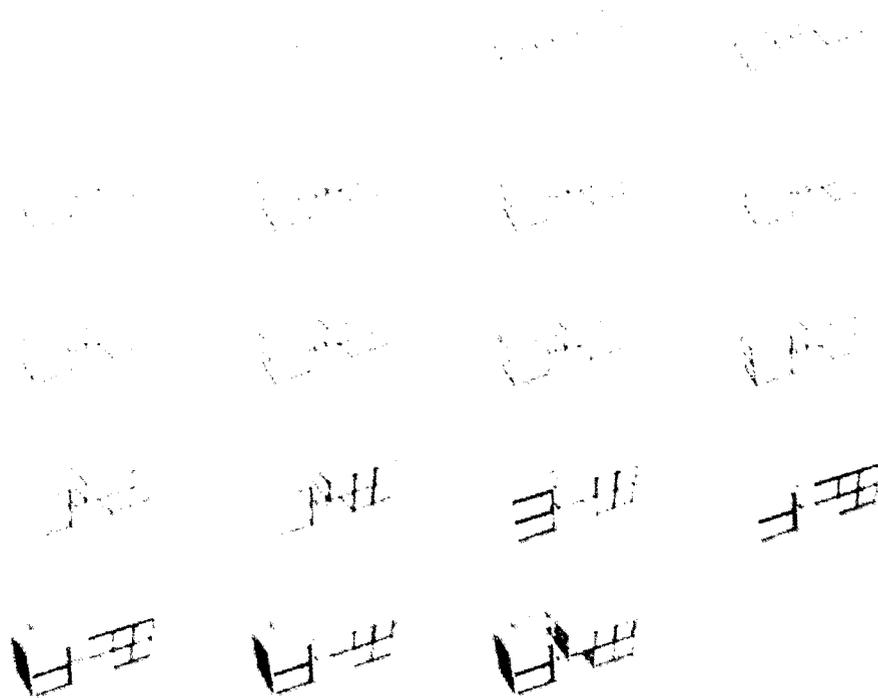


Figure 3.4: Sequencing Schedule for Onsite Assembly of Loblolly House.
 (Source: AEC Bytes, www.aecbytes.com, © KieranTimberlake Associates)

3.3. Computer in Cost Estimations

Similar to the exploitations of computers in design and drafting, traces of exploiting them in cost estimating tasks appeared in the sixties with an article titled "Computerized Cost Estimating" published in *Architectural Record* March 1967 issue (Haward 1998). Since then, the advancements made in computer hardware and software have greatly helped architects, engineers and cost estimators in measuring, counting and organising the data required to built the cost estimate reports, as well as perform the lengthy repetitive mathematical operations to build such reports. Among the possible uses of computer in estimating according to (Peurifoy and Oberlender 2002) are:

- Maintaining master checklists
- Maintaining an inventory of subcontractors, vendors, and suppliers
- Maintaining bidding records of competitive bidders
- Performing material quantity take-offs
- Storing and retrieving historical cost data
- Storing and retrieving labour and equipment productivity
- Establishing codes for labour and equipment resources
- Extending prices and summarizing costs at various levels
- Distributing overhead and costs
- Analyzing risk and assessing contingency for mark-up
- Preparing and delivering the bid or proposal in electronic form
- Sharing of cost data and information within office or company

The development of digitizers helped greatly in decreasing the amount of the time required to obtain the measurements and the required dimension. The availability of cost databases and the development of electronic drawings, which has become a standard in the industry, offer a wealth of information that can be used to help estimate the construction cost (Tong 2005).

On the other hand the recent development in computer software represented by BIM promote a big impact on the methods used and the quality / accuracy of the performance of cost estimators (Shen and Issa, Quantitative Evaluation of the BIM-Assisted Construction Detailed Cost Estimates 2010)

Nevertheless computers cannot replace estimators (Eastman, et al. 2008), as they asses and evaluate project specific conditions that impact cost, like a special slab conditions or scheduling and productivity issues...etc..

3.3.1. Computers Aided Quantity Take-Off

Use of computers in quantity take-off was pioneered by Monk & Dunstone in U.K., a paper by David Smart was presented in the QS general meeting of the Royal Institution of Chartered Surveyors (RICS) in 1961 (Haward 1998). Since then the IT industry has come a long way with many commercial packages that offers advances and sophisticated tools to help in the task of quantity take-off. The computer aided quantity take off has the advantages to reduce the amount of mistakes, reduce the time if the task was performed manually, consequently, reducing the cost of the project overheads (Tong 2005).

3.3.1.1. 2D Based Quantity take-off

2D quantity take-off relies on creating computerized measuring tools to trace printed plans (using a digitizer) or electronic 2D drawings. Then the user has to input the 3rd dimension as well as other information like material and various properties. This extra input depends on the user judgement as well as his understanding of the project. Many commercial software solutions are available for this end. For research purposes a 2D quantity take-off software package called Izone-MTO developed by ArchiData has been examined.

Izone-MTO

Izone-MTO is a 2D based quantity take-off system that relies on creating four types of generic AutoCAD objects depending on the nature of the item being quantified (ArchiData n.d.). These are; Point, Linear, Surface and Volume.

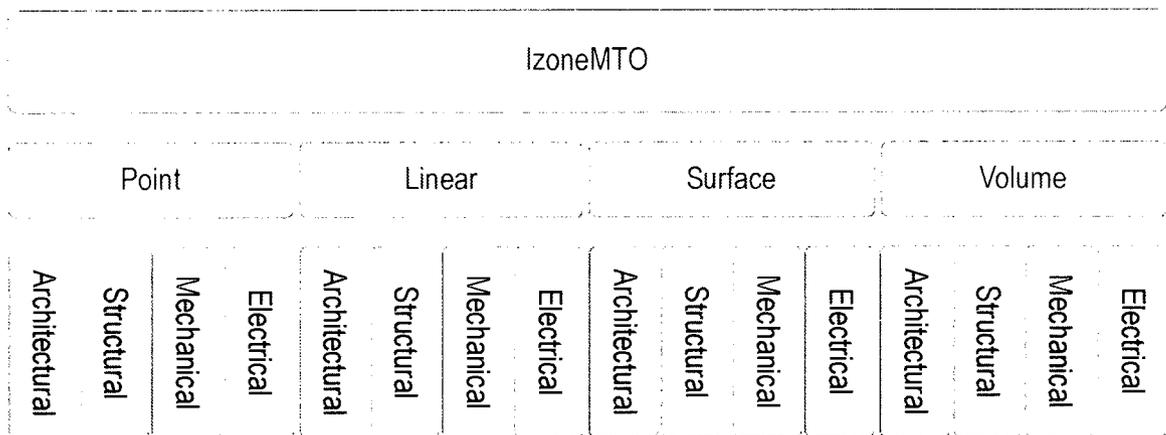


Figure 3.5: Izone-MTO objects (source: ArchiData)

Since these are generic objects, in themselves, they don't carry any significance. Hence the system relies on the user input to associate them with meaningful items. The ambiguity of these objects can be seen very clearly in (Figure 3.5) as

the same objects serve all disciplines, and they gain their meaning only from the associated UniFormat code.

These objects are assigned special attributes in order to identify them and link them to a database engine. Further the system requires from the user to allocate these objects within “Zones”, which can be nested, in order to be able to construct the data structure (Figure 3.6).

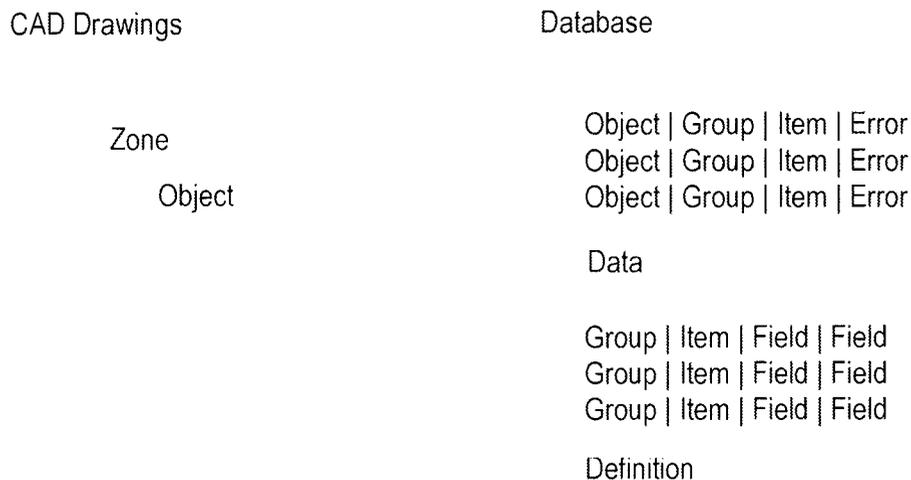


Figure 3.6: Izone-MTO Zoning (ArchiData n.d.)

As a conclusion, Izone-MTO provides a set of very advanced tools for 2D based quantity take-off. However, it remains as a semi-automated system that requires tremendous user input (for the 3rd dimension as well as many other parameters) that has to be repeated for every single item. Therefore quantity take-off process stays as time consuming task.

3.3.1.2. 3D Modeling Based Quantity take-off

A 3D based quantity take-off differs conceptually from the 2D based systems (Figure 3.7). In the 3D systems the building elements are already defined as real-

life objects. The modeling process takes place based on the 2D drawings or by starting from scratch during the design phase.

Estimators can benefit from such a system to respond rapidly to changes in critical phases of the project, a challenge they face on daily bases (Eastman, et al. 2008). As these systems have all elements quantified with high accuracy. Therefore, the user input during the quantity take-off process is minimal or none depending on the system features, structure and capacity.

An excellent example of this type of systems is a research titled “A 3D Modeling for Detailed Quantity Take-Off for Building Projects” (Tong 2005) has been examined as a case study for this research

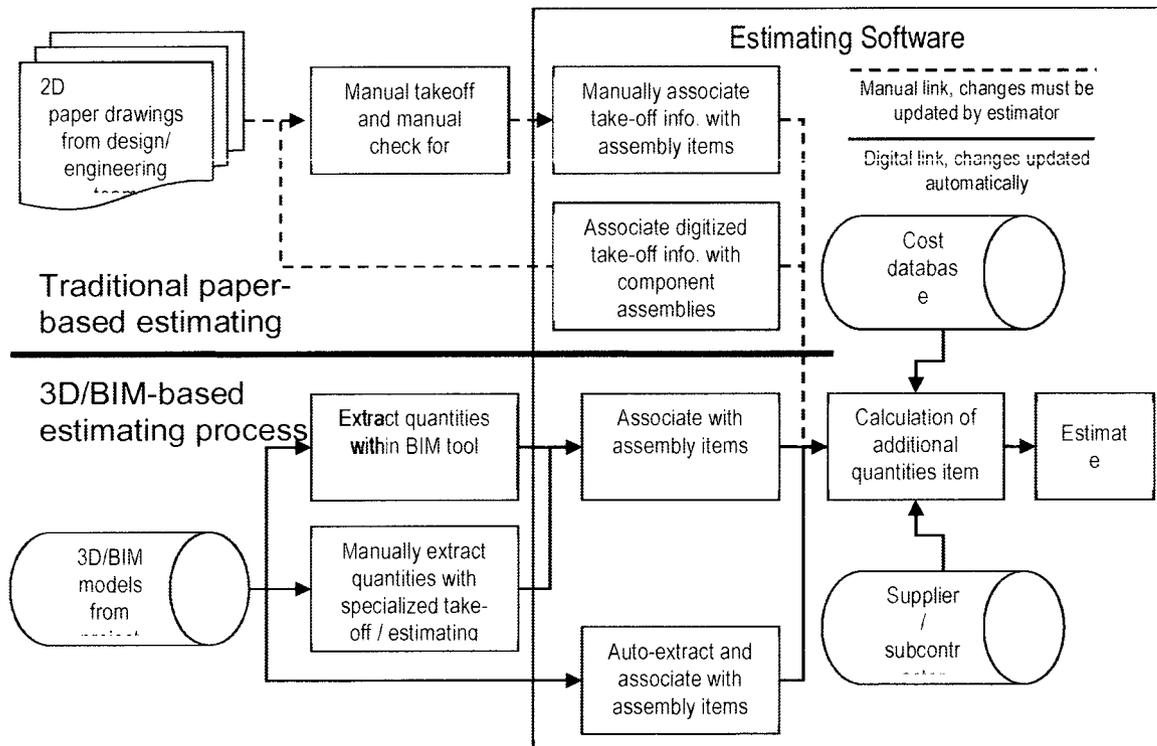


Figure 3.7: Conceptual diagram of BIM quantity take-off and estimating process.

Source (Eastman, et al. 2008)

B. Tong system architecture is quiet simple; conceptually, it relies on linking a database of building elements to AutoCAD where these elements acquire their physical properties. Then AutoCAD will feed the database with the elements dimensions, which will be used to generate the quantity-take off (Figure 3.8). The output of this system is a set of tables detailing the quantities (Figure 3.9). However the results have to be processed further and associated with cost data in order to create cost estimates.

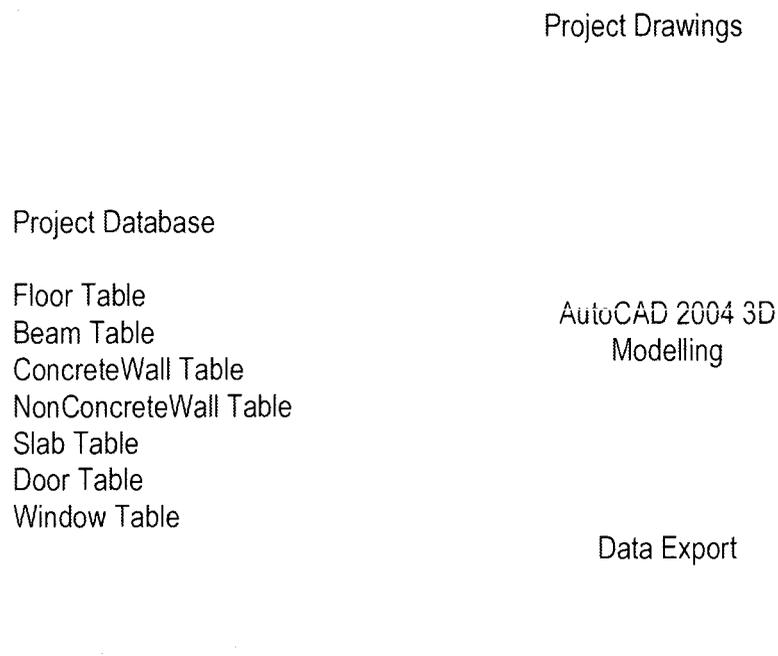


Figure 3.8: Architecture of Proposed Model (Tong 2005)

Microsoft Excel - Beams

id	width(mm)	height(mm)	length(mm)	subtract(m ²)	formwork area(m ²)	unit	factor	quantity	component type	price
1	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
2	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
3	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
4	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
5	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
6	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
7	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
8	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
9	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
10	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
11	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
12	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
13	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
14	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
15	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
16	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
17	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
18	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
19	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
20	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
21	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
22	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
23	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
24	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
25	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
26	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
27	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
28	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
29	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
30	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
31	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
32	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
33	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
34	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
35	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
36	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
37	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
38	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
39	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
40	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
41	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
42	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
43	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
44	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
45	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
46	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
47	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
48	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
49	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
50	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
51	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
52	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
53	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
54	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
55	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
56	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
57	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
58	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
59	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
60	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
61	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
62	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
63	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
64	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
65	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
66	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
67	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
68	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
69	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
70	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
71	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
72	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
73	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
74	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
75	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
76	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
77	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
78	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
79	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
80	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
81	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
82	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
83	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
84	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
85	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
86	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
87	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
88	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
89	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
90	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
91	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
92	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
93	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
94	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
95	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
96	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
97	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
98	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
99	100	100	1000	0.01	0.2	m	1.0	100	Beam	100
100	100	100	1000	0.01	0.2	m	1.0	100	Beam	100

Figure 3.9: Output Table of Beams (Tong 2005)

3.3.2. Computers and Cost Estimation Reports

Today, the computer is the most often used tool by estimators, as it helps them to avoid the drudgery of the repetitive tasks and helps them to focus on alternative construction methods or assess productivity. Consequently, providing better estimates and freeing time to perform optimization.

There are two main types of computer aided estimating software (Tong 2005) that will be reviewed here below:

3.3.2.1. Spreadsheets based software

In the case of spreadsheets, the computer duplicates the manually filled tables and forms but it adds the functionality of automatically performing the calculation (Figure 3.10).

	A	B	C	D	E
1					
2		Summary of Costs for Bids			
3					
4	Item	Labour	Material	Equipment	Total
5	Install foundations	\$2,000.00	\$0.00	\$3,000.00	\$5,000.00
6	Build Structure	\$4,000.00	\$7,000.00	\$2,000.00	\$13,000.00
7	Finish work	\$3,000.00	\$4,000.00	\$1,000.00	\$8,000.00
8	Clean up and move off	\$1,000.00	\$1,000.00	\$2,000.00	\$4,000.00
9	Direct Cost totals	\$10,000.00	\$12,000.00	\$8,000.00	\$30,000.00
10	Overhead				\$2,400.00
11	Contingency				\$500.00
12	Profit				\$3,290.00
13	Total bid				\$6,190.00

Figure 3.10: Simple spreadsheet of bid summary (Peurifoy and Oberlender 2002)

Since the computer outweighs human performance with a calculator significantly, spreadsheet has become a standard solution in cost estimate preparation. Implementing spreadsheets helps omitting the arithmetical errors, which one of the five most common errors (Halpin 1985), however it remains as an interim step between paper and pencil, and a computer estimating solution as well as an extremely limited solution of multi-user environment (Peurifoy and Oberlender 2002).

3.3.2.2. Off-the-shelf solutions

The off-shelf solutions usually provides more functionality than spreadsheets, including but not limited to; forecasts, cost tracking, accounting and financial reports, reduction of data entry burden as well as often providing the support for multi-user environment. Hence, they help to reduce transposition mistakes in copying or transferring figures.

As the nature of construction projects differs, we find that specialized estimating software tend to cover the following topics (Peurifoy and Oberlender 2002):

- Residential construction
- Building construction
- Infrastructure (heavy/highway) construction
- Specific trades, such as electrical and mechanical
- Take-off systems, sometimes with estimating modules

However, few attempts have been made to integrate cost estimation solutions with quantity take-off software, and no framework has been established for such integration.

3.4. Potentials of Electronic Document

In the past decade the software companies started to shift towards integration and interoperability as the market needs has grown up beyond the primary transition toward electronic documents (Hammad 2008).

To address the issue of interoperability as a mean to integrate the various applications into a smooth and efficient workflow many standards have been founded. One of the promising and growing in steady steps is Industry Foundation Classes (IFC). The IFC model is a neutral and open specification. It is an object oriented file format with a data model developed by the International Alliance for Interoperability (IAI) that allows different software to communicate between them as well as to carry properties and relations beyond the geometrical representations of traditional CAD document. Consequently we find that IFC has

been widely adopted by BIM developers. The IFC model architecture is based on four layers architecture, and it is developed in way to accommodate the various domains and applications of the construction industry.

3.5. Summary

The advents of IT in the last two decades have laid the path for many transformations in the practice of the construction industry. Starting with simulating the manual process, to develop new ways of thinking that emerged in consequence to the growing power and increasing popularity of personal computers. Software for construction application targeted all the various tasks and requirements of the practice, however, the industry itself adapts much slower than the rapidly changing pace of information technology. The key benefits of using computers are (Rivard 2000):

- Increase in the quality of documents
- Speed up the process to obtain desired results.
- Decrease in the number of mistakes in documentation
- Ease of modifications, exploring alternatives or applying value engineering
- Alleviate the burden of manual work allowing the practice to address more important issues.
- Allowing a much higher level of coordination between different disciplines.

This chapter and chapter two established the ground on which this research will base the methodology and the proposed model as presented in chapter 4 and 5.

CHAPTER 4

Methodology

4.1. Introduction

Previous chapters covered cost estimate as presented in the literature, as well, the current state and trends of using computers in cost estimating. This chapter will present the process followed to develop the proposed model for “Integrated Cost Budgeting and Cost Estimation Model for Building Projects” as well as the implemented method in order to achieve the research fore set objectives.

The model development cycle implemented the iterative and incremental model (Figure 4.1). The present chapter will cover; planning, requirements, analysis and design. Afterwards, Chapter 5 will cover implementation, followed by chapter 6 that will present a case study as a testing and validation. Finally, chapter 7 will present the evaluation.

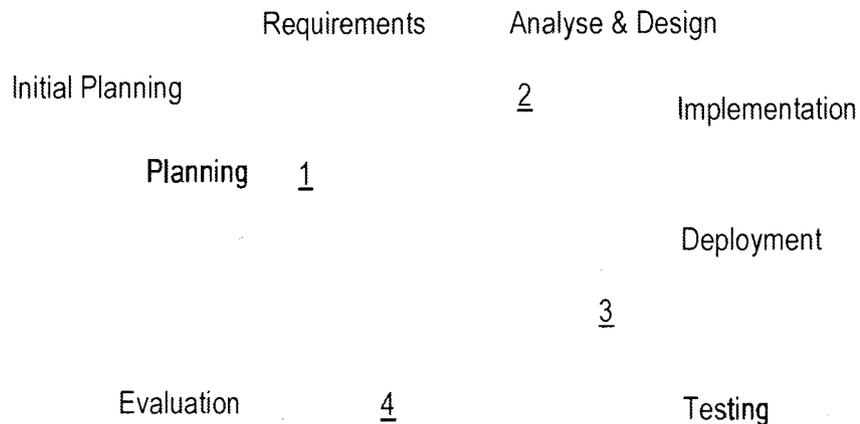


Figure 4.1: Model Development Cycle

4.2. Requirements

In order to be practical and establish a base for future expansions, the proposed model must be designed to meet the actual needs of cost estimate process. In Addition, it has to respond to the following requirements:

- Efficiency; the system should be able to process large projects in a timely manner.
- User friendly; the user has to be presented with a logical and easy to use interface as well as an easy to understand cost estimate reports.
- Flexible; the system should be able to accommodate inputs from various data sources as well as it should rely on hard-coded solutions only when the technology provides no other choice; to allow modifications and revision of the system.
- Modular; to allow for future expansions and interoperability with other systems.

4.3. Analysis and Design

The analysis phase is represented by restudying the estimating process from input / output perspective, as well as conducting detailed study of the mapping process of Elemental Work Breakdown Structure (EWBS) to Trade based Work Breakdown Structure (TWBS) and finalized by a quick review of Relational Database (RDB) as well as its Management System (RDBMS) along with AutoDesk Revit Data structure.

On the other hand, the design phase put in place the various blocks required to construct the targeted cost estimating model.

4.3.1. Estimating Process

Chapter 2 had covered cost estimating process in a detailed manner. However, In order to streamline the estimating process, it must be analyzed and studied in terms of inputs, outputs and controls.

To perform a cost estimate two inputs are required; project design that will define the scope of work to be performed and cost data for the unit of work to be performed. To properly define the scope of work an appropriate WBS must be selected and applied to the project design, the smaller components that result from applying the WBS control and guide the quantity take-off process. The generated bill of quantities (B.O.Q) will function as a control to the cost data lookup process, to determine the applicable inputs (Figure 4.2).

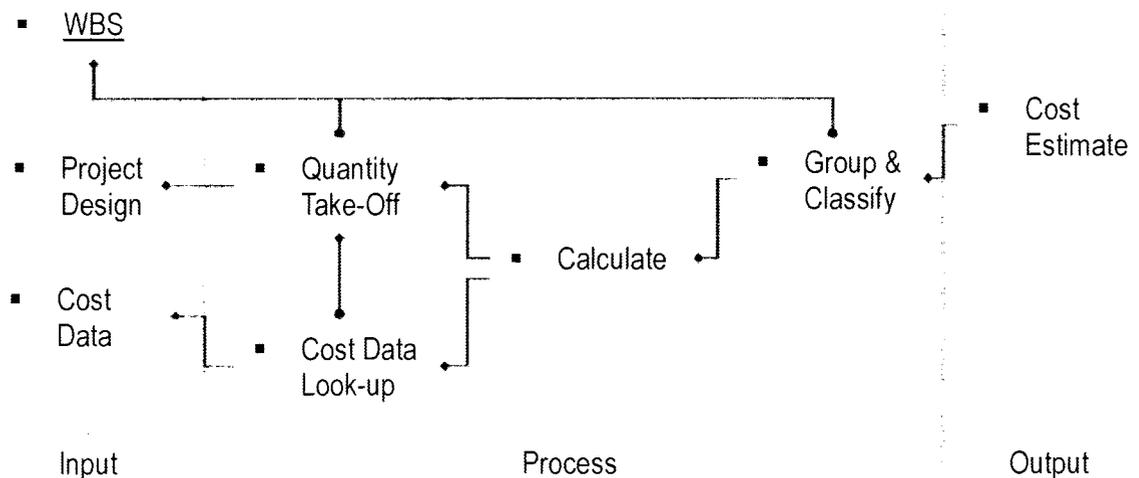


Figure 4.2: Cost Estimating Process

The next step is to perform the calculations using the B.O.Q with the selected cost data. And finally group and classify the results of the calculation process to obtain the output that is the cost estimate. The grouping and classification process is controlled by the selected WBS as well.

4.3.2. Elemental Cost Estimate

Elemental unit rate cost estimation depends on a simple concept; components that are commonly encountered in the construction are viewed as estimating group (Halpin 1985). This approach helps saving time due to the grouping nature of assemblies; instead of quantifying each component, the surveyors account the iterations of the assembly (that consist of PPQ and PCQ) as well can be used at early stages of the project were many pieces of the project information is still unavailable.

CSI / CSC focus on that elemental cost estimate is very useful during design phases for value engineering endeavours as it provide an excellent analytical views of cost data and budget distribution allowing AEC to fine tune the project (CSI and CSC 2005)

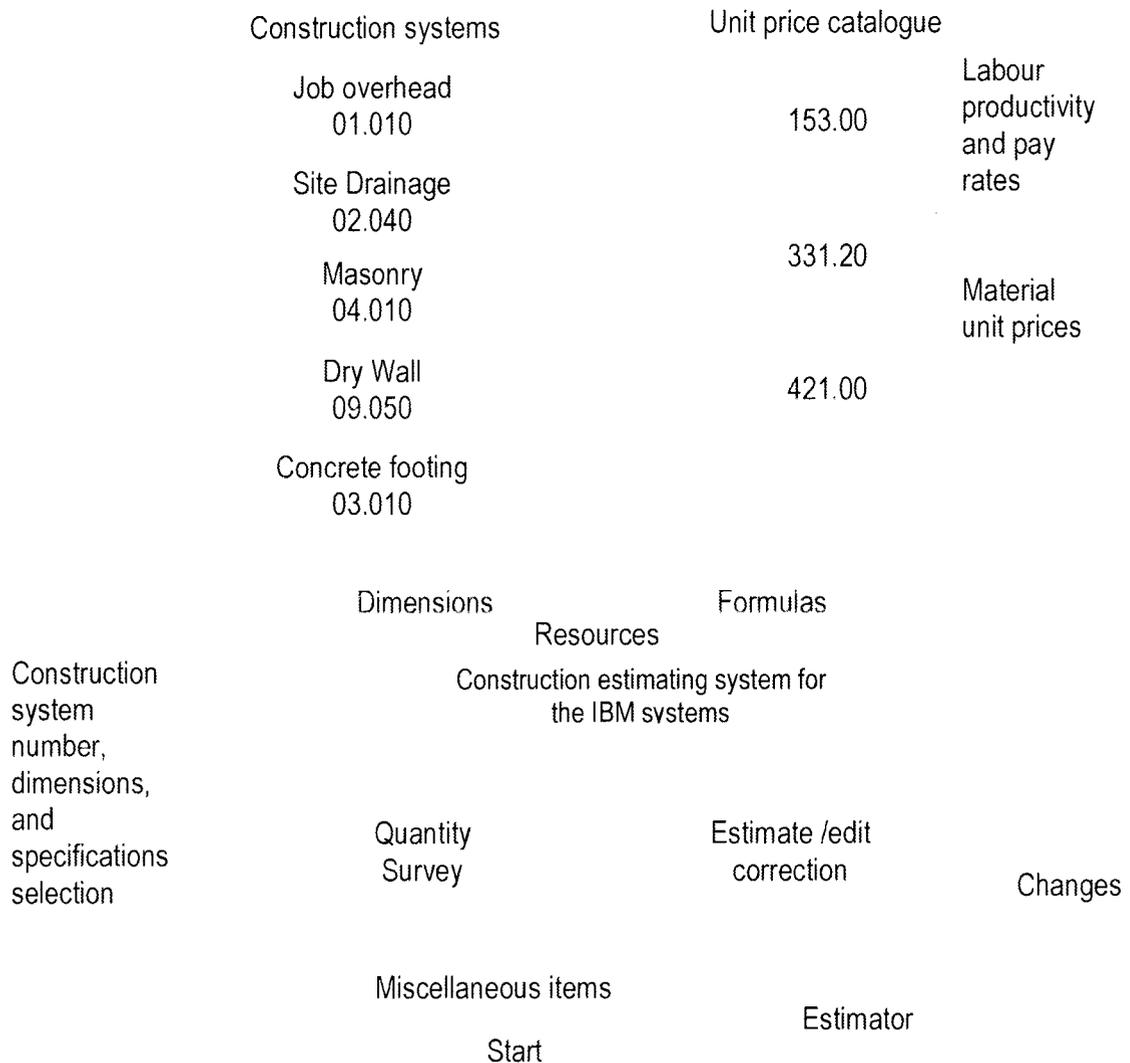


Figure 4.3: Work Package (Elemental) Concept (Halpin 1985)

Careful examination of the elemental cost estimate reveals many advantages that promote its adaptation. These include, but not limited to; Elements or assemblies have imbedded within their data; PCQ (i.e. wall sanding), temporary installation (i.e. concrete form works) and minor items in the PPQ (i.e. wood beam connectors). This information can be extracted from the assembly and used to generate other WBS based estimate.

4.3.3. Mapping Elemental WBS to Trade WBS

Chapter 2 examined briefly EWBS and TWBS represented by UniFormat and MasterFormat 2004 respectively. As well, it covered the relationship that governs them, along with their purposes and uses.

To further explore that relationship and the mapping process, two examples will be presented to understand thoroughly the mapping process and to appreciate the advantages of using EWBS system over TWBS system to build an Integrated Cost Budgeting and Cost Estimation Model for Building Projects.

First example studies a composite assembly of external wall, adapted from RS Means Assemblies Cost Data Book 2008, made of brick veneer with wood studs backing (Table 4.1) to demonstrate how the assembly components are mapped to the various corresponding divisions in MasterFormat 2004. The results of the mapping process show how a single assembly will have its components get separated over multiple divisions of MasterFormat (Table 4.2).

Alternatively the second example, examines two different simple assemblies, containing materials and work activity in the same MasterFormat 2004 division, to demonstrate how their components add up under the same MasterFormat Division. The first is a flooring assembly (one way beam and slab structure) and the second is basement reinforced concrete wall (Table 4.3 and Table 4.4). The analysis of the mapping results (Table 4.5) exhibits that it is not possible to reverse the mapping process to convert TWBS to EWBS without extending the TWBS data with information about the originating EWBS.

UniFormat System Components	Qty	Unit	Cost Per S.F.			Master Format 2004
			Mat.	Inst.	Tot.	
System B2010 129 1100						
Standard Brick Veneer, 2"x4" Stud Backup @ 16" O.C., Running Bond						
Wash smooth brick	1.000	S.F.	0.04	0.85	0.89	04 01 20.52
Wall ties, corrugated, 7/8"x7", 22 gauge	0.003	Ea.	0.02	0.14	0.16	04 05 19.16
Standard brick wall, 4" thick, running bond	1.000	S.F.	5.95	9.90	15.85	04 21 13.13
Flashing, copper, paper-backed	0.010	S.F.	0.10	0.31	0.41	04 23 19.16
Shelf angle	1.000	Lb.	0.93	0.87	1.80	05 12 23
Wood stud partition, backup, 2" x 4" @ 16" O.C.	1.000	S.F.	0.41	0.95	1.36	06 11 16
Sheathing, plywood, CDX, 1/2"	1.000	S.F.	0.57	0.68	1.25	06 16 53
Fiberglass insulation, batts, 3-1/2" thick paper backing	1.000	S.F.	0.61	0.35	0.96	07 21 13.16
Joint backer rod	0.100	L.F.		0.10	0.10	07 91 23
Sealant	0.100	L.F.	0.02	0.26	0.28	07 92 13
Total			4.64	13.62	18.26	

**Table 4.1: Mapping Composite Assembly to MasterFormat 2004
(adapted from RS Means Assemblies Cost Data Book 2008)**

MasterFormat 2004		Qty	Unit	Cost Per S.F.		
				Mat.	Inst.	Total
04	Masonry					
04 01 20.52	Unit Masonry Cleaning	1.000	S.F.	0.04	0.85	0.89
04 05 19.16	Masonry Anchors	0.003	Ea.	0.02	0.14	0.16
04 21 13.13	Brick Veneer Masonry	1.000	S.F.	5.95	9.90	15.85
04 23 19.16	Masonry Embedded Flashing	0.010	S.F.	0.10	0.31	0.41
05	Metals					
05 12 23	Structural Steel for Buildings	1.000	Lb.	0.93	0.87	1.80
06	Wood, Plastics & Composites					
06 11 16	Mechanically Graded Lumber	1.000	S.F.	0.41	0.95	1.36
06 16 53	Moisture-Resistant Sheathing Board	1.000	S.F.	0.57	0.68	1.25
07	Thermal & Moisture Protection					
07 91 23	Backer Rods	1.000	S.F.	0.61	0.35	0.96
07 92 13	Elastomeric Joint Sealants	0.100	L.F.		0.10	0.10
07 21 13.16	Fibrous Board Insulation	0.100	L.F.	0.02	0.26	0.28

Table 4.2: Results of Mapping a Composite Assembly to MasterFormat 2004

UniFormat System Components	Qty	Unit	Cost Per S.F.			Master Format 2004
			Mat.	Inst.	Total	
System B2010 101 2100						
Conc. wall, reinforced, 8' high, 6" thick, plain finish, 3000 psi						
Forms In Place, wall, job built plyform to 8', 4 uses	2.000	SFCA	2.20	11.0	13.20	03 11 13
Reinforcing in place, walls, #3 to #7	0.752	Lb.	0.40	0.29	0.69	03 22 16
Concrete Ready mix, regular Weight 3000 psi	0.018	C.Y.	1.98		1.98	03 31 13
Place and vibrate concrete, wall 6" thick, pump	0.018	C.Y.		0.73	0.73	
Finish wall, break ties, patch void	2.000	S.F.	0.06	1.60	1.66	
Total			4.64	13.62	18.26	

Table 4.3: Mapping Simple Assembly to MasterFormat 2004 (Example 1)
(adapted from RS Means Assemblies Cost Data Book 2008)

UniFormat System Components	Qty	Unit	Cost Per S.F.			Master Format 2004
			Mat.	Inst.	Total	
System B1010 219 3000						
BM. & Slab One way 15'x15' Bay, 40 PSF S.Load, 12" Min. Col.						
Forms In Place, Flat Plate to 15' High, 4 uses	0.858	S.F.	1.34	4.25	5.59	03 11 13
Form in place, exterior spandrel, 12" wide, 4 uses	0.142	SFCA	0.18	1.27	1.45	03 11 13
Form in place, interior beam. 12" wide, 4 uses	0.306	SFCA	0.46	2.25	2.71	03 11 13
Reinforcing in place, elevated slabs #4 to #7	1.600	Lb.	0.85	0.62	1.47	03 22 16
Concrete Ready mix, regular Weight 3000 psi	0.410	C.F.	1.67		1.67	03 31 13
Place and vibrate concrete, elevated slab less than 6", pump	0.410	C.F.		0.56	0.56	
Cure with sprayed membrane curing compound	0.010	C.S.F	0.05	0.08	0.13	03 39 23.13
Total			4.64	13.62	18.26	

Table 4.4: Mapping Simple Assembly to MasterFormat 2004 (Example 2)

		Qty	Unit	Cost Per S.F.		
				Mat.	Inst.	Total
03	Concrete					
03 11 13	Structural Cast-in-Place Concrete Forming	2.858	SFCA	2.20	11.0	13.20
03 15 xx	Concrete Accessories	0.142	SFCA	0.18	1.27	1.45
03 22 16	Epoxy-Coated Reinforcing Steel	2.352	Lb.	0.40	0.29	0.69
03 31 13	Heavyweight Structural Concrete	0.428	C.Y.	1.98		1.98
03 39 23.13	Chemical Compound Membrane Conc. Curing	0.010	C.S.F	0.05	0.08	0.13

Table 4.5: Results of Mapping Two Simple Assemblies to MasterFormat 2004

4.3.4. Relational Database management System (RDBMS)

4.3.4.1. RDBMS Definition

RDBMS is a database management system (DBMS) that is based on the relational model as introduced by E. F. Codd. As brief definition; RDBMS is a DBMS in which data is stored in the form of tables which are interconnected with relationships. The main advantage of RDBMS is the efficiency of the database.

To understand how it is different from a normal database a simple example is presented here. Let's assume we have two records of employees in a company, the first lists the equipment assigned to the employ's cubical and the other keeps the contact information, in a normal DBMS those tables look like this:

ID	Employee Name	Home Tel.	Cell	Address	City
010	John Doe	514-333-6161	514-666-3131	4 - 3230 Boul. Saint Laurant	Montreal
015	Nikkita John	514-999-1616	514-666-6969	10 - 69 Rue Saint Michel	Montreal

Table 4.6: Employee Contact Table

Employee Name	Department	Ext. Number	Computer ID	Printer
John Doe	CR	30	Desktop IBM-1010	HP Laser 1070
Nikkita John	Sales	69	Laptop Dell-6969	Canon 6969

Table 4.7: Department and Equipment Table

This simple example demonstrate clearly is redundancy in data that will impact DB engines performance, as well if we need to update a record, e.g. the a correction in city name that may mean modifying thousands of records. The situation will get even worse if it was needed to join the tables to generate a list of employees' addresses with the equipment assigned to them.

On the other hand in RDBMS this data will be stored in four tables with relationships integrating them to eliminate data redundancy (Figure 4.4).

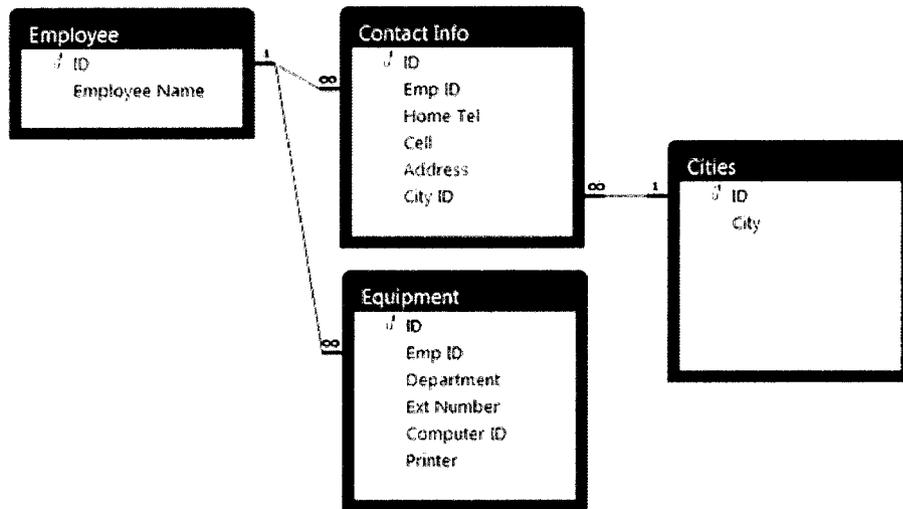


Figure 4.4: RDBMS

The process of breaking down the data into multiple tables with relationships is called "Normalization" (Elmasri and Navathe 2000).

4.3.4.2. Queries and SQL (Structured Query Language)

In RDBMS we can use queries to generate data records across multiple tables. One of the most common query languages is SQL (Structured Query Language). In brief SQL is a database computer language designed for the retrieval and management of data in RDBMS. The cross tables query that will list employees with their contact information and the equipment assigned to them would look like:

```
SELECT Employee.*, [Contact Info].[Home Tel],
[Contact Info].Address, Cities.City,
Equipment.Department, Equipment.[Ext Number],
Equipment.[Computer ID], Equipment.Printer
FROM (Cities INNER JOIN (Employee INNER JOIN [Contact
Info] ON Employee.ID = [Contact Info].[Emp ID]) ON
Cities.ID = [Contact Info].[City ID]) INNER JOIN
Equipment ON Employee.ID = Equipment.[Emp ID];
```

The result from running this query is illustrated in Figure 4.5.

ID	Employee No	Home Tel	Address	City	Department	Ext Number	Computer ID	Printer
1	John Doe	(514) 333-6161	4 - 3230 Boul. Saint Laurant	Montreal	CR	30	Desktop IBM-1010	HP Laser 1070
2	Nikkita John	(514) 999-1616	10 - 69 Rue Saint Michel	Montreal	Sales	69	Laptop Deli-6969	Canon 6969

Figure 4.5: Cross Tables Query Results

4.3.5. AutoDesk Revit

4.3.5.1. Introduction

Chapter two has introduced BIM applications and compared it to CAD. As well, it demonstrated the advantages in of using BIM over using CAD for cost estimate purposes. This paragraph will list available BIM packages and present a quick analysis of their differences.

Revit along with ArchiCad are the only widely used software solutions that are built from scratch to be a BIM solution. On the other hand, AutoCAD Architecture, Mechanical and Electrical Desktops as well as Bentley Architecture, Structural, Building Mechanical Systems and Bentley Building Electrical Systems are built on top of CAD software (AutoCAD and Bentley MicroStation), which imposes serious limitations and performance issues. Between Revit and ArchiCad the following should be considered:

- Revit has the ability to generate new parametric components without the need to learn any programming language (visual programming). On the other hand, ArchiCad requires learning Geometric Description Language (GDL) in order to develop fully parametric components.
- ArchiCad do not have companion products to support structural, mechanical and electrical designs. Revit is available for; Architecture, Structure and MEP
- Nonetheless, ArchiCad has the advantage of running on Windows™ or Mac OS, while Revit runs only on Windows™

4.3.5.2. Revit: Software Architecture

In order to be able to read quantity take-off from Revit, its architecture must be analysed and understood. Revit organizes its object in hierarchical format that consist of four levels:

- Categories (root parent): is the first level and it serves organizational purposes. Categories are not limited and the user can create as many as needed.
- Families (child of Categories and parent of types): is the second level, where a family can belong to one category only. Families identify the function of Revit object Types and the available parameters for that object type. Revit supports two types of families:
 - System Family: Revit uses these for its internal functions and objects that holds generic information, for example is the project information, in which Revit stores the project address, name, number...etc.
 - Project Families: Revit uses these families to define building components, like walls, doors ...etc., project annotations object as well as generic objects that can be used to model any object that does not fit in the forth mentioned families. (Figure 4.6) shows some the families supported by Revit Architecture. These families are stored within the project file. However they can be stored as template to build a library that can be used in multiple projects.
- Types (child of Families and parent of Instances): is the third level, they are the core of Revit objects and they serve to define different variations of the same family, as in the case of two identical windows but one is having its glass divided into four squares. Types hold, as well, another set of parameters of their own.

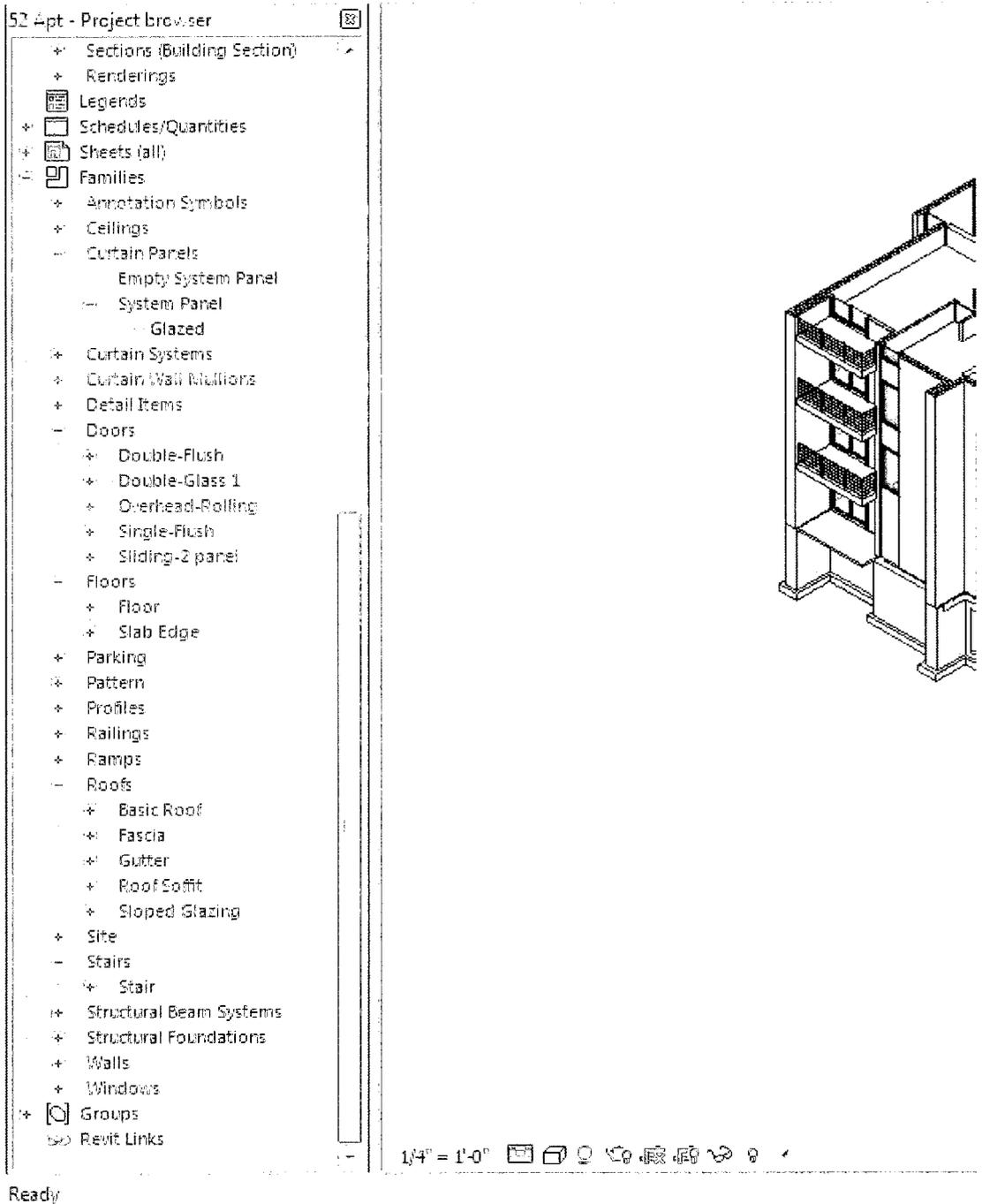


Figure 4.6: Project Browser; Revit Project Families

- Instances (Child of Types): is the actual Revit objects placed in geometric and spatial relations with other objects inside the model, an instance can have its own parameters as well.

It is of extreme importance to note that modifications at a parent level will propagate to all children of that parent by inheritance.

The internal structure of Revit file is a propriety file format which has an extension of “rvt”. However the contents of the file can be accessed in two ways:

- Application Programming Interface (API); is a programming interface that exposes Revit objects to Integrated Development Environment (IDE). Currently it supports Visual Basic, Visual C++ and C#.
- Exporting; Revit supports exporting its contents to multiple file formats. This allows Revit to be integrated in different workflow configurations.
 - CAD Formats; supports DWG (AutoCAD native format), DXF (Drawing eXchange Format), DGN (Microstation native format) and SAT (ACIS SAT).
 - Open Database Connection (ODBC); is a driver more than a file format, as the format will be determined by the database application that represent the other end of the connection. This is of a great importance to the research as it will be used to export the components of Revit project.

- IFC; as discussed in chapter 3, it is a standards for interoperability between software solutions. IFC is the only format that maintain all BIM relations and objects' definition.
- gbXML; is a file format that is common to electrical and energy analysis software.

4.3.5.3. Revit Database Structure

Exporting Revit project to a database using ODBC, will generate an RDB. The format of the database depends on the driver used to configure the ODBC. The generated RDB consists of more than 160 tables that hold the records of Revit model objects. It should be noted that the ODBC does not export the full contents of the Revit file (e.g. views are not exported), if full access is required then the API will be the proper interface. At the first glance the database structure may seems extremely complex, but a simple analysis will reveal the relationships that govern and organize these tables (Figure 4.7).

They can be categorized in two groups:

- Generic Tables; each is designed to serve different purpose. For example the Assembly Codes table holds the EWBS available to the user. Another example is Project Information table, which holds project name, number and address as well as client name...etc.
- Objects Tables; each object definition consists of two tables, one holds the family and type parameters and the other table records the instances

parameters and their geometrical and spatial information as well as their attributes. The Doors family is illustrated as an example (Figure 4.8).

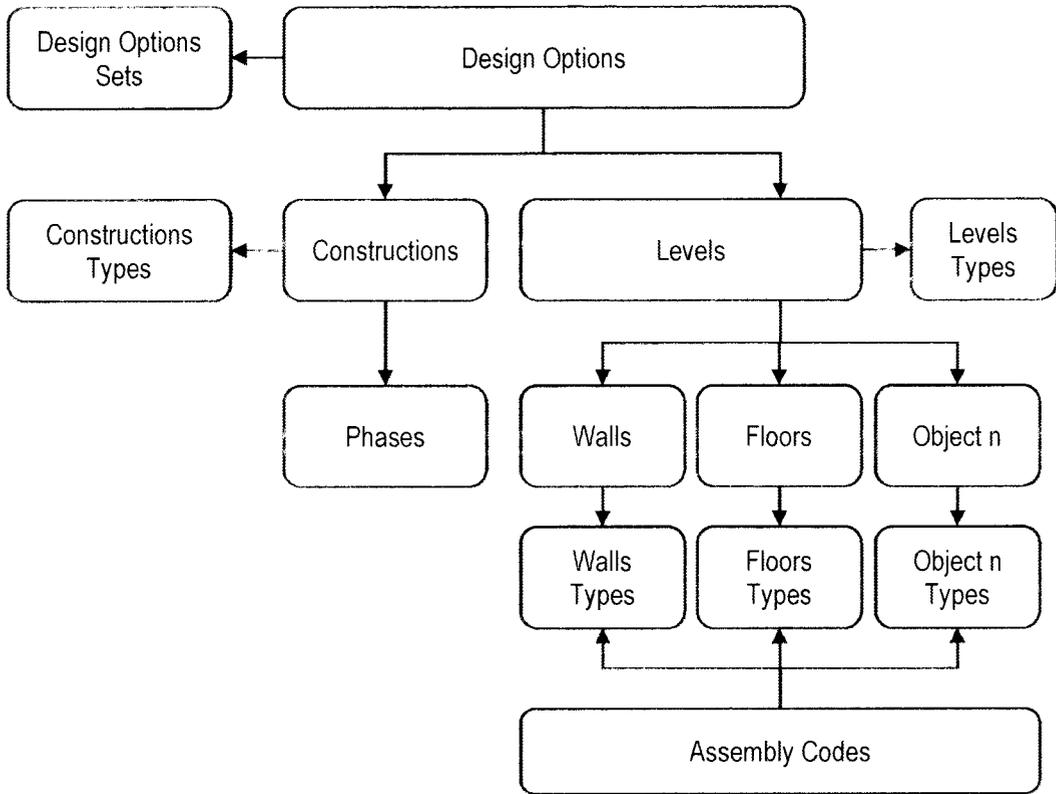


Figure 4.7: Revit Tables Structure

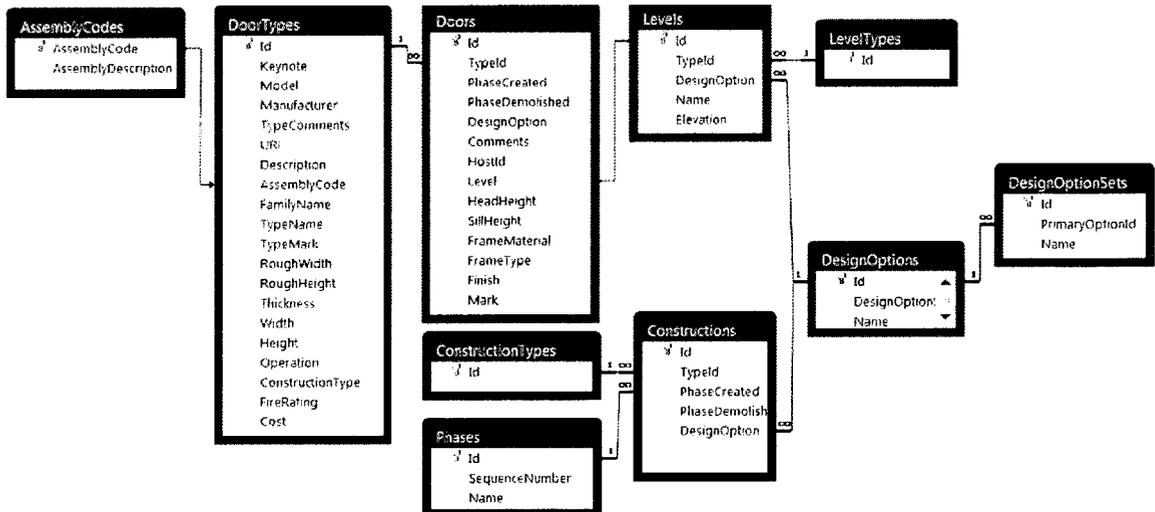


Figure 4.8: Doors Family (Types and instances) Tables Relationships

A brief description of the function of those tables is provided herein below:

- Design Options and Design Options Sets; two tables to define the multiple design options. For the objectives of this research a one design option project will be assumed for the proposed model implementation.
- Levels and Level Types; is a set of data where each datum defines a level in the project, it can be associated with a plan view or just a level setting reference point. For the research objectives these tables do not render any implications.
- Objects and Object Types; the vast majority of Revit tables are in these types; they define and stores all parameters for the Revit object family, type and instances.
- Assembly Codes; Stores all the codes for the EWBS that can be associated with objects types. This table and the objects and objects types tables are of the utmost interest for the research objectives

4.4. Design Stage

In this stage, all the findings from previous steps along with some techniques that will be discussed in the following paragraphs will be brought together to develop the proposed model architecture to respond to research objectives and system requirements and specification.

4.4.1. Cost Data Processing

In order to make the model flexible in terms of connecting to heterogeneous cost data, a neutralization layer that process cost data and standardize it is required.

The output of this layer will be mapped to EWBS (UniFormat) then aggregated together in Global Assembly Catalogue (GAC) that lists all available assemblies. Additionally, Assemblies' components are standardized and mapped to TWBS (MasterFormat) then Aggregated to form the Systems Components Master List (SCML). Different cost data represent the input for the Cost Data Process, EWBS represents the control and both GAC and SCML are the outputs (Figure 4.9).

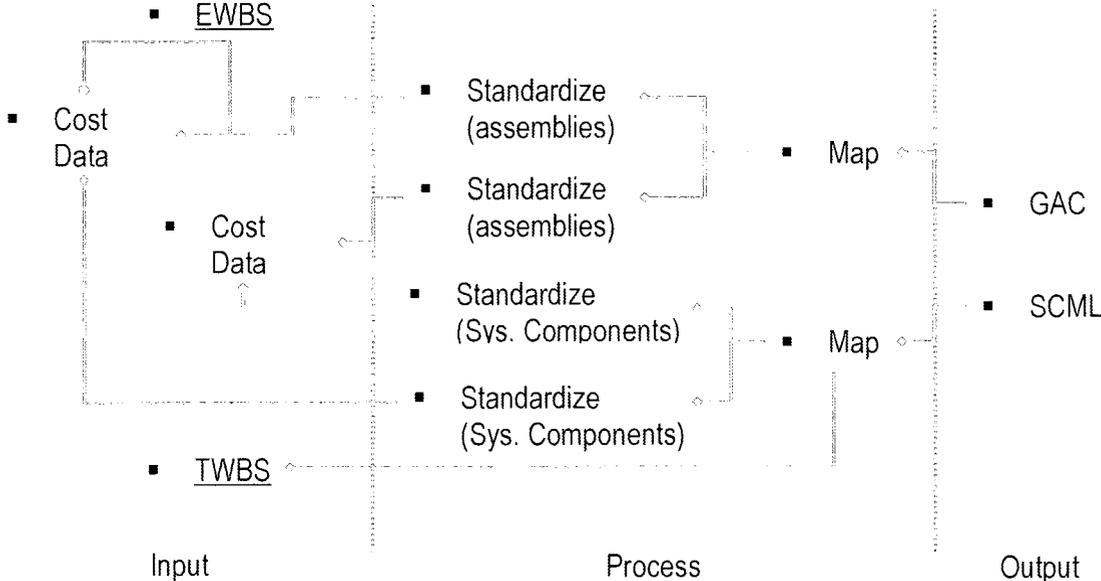


Figure 4.9: Cost Data Processing

4.4.2. Quantity Take-off Process

The next step is to perform the quantity take-off. This achieved by using the geometrical data from Revit and cost data from GAC as inputs. The user functions as control to the linking process between the geometries and their corresponding assemblies. Then the data will be exported. The output of the quantity take-off process (Figure 4.10) will be and Elemental Bill of Quantities (B.O.Q.)

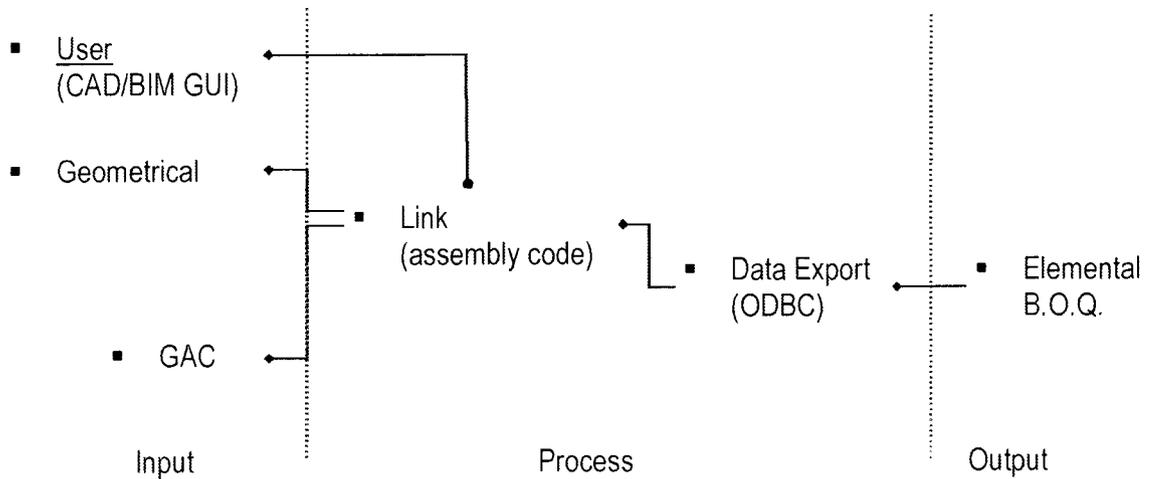


Figure 4.10: Quantity Take-Off Process

4.4.3. Cost Calculation Process

The next step will be the cost calculation, where the outputs of the previous steps are connected through the cost data lookup to perform the proper calculation. The two paths for the cost calculation process are demonstrated below along with the two outputs; elemental cost and trade cost (Figure 4.11).

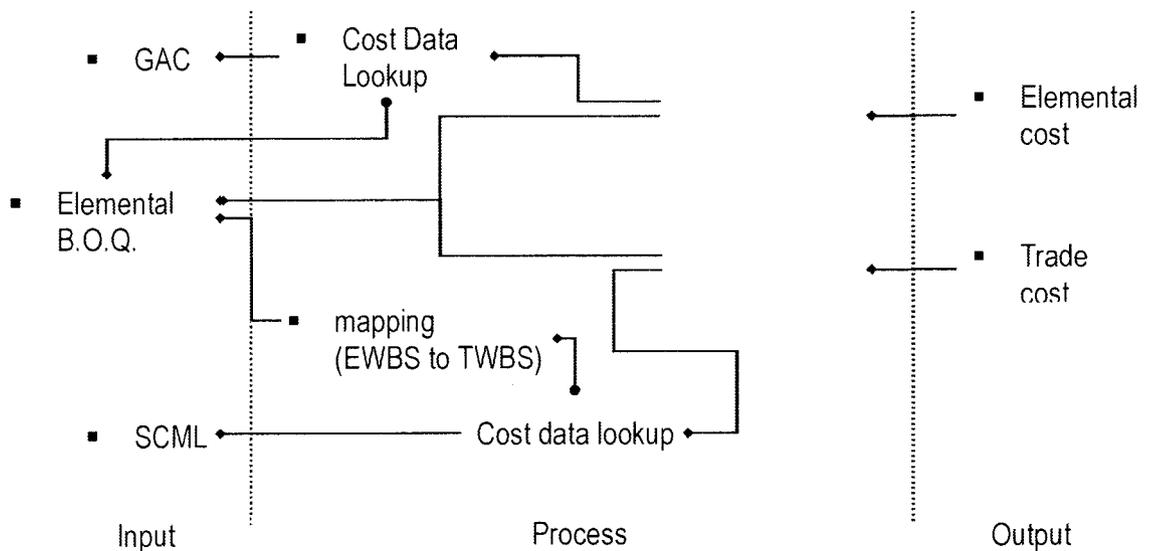


Figure 4.11: Cost Calculation Process

4.4.4. Cost Estimate Reporting Process

The final step is collecting the previous outputs and feed them into the cost estimate process where the user function as a control to select the type of required report. The inputs are grouped and classified to generate the outputs, which are of at least two types elemental cost reports and trade based cost reports.

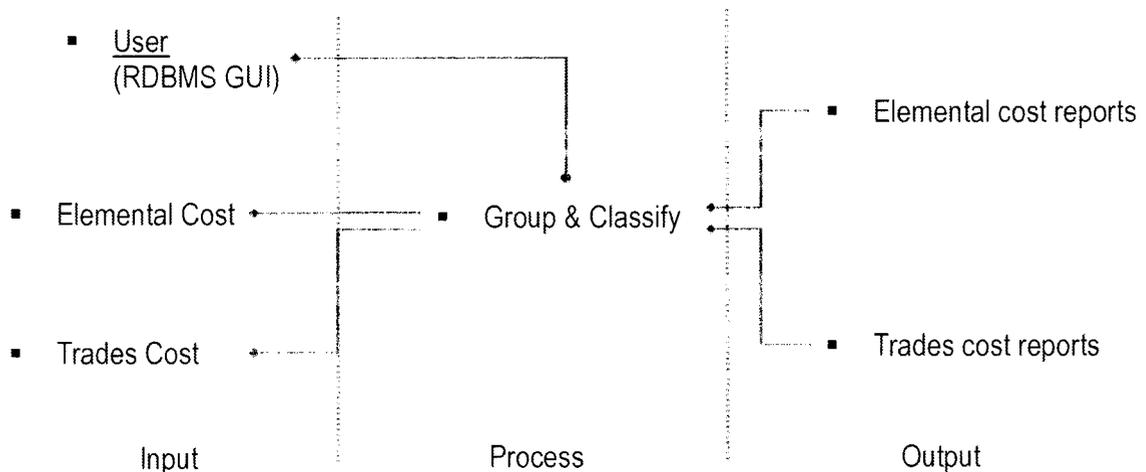


Figure 4.12: Cost Estimate Reporting Process

4.5. Summary

This chapter covered the methodology followed to develop the model, its components process and configuration, as well as analysed Revit software architecture to lay the foundation for implementation stage, which will be the focus of the next chapter. The key findings of this chapter are:

- Using the EWBS approach, rather than TWBS approach, can overcome technological limitations as well as reduce the required resources for the cost estimate process. More, it allows the proposed model to be

implemented since early design stages to serve as a vital tool in cost budgeting and value engineering.

- Revit exposes its objects through multiple interfaces, the selected interface to read Revit objects geometrical information is through Open Database Connectivity (ODBC).
- Using two tiers architecture will increase the system performance as well as provide central database for cost estimating purposes.
- Distributed database approach will provide the proposed model the flexibility for accommodating multiple cost databases as well as the potential of up-scaling the implemented model to increase the performance.

CHAPTER 5

Proposed Model Implementation Development and Architecture

5.1. Introduction

In the previous chapter the foundation for developing the proposed model were established. This chapter will demonstrate the process of model implementation, covering all components like tables, forms, queries and reports.

5.1.1. Generic Architecture

On a conceptual level, there are two options to approach the proposed model architecture:

- Single tier architecture: where all the new data extension is included within the original file. The main advantage of this approach is portability, however it has many disadvantages as well, including the solution will be designated for one software solution as well the file size may grow extremely big which will imposes a performance stress on the computers. Considering the actual file size for a project designed using Revit, and the fact the portability in not a factor in the current research; this option is considered not valid.
- n tiers architecture: where the information are split over multiple files or locations. The advantages of this approach are numerous and will be listed and discussed along this chapter. The proposed model is extremely

simplistic and depends on two-tier architecture that integrates in an interactive manner (Figure 5.1).

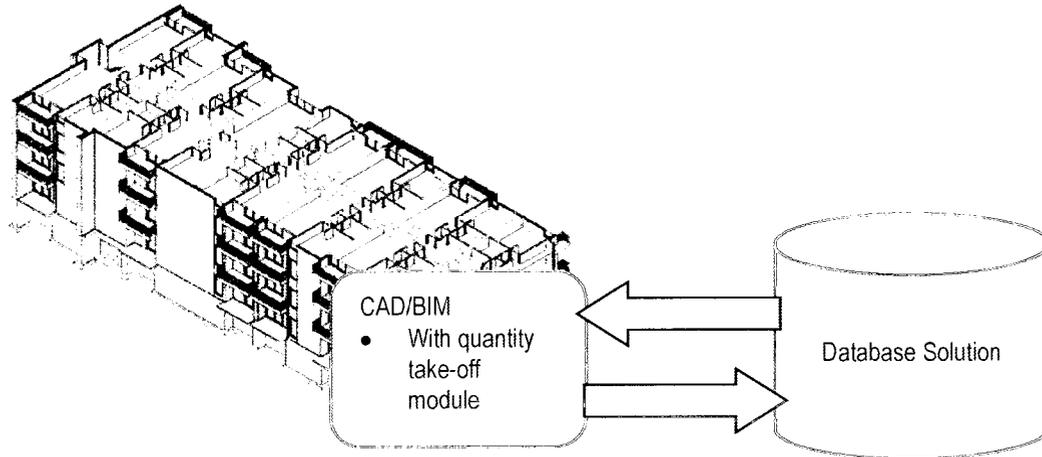


Figure 5.1: Proposed Model on Conceptual Level

The two parts are linked through an identifier. Once again, there are two options:

- Store linking identifier in the database, for example object id. From the CAD/BIM.
- Store linking identifier in the CAD/BIM file. This represents the solution adapted in this research. The main reason behind this is the advantages of the GUI (Graphical User Interface) of the CAD/BIM software, as well as the seamless integration that can be achieved. The chosen linking identifier will be the EWBS (Assembly Breakdown Structure).

5.1.2. Proposed Model Configuration

By examining the proposed model more closely we can define the required configuration to establish generic data flow and the different processes that must be executed in order to achieve the fore set objectives. It is a four steps configuration (Figure 5.2):

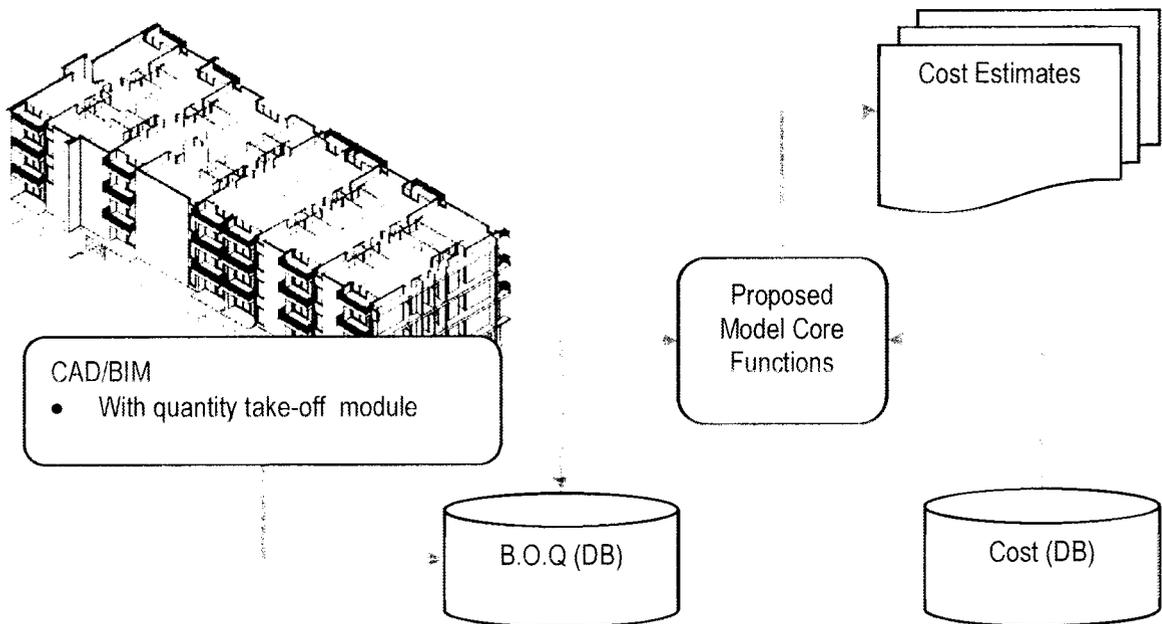


Figure 5.2: Proposed Model Configuration

1. CAD/BIM generates the quantity take-off by exporting them into a database
2. The proposed model core functions will:
 - Read quantity take-off database.
 - Fetch related cost information a separate database.
3. Group and classify the harvested information.
4. Generate the cost estimate report.

5.1.3. Proposed Model Architecture

To allow for maximum flexibility and efficiency in the proposed model, the distributed databases model architecture is adopted (Figure 5.3). The distributions of database components render many advantages including:

- Improves the system performance in certain aspects; especially maintenance, as well reducing security and rights management complexity, which is an essential part to prevent mistakenly modifying database records.
- Allow cost sources databases to be remotely allocated (e.g. linking with a manufacturer database or linking to web service provider) in order to increase the system resourcefulness.
- Provides the possibility to distribute the databases over multiple servers for large scale operations, to maintain high performance.

5.1.4. Proposed Model Architecture Components

The proposed model architecture components' functions explained hereinafter:

- EWBS and TWBS are elemental work breakdown structure and trade based work breakdown structure; these are pivotal databases as they provide the breakdown structure for the system. For the research purposes, UniFormat and MasterFormat 2004 were adopted, as they are the most commonly used in North America. OmniClass tables 21 and 22 can be used as well.

- Cost databases, these can be an In-house developed database, cost data provider (e.g. RS Means) or a manufacturer database. They should be classified according to using EWBS breakdown structure recognized by the system. They are backend databases for the user.
- Global Assemblies Catalogue (GAC) is database query stacking cost from different resources and exposing them to the user through Revit GUI. This is an in-system database and it is a frontend database for the user.
- System Core Functions (Set-1) is a set of database functions and programming code responsible of matching the quantity take-off with the corresponding cost data that were selected by the user from CAG. They generate EWBS cost estimate reports as well as assemblies' components to be used in generating the TWBS cost estimate report.
- System Core Functions (Set-2) is another set of database functions that perform the EWBS to TWBS mapping process. They generate TWBS cost estimate reports.
- Systems Components Master List (SCML) is a database query where assemblies individual components are stacked together to enable System Core Functions (Set-2) to perform the EWBS to TWBS mapping process
- Generic; is a collection of tables that provides different information:
 - Units Table; provides metric and imperial units and their corresponding conversion factors.
 - Revit Categories; is Revit internal categories. It controls when to show certain assemblies in filtered view.

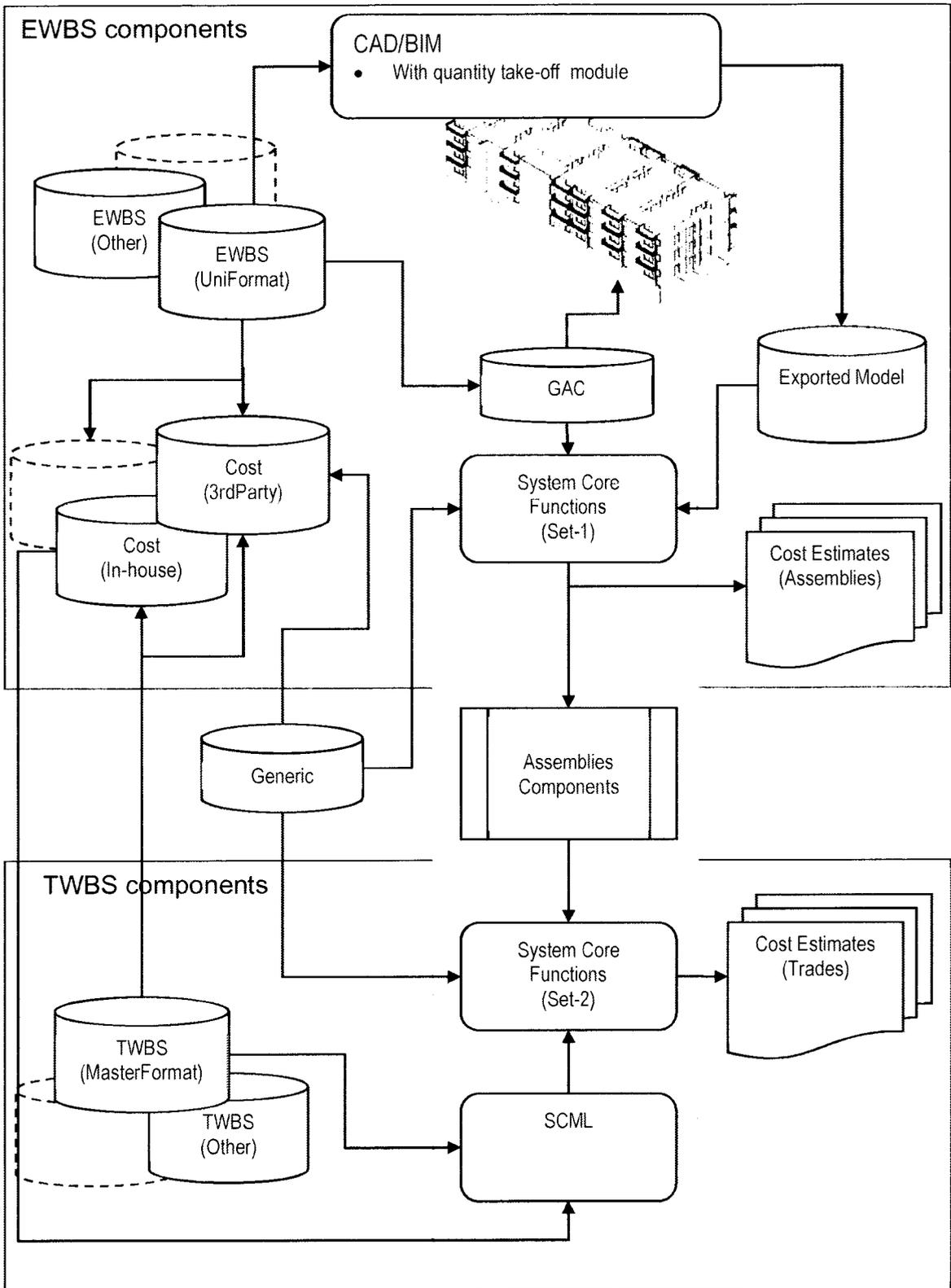


Figure 5.3: Proposed Model Architecture

5.2. Database implementation

The proposed model consists of a minimum of six separate databases; EWBS, TWB, at least one source of cost data, the exported B.O.Q., generic DB and the DB that Performs the cost estimation process.

5.2.1. Generic Database

This database consists of two tables that feed the model with its data:

- Units table; stores conversion factors between metric and imperial system. It consist of four fields; ID, Base, Unit_Type and Conversion_Factor (Figure 5.4). It should be noted that Revit exports its model in metric system even if the project was built using imperial system.
- Revit Categories; is a table used for linking assemblies to corresponding Revit objects. This link is optional and used to filter the exposed assemblies when a certain Revit object is selected. It consists of three fields; ID, Revit_Catogory and Description.

ID	Base	Unit_Type	Conversion_Factor	Add New Field
1	L.F.	Length	3.28083989501312	
2	S.F.	Area	10.7639150511824	
3	C.Y.	Volume	1.30795037636272	
4	Ton	Mass	0.001	
5	Ea.	Unit	1	
6	Lb.	Mass	2.20462442018378	
7	SFCA	Area	0	
8	m.	Length	1	
9	cm.	Length	10	
10	m2	Area	1	
11	m3	Volume	1	
12	Kg.	Mass	1	
13	B.F.	Length	3.28083989501312	
*	(New)			0

Figure 5.4: Units Table Snapshot

5.2.2. EWBS Database

Due to the wide spread of UniFormat in North America, it is adopted as an example of EWBS. Hence the database is designed to accommodate its structure. The database consists of three tables each governing one of the three levels of UniFormat (Figure 5.5).

The fields defined in these tables are identical; ID, Division, Title and Parent that do not exist in UFLevel_I as it is the root table.

Those tables are managed through a Graphical User Interface (GUI) that consists of three forms (Figure 5.6); a parent form that is a container and governs level 1 and another two sub-forms that govern level 2 and 3. Selecting a certain record in Level I form will update Level II sub-form to reflect only the child records. The same applies to selecting a record in Level II will update the records in Level III sub-form subsequently. This update is achieved through a small Visual Basic (VB) subroutine.

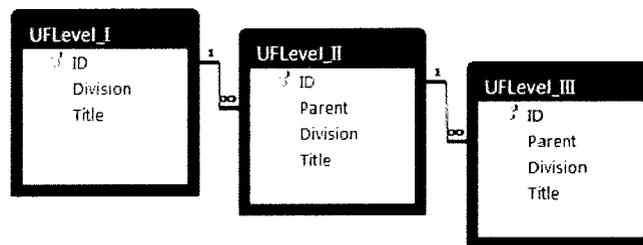


Figure 5.5: EWBS UniFormat Database Structure

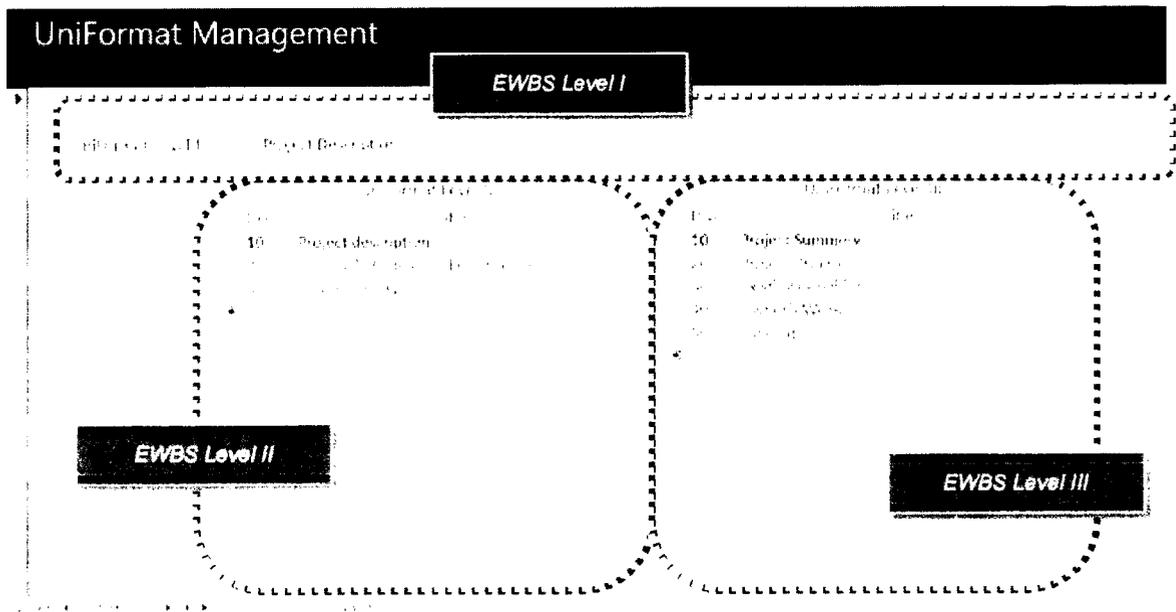


Figure 5.6: EWBS Database GUI

5.2.3. TWBS Database

TWBS database implementation is very similar to EWBS database, for the research purposes MasterFormat 2004 is adopted and it requires six tables (Figure 5.7). A GUI similar to that of EWBS database is provided as well as a report to print the whole TWBS for reference and check-up purposes.

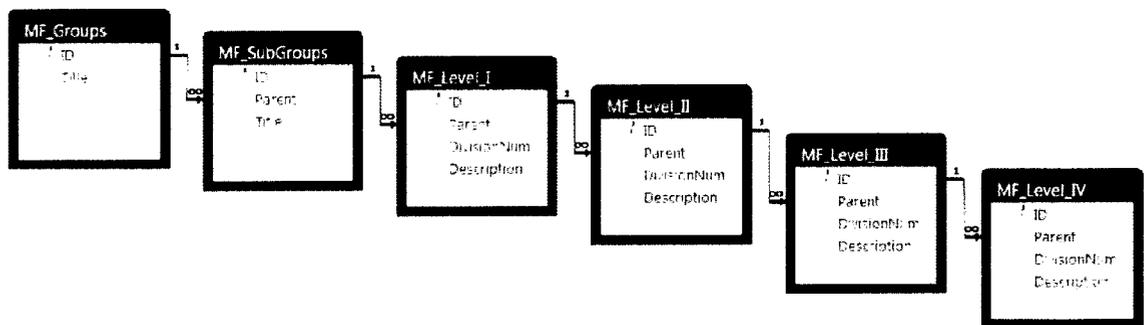


Figure 5.7: TWBS Database Structure

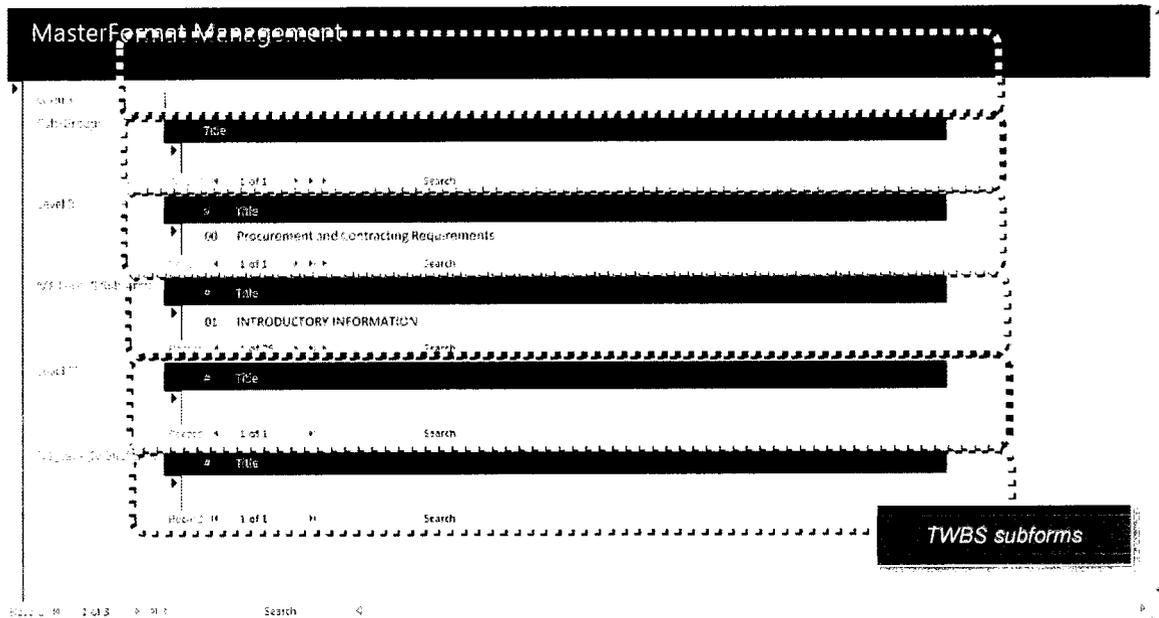


Figure 5.8 : TWBS Database GUI

5.2.4. Assemblies Cost Databases

The cost databases are backend databases as they serve to feed the Global Assemblies Catalogue (GAC), which functions as frontend. As discussed in earlier cost databases can be located remotely or distributed over multiple backend servers for large scale operations. A typical structure for the assemblies cost database consists of Breakdown Structure Tables (linked tables from external database). Usually, these are from three to five tables depending on the adopted breakdown structure, as well as the table of Units the generic database. The EWBS cost database itself contains four tables (Figure 5.9):

- Major Classification table; this table records assemblies types (e.g. Brick Veneer External Wall). It serves as level four for UniFormat. It also defines the method used to quantify the assembly. In the example of the in-house cost database; “OmniClass table 21 – Elements” numbers are used and in

the case of the RS Means assemblies cost database example the used numbering is RS Means coding system.

- Individual Line Number table; is where the various instances of the assemblies are stored along the cost for materials and installation for that instance. Also it has a Boolean field that specify if that assembly is broken into its components in order for the system to determine the possibility of generating TWBS cost estimate. Also it incorporates five fields to specify the different specs of each assembly instances (e.g. in case of wood floors, bay size, beam depth...etc.). if more fields are required this table can be expanded easily.
- Fields Headers; this table stores the specs fields headers as they change depending on the assembly they are describing.
- System components; is a table for storing the components of each assembly instance when available along with the material and installation cost, quantity and unit of measurement. As well as a TWBS number to link the different corresponding components to their corresponding TWBS section.

It should be noted that the total cost (material + installation) is not stored in the database to increase the efficiency of database and maintain its integrity. Nevertheless, it will be calculated as needed during the run-time.

These tables are exposed to the user through a GUI screen which consists of eight different forms (In the case of UniFormat) that integrate flawlessly in one coherent screen (Figure 5.10)

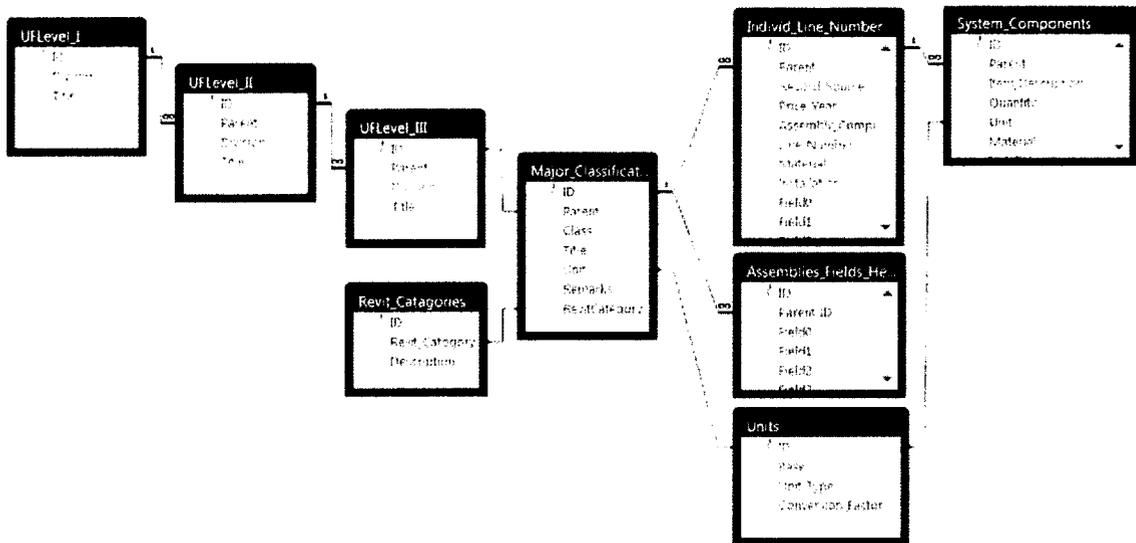


Figure 5.9: Assemblies Cost Database Structure

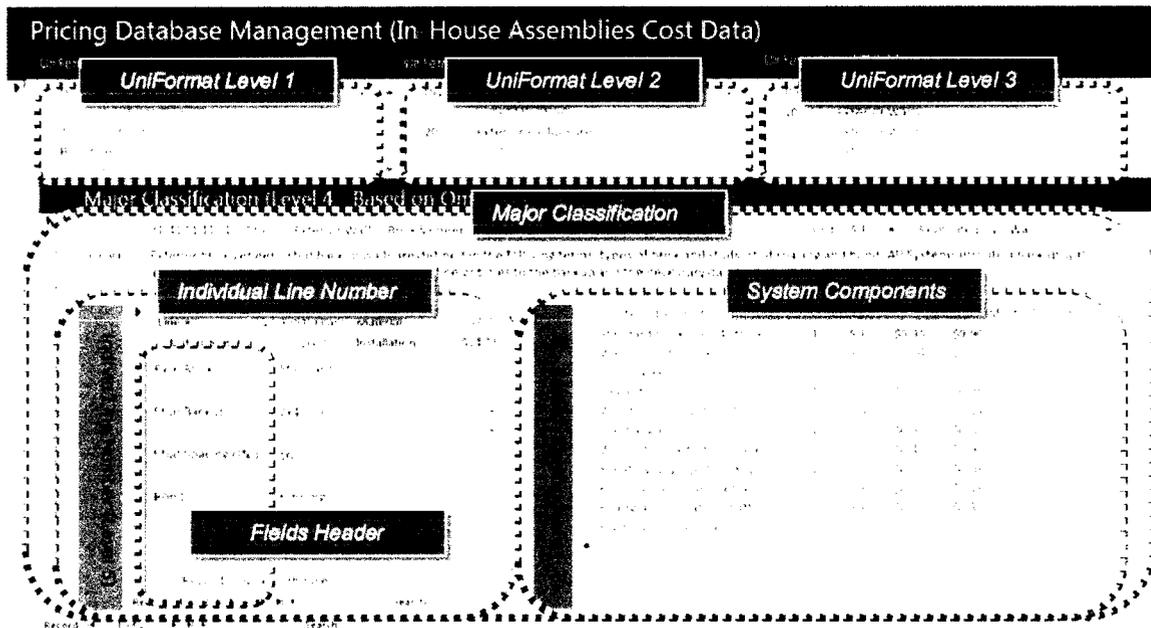


Figure 5.10: Assemblies Cost Database Management GUI Sub-forms

The GUI consists of one parent form that serves as a container and seven different sub-forms which correspond to each table. Child forms are placed together in logical layout to facilitate the maintenance and updating operation

5.2.5. GAC Implementation

Technically speaking, GAC is Union query to gather all the cost information from different databases and aggregate them in one comprehensive table, listing all available assemblies with their cost and specification data, as well as other information concerning that record (Figure 5.11). The query itself is included herein below:

```
SELECT Cost_Inhouse.* FROM Cost_Inhouse
UNION ALL
SELECT Cost_RSMEans.* FROM Cost_RSMEans
ORDER BY Full_ID;
```

As new cost databases are connected to the system they are added to this query. To exposes its contents the user through the GAC.

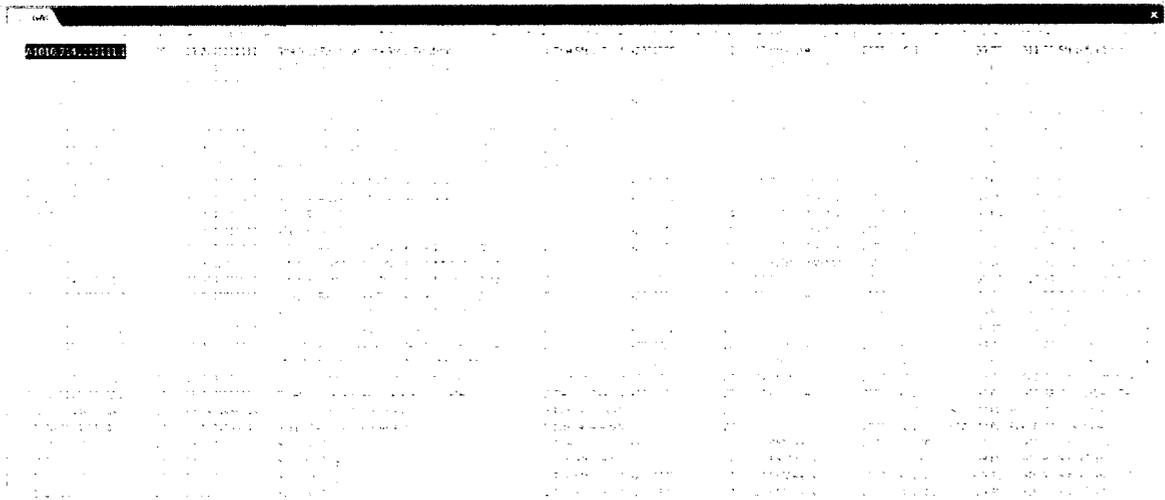


Figure 5.11: Snapshot of GAC

5.2.5.1. Exporting GAC to Revit

Revit objects types have a built in support to associate them with an assembly code. It uses a propriety text file (loaded upon program start) that stores all the

assembly codes. To be able to connect Revit objects with cost databases, those assembly codes must be identical to the corresponding ones in the databases. Hence the second function of the GAC is to export all its cost records to Revit, where its records will be exposed to the user through Revit GUI in the Object Type Properties dialogue box (Figure 5.12).

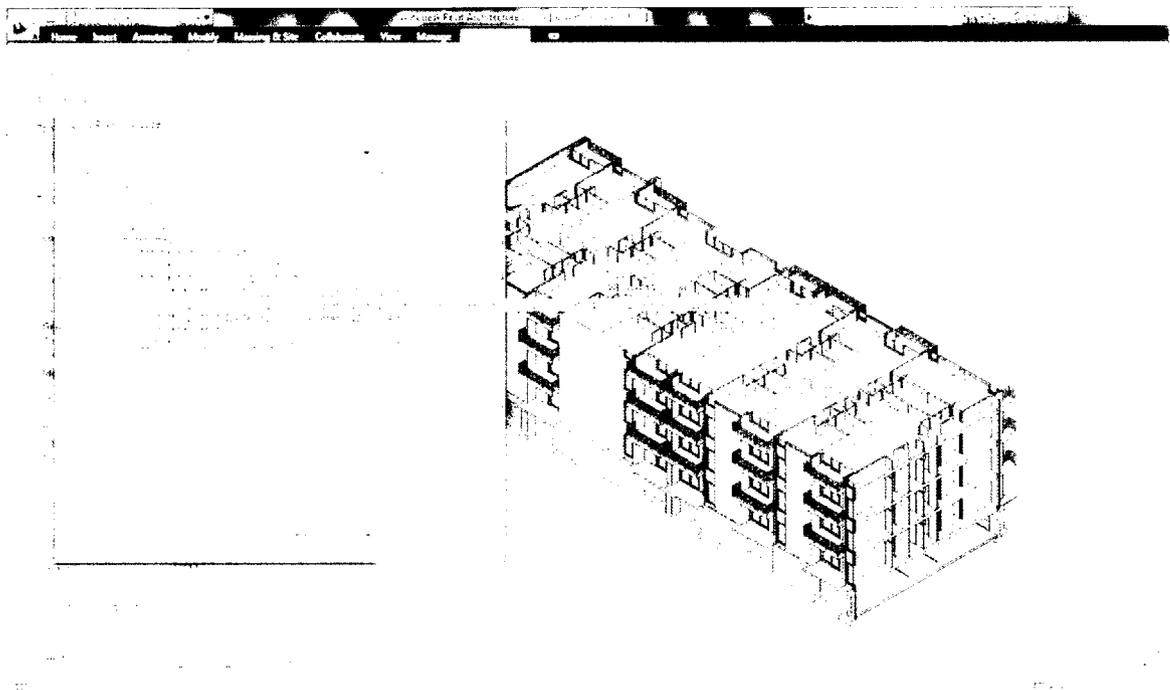


Figure 5.12: Selecting Assemblies from GAC inside Revit

In order to export GAC records to Revit, a group of eight queries were built to convert the records in GAC to Revit compatible format. The export function must be called each time the cost records are updated or new cost database is integrated in the system. The export function was embedded in Access to perform this task with few clicks.

5.3. Proposed Model Core Functions Implementation

To ensure a flexible system that can communicate with multiple output formats from different packages, as well as accommodate different and multiple breakdown structures the core functions were built with multi-layer structure. The proposed model set up five layers (Figure 5.13)

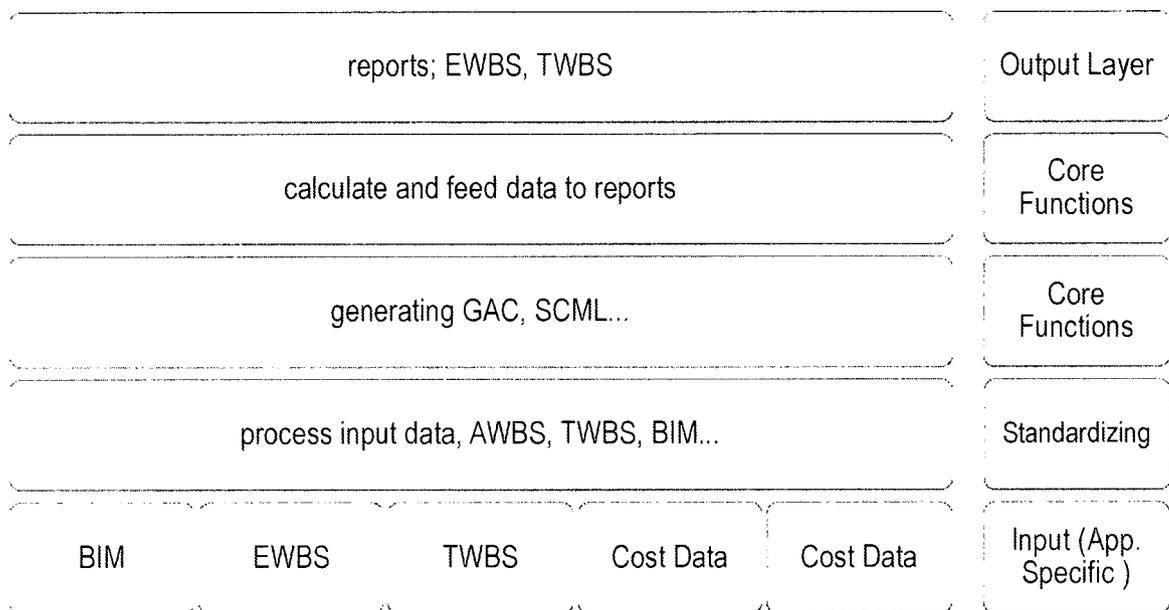


Figure 5.13: Proposed Model Topology

1. Application Specific Tables: these tables depend entirely on the adopted solution for quantity take-off, the adopted breakdown structures a cost databases.
2. Standardizing queries: is a set of queries that are built to read the different tables mentioned hereinabove and expose their records in a standardized way to Core Functions layer.
3. Generating GAC and SCML; is a set of queries that built these components.

4. Core Function Layer: is a set of queries that performs the arithmetic calculations as well as applying the required breakdown structure to the results
5. Output layer: is a presentation layer that reads the results from the core functions layer and apply visual styling to build presentable reports.

5.3.1. Cost Calculation Mechanism

For each Revit object type a query is built to calculate the cost of each of its instances. However, the quantifying unit depends on the cost database units. For example walls can be quantified using different units depending on the wall type.

5.3.1.1. Quantifying Units

Although any building project has a wide variety of items their quantifying units fall within four categories:

- Linear; e.g. walls, skirting, piping ...etc.
- Surface; e.g. walls, doors, windows, floors, roofs, painting....etc.
- Volume; e.g. walls, floors, roofs ...etc.
- By unit; e.g. doors, windows, diffusers, furniture, elevators ...etc.

The system is designed to auto-select the appropriate quantifying unit to match the selected unit cost.

5.3.1.2. Cost Calculation Queries

The cost calculation queries are the spine of the proposed model, for each Revit object type there is one query that calculates the cost of its instances (Figure

5.14 and Figure 5.15). Each of those queries performs the following steps to fetch the cost for each instance of the assembly that is present in the Revit model:

- Fetch the assembly code associated with the Revit object instance from Revit table
- Fetch the quantifying unit associated with assembly cost data from the CAG
- Based on the unit type it will select the suitable geometrical information to quantify Revit object
- Perform unit conversion as required (if it is the same unit the conversion factor 1 is used) to match the quantity unit with cost data unit
- Calculate the cost for the material
- Calculate the cost for the installation

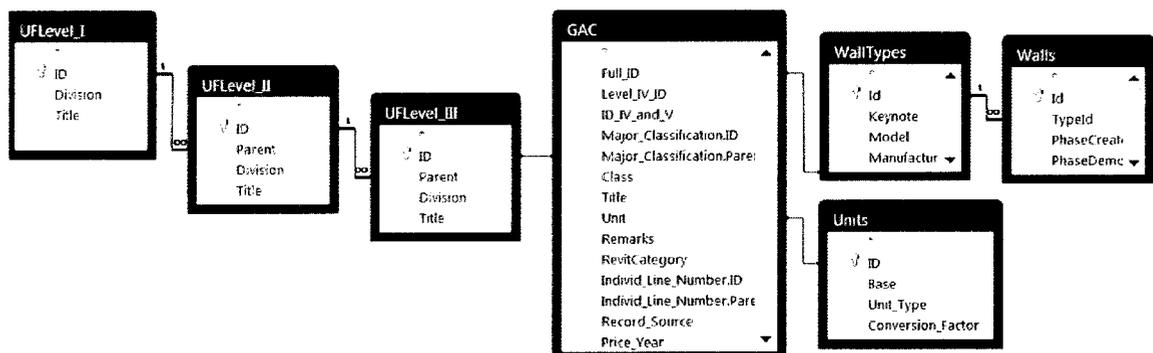


Figure 5.14: Object Type Cost Calculation Query

5.3.1.5. Building Cost Estimate Reports

The final step in the implementation process of the proposed model is building cost estimate reports that will present the calculated data in useful format. This is achieved by using MS Access 2007 features. The report creation process is straight forward and requires three steps:

- Select the data source query or table
- Place the fields
- Group the fields to generate the required hierarchy
- Add the totals fields

Figure 5.17 illustrates the report design view

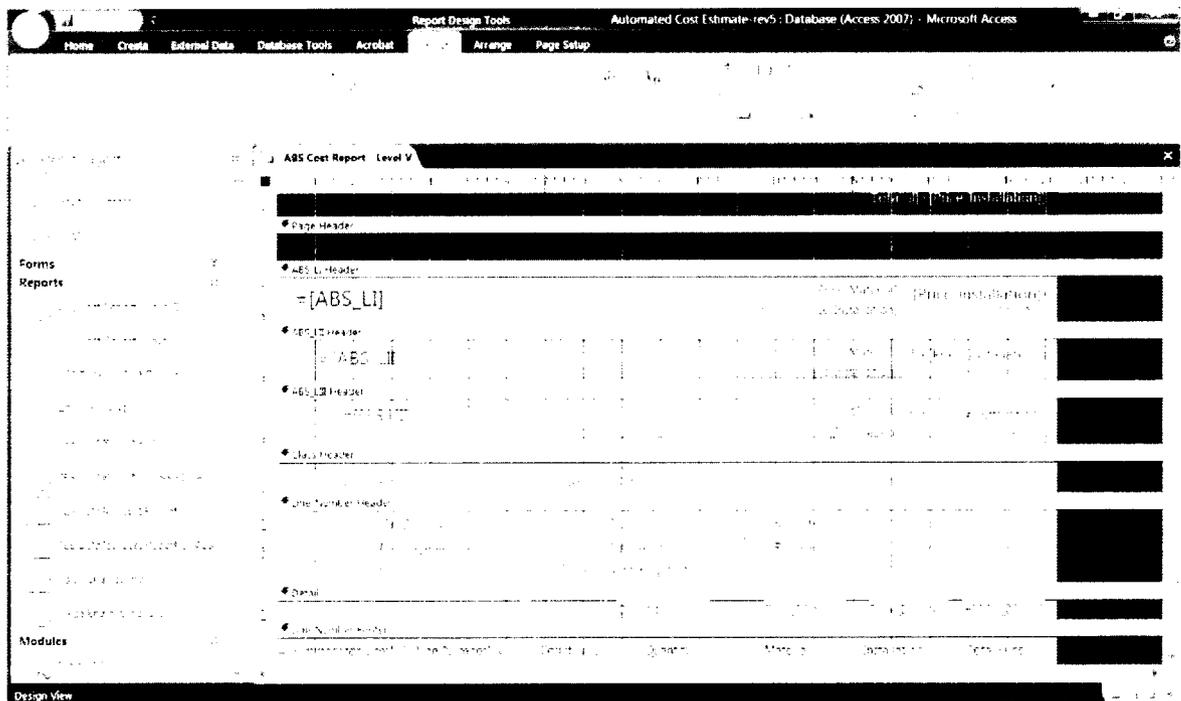


Figure 5.17: Report Design View

5.4. Proposed Model Data Flow

To summarize the proposed model architecture and recap the function of each of its component two dataflow diagrams are presented; EWBS cost estimate dataflow (Figure 5.18) and TWBS cost estimate dataflow (Figure 5.19).

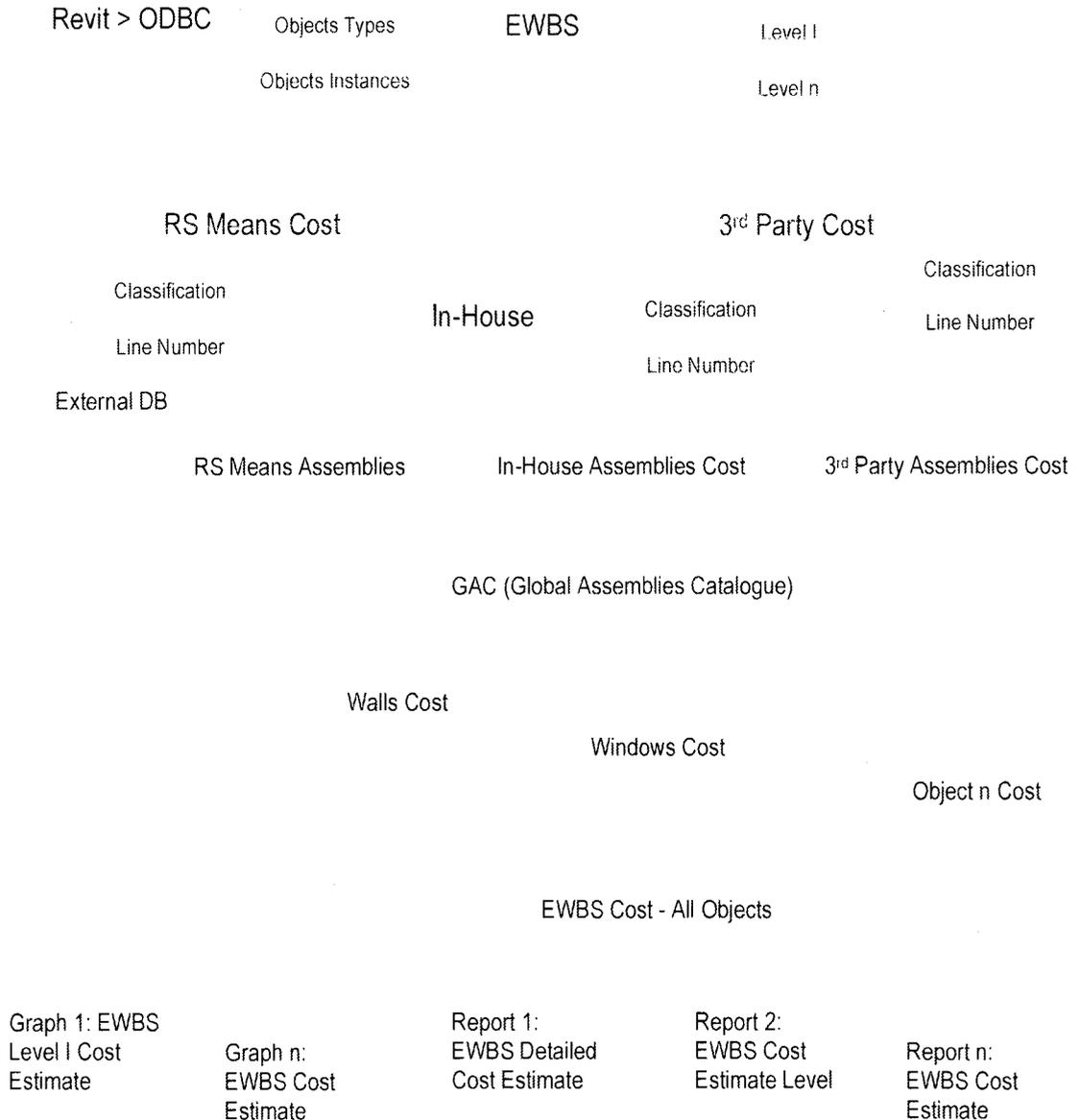


Figure 5.18: Data flow for EWBS Cost Estimate

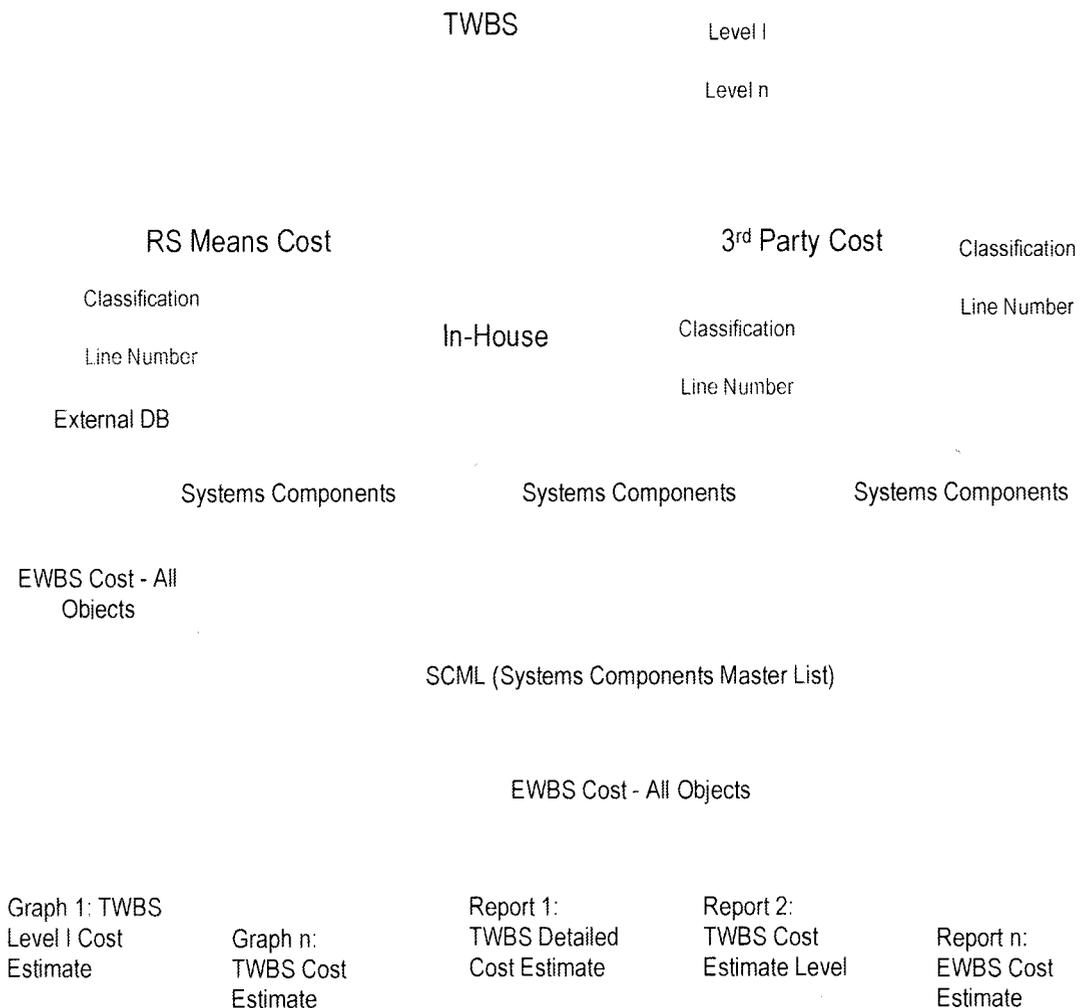


Figure 5.19: Dataflow for TWBS Cost Estimate

5.5. Proposed Model Benefits

The two-tier architecture coupled with the EWBS approach to quantity take-off, give the proposed a model many advantages over single tier architecture and/or other models that depends on TWBS. Those advantages are listed herein below:

- The proposed model can work with any breakdown structure that is assembly based. However, for the research purposes UniFormat will be

used as EWBS and MasterFormat as TWBS due to their wide usage in North America (Wirahadikusumah 2007).

- Independence of CAD/BIM package:
 - The proposed model can integrate with any software solution that is able to export quantities in assemblies.
 - Version independence; as both the CAD/BIM module and the database module can be upgraded without imposing any upgrades on the other module. However if the exportation structure changes, it will require performing modification in the importation module inside the database module.
 - Centrality of costing databases allows updating multiple projects costs simultaneously.
 - Allow integration with various sources of cost databases.
- Flexibility; material specification and construction related decisions can be fed to the system at any stage. Therefore more detailed information can be added the moment they become available.
- User friendly; allowing different members of the project team to work in a familiar software environment, as specifying more detailed information can be done in either part, therefore cost estimators and project managers are not required to learn how to operate the CAD/BIM software; especially that current BIM solution requires intensive training.
- Central Cost Database; Design firms and construction companies deals with multiple project at the same time, nonetheless a system that

manages multiple projects is not fully developed yet (Kim and Liu 2007). The centrality of cost database means the capacity of propagating changes in cost data to multiple projects simultaneously.

5.5.1. Benefits of Using Elemental Work Breakdown Structure (EWBS)

Designing the proposed model based on EWBS plays a major role in providing the following benefits:

- Quantity take-off accuracy does not require robust and meticulous 3D model. Rather, it depends on the robustness and fastidiousness of the assemblies' database, which in its turn will render two advantages:
 - Dramatically reduce 3D modeling time.
 - Provides a solution to the limitations of the current technology, since it is impossible to include everything in the building 3D model (e.g. pieces of wood in siding finish, bolts, screws, nails...etc.)
- Although CAD/BIM can be used to automatically generate Bill of Materials based on the selected TWBS, there are serious limitation to this function due to the lack of configurable construction knowledge (Shen, Issa and Gu 2007) which affect the PCQ costing. On the other hand Assemblies have built-in data for PCQ that can be modified in accordance with the construction process/ construction method.
- EWBS can be mapped to TWBS generating PPQ and PCQ while the reverse is impossible due the lack of association between the PPQ and PCQ in TWBS (refer to 2.10.1.3 and 4.3.2 for details on mapping UniFormat to MasterFormat 2004 as well as appendix C).

5.6. Summary

This chapter presented the development of the proposed model in detail, covering the implementation of every component by making use of RDBMS, SQL, and ODBC. The design is accomplished in manner that the whole backend complex processes are completely hidden from the user behind an extremely simple GUI. All the steps of the implementation stage have been documented with description in addition to supporting figures and tables.

The proposed model architecture proved its flexibility in accommodating different cost databases along with multiple and different breakdown structures, which will give the user the freedom to respond to different requirements of various projects.

Validating the proposed model will be covered in next chapter which is dedicated to examine the results of the implementation processes and measure the performance.

CHAPTER 6

Proposed Model Validation and Performance

6.1. Introduction

Chapter six will describe the testing and validation process of the developed model. Performance is bench marked and validated through a case study, where a residential building in Montreal of four floors and a basement is created using a BIM solution (Revit), using typical construction materials and methods for the project location, as well using RS Means Cost data for validation purposes.

6.2. System Initialization

Before starting to use the system, we need to prepare three databases; Generic, UniFormat (EWBS) and MasterFormat (TWBS). These steps are needed to be followed only once for new setup of the system or can be avoided by installing the system with pre-populated databases. Yet, these databases can be access for modification to extend, modify or reduce the available options during anytime.

6.2.1. Populating Generic Database

This is a database of two table that provides the system with unit conversion factors, (Figure 6.1) and Revit Categories.

Since Revit always export quantities using the metric system (although the software is capable to work with imperial system for the user interface) entries for the metric system as well provided.

ID	Base	Unit_Type	Conversion_Facto	Add New Field
1	L.F.	Length	3.28083989501312	
2	S.F.	Area	10.7639150511824	
3	C.Y.	Volume	1.30795037636272	
4	Ton	Mass	0.001	
5	Ea.	Unit	1	
6	Lb.	Mass	2.20462442018378	
7	SFCA	Area	0	
8	m.	Length	1	
9	cm.	Length	10	
10	m2	Area	1	
11	m3	Volume	1	
12	Kg.	Mass	1	
13	B.F.	Length	3.28083989501312	
*	{New}		0	

Figure 6.1: Units table Snapshot populated with unit conversion factors

Revit categories are Revit internal numbers and they do not follow an established standard. This numbers helps filtering cost data inside Revit when the GAC is exported back to Revit to expose the costing database for the user.

6.2.2. EWBS and TWBS databases

Breakdown structures databases must be populated as well, while EWBS database is mandatory, TWBS database is optional and will be needed only if TWBS reports needed.

6.2.2.1. Populating the UniFormat Database (EWBS)

As the proposed model depends on EWBS, UniFormat has been adapted for testing purposes (it is common EWBS in North America). Two data entry methods are available:

- Using the provided management form; first we start populating Level 1, then the related sub-items in Level 2 finally the related sub-items in Level 3 (Figure 6.2) to feed the corresponding tables.

- Using datasheet view of the tables; it is provided by default in MS Access (Figure 6.3) and it gives the advantage of pasting multiple entries at once.

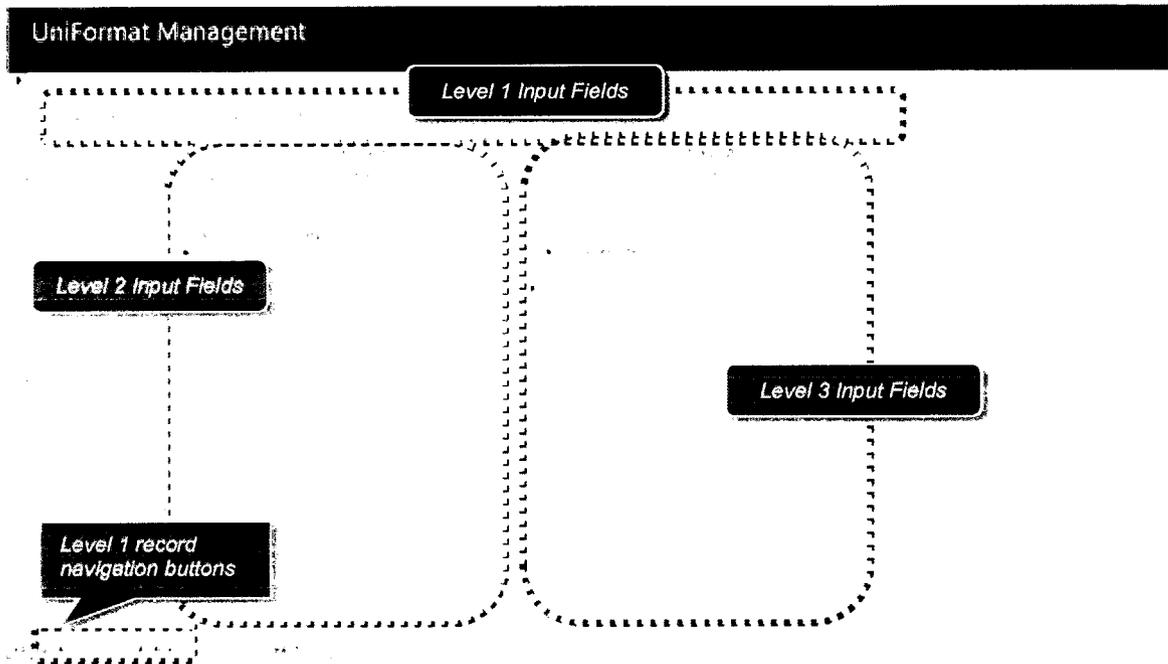


Figure 6.2: UniFormat (EWBS) Management GUI

The screenshot shows the UniFormat (EWBS) tables in a datasheet view. The table has columns for ID, Division, and Title. The data is organized hierarchically, with expandable sections for each level. The following table represents the visible data in the screenshot:

ID	Division	Title	Action
1	Project Description		Add New Field
2 A	Substructure		
4 10 Foundation			
16 10	Standard Foundation		Add New Field
17 20	Special Foundations		
18 30	Slab on Grade		
5 20 Basement Construction			
19 10	Basement Excavation		Add New Field
20 20	Basement Walls		
3 B	Shell		
4 C	Interiors		
5 D	Services		
6 E	Equipment and Furnishing		
7 F	Special Construction and Demolition		
10 Special Construction			
20 23	Selective Demolition		Add New Field
8 G	Building site work		
9 Z	General		

Figure 6.3: Populating UniFormat (EWBS) Tables using datasheet

6.2.2.2. Populating the MasterFormat Database (TWBS)

For the TWBS cost estimate reports, MasterFormat has been adopted for the case study. Similar to EWBS database population methods; a management form is provided (Figure 6.4) or MS Access built-in datasheet view can be used.

The screenshot displays the 'MasterFormat Management' interface. It features a hierarchical tree structure on the left side, with the following levels and items:

- Group: SPECIFICATIONS GROUP
 - Facility Construction Subgroup
 - Record # 2 of 5 | Search
 - Level I
 - Title
 - 03 Concrete
 - Record # 2 of 12 | Search
 - Level II
 - Title
 - 20 CAST-IN PLACE CONCRETE
 - Record # 13 of 45 | Search
 - Level III
 - Title
 - 53 Miscellaneous Cast-in-Place Concrete
 - Record # 1 of 1 | Search
 - NOT Level IV Subgroup
 - Title
 - Record # 1 of 1 | Search

At the bottom of the interface, there is a status bar showing 'Record # 2 of 5 | Search | 0'.

Figure 6.4: MasterFormat Management Form

At this point we have completed the initialization phase and the system is ready to start building the cost database(s).

6.2.3. Establishing the ODBC

Last step in system initialization is to establish database connection between Revit and the other components of the system. Revit will use this connection to export quantities of the elements that are present the project at any time.

After loading Revit, a new project must be created; by selecting "Project..." from "File/ New" menu.

Next step will be selecting “ODBC database...” from “File/Export” menu. This will launch the ODBC wizard, starting with the File Data Source selection dialogue. In the case of creating a new DSN the button “New” should be clicked to invoke the the ODBC driver selection dialogue to build the DSN. For the testing environment the “Microsoft Access (*.mdb, *.accdb)” driver is the right choice (Figure 6.5).

After choosing a file name and location for the DSN, the “ODBC Microsoft Access Setup” Dialogue is invoked. At this point we have the choice to connect to existing database file or create new one (Figure 6.6).

After finalizing the MS Access file creation, Revit should be exited. At this stage the system initialization is completed.

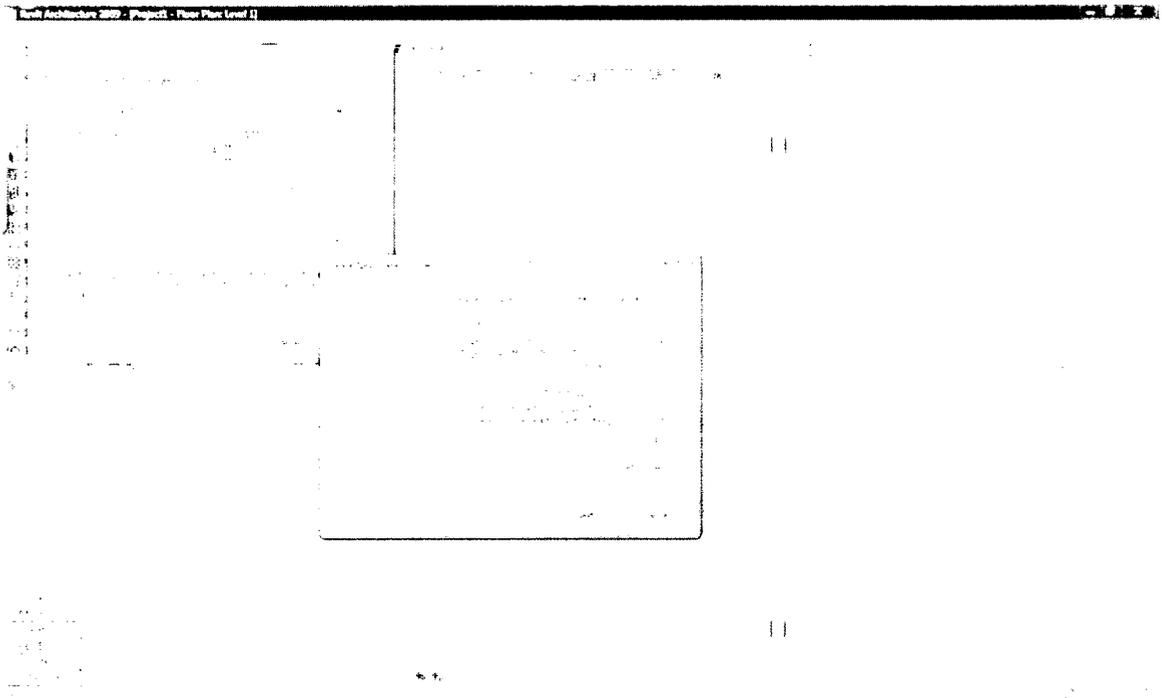


Figure 6.5: Selecting ODBC Driver

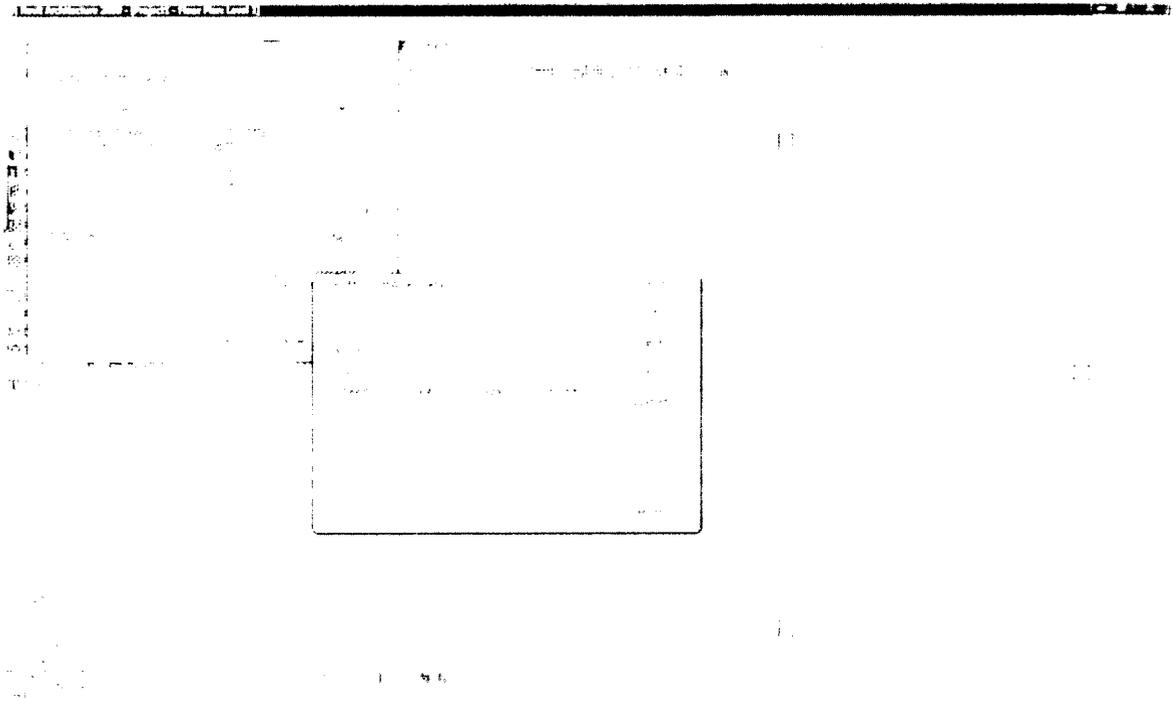


Figure 6.6: ODBC setup

6.3. Preparing Cost Database(s)

The following text will demonstrate how to populate database(s) with sample cost data from "RS Means Assemblies cost data 2008" (RSMMeans 2008) has been used in support of case study. Consequently Level 4 and 5 numbering from RS Means is implemented.

Cost data for the following items are entered as a proof of concept:

- Foundations
- External walls (brick veneered and concrete cast in place)
- Internal partitions
- Doors and windows
- Roofs, floors and slab on grade

As well in order to demonstrate the system ability to use multiple cost databases, a secondary database for in-house cost data is set up where OmniClass numbering has been used for Level 4 and sequential numbers for Level 5. Manual data entry process is illustrated herein below (Figure 6.7 - Figure 6.10).

- First step; selecting the applicable EWBS (3 levels of UniFormat). To add a new record the user will start by selecting EWBS level 1, this will refresh and update the available items in level 2 to list only the child records of the corresponding item in Level 1. In a similar manner, selecting an item from level 2 will refresh and update the available items in level 3.
- Second step; is to fill in major classification number and title (e.g. external wall, brick veneer with wood stud backup), a measuring unit (cost base unit), Revit category if required as well as any remarks that apply to this class.
- Third Step; is to supply the individual instances of the major class (e.g. the brick veneer can be running bond, Flemish bond...etc.) along with other specs that identify and differentiate each entry. The system allows up to five specs parameters (Figure 6.9). The cost in this section is the unit-cost (Material and installation) used to calculate the element cost.
- The fourth and final step is optional; and can be used in case it is required to generate TWBS cost estimate. If this is the case, then the component check box must be checked and the different field to be filled with the appropriate data (Figure 6.10). These fields are the ones that allows the system to perform mapping from EWBS to TWBS

Although cost database(s) has been populated manually, it can be imported or connected to as external source(s), which allows the system to integrate cost data from subcontractors and manufacturers directly.

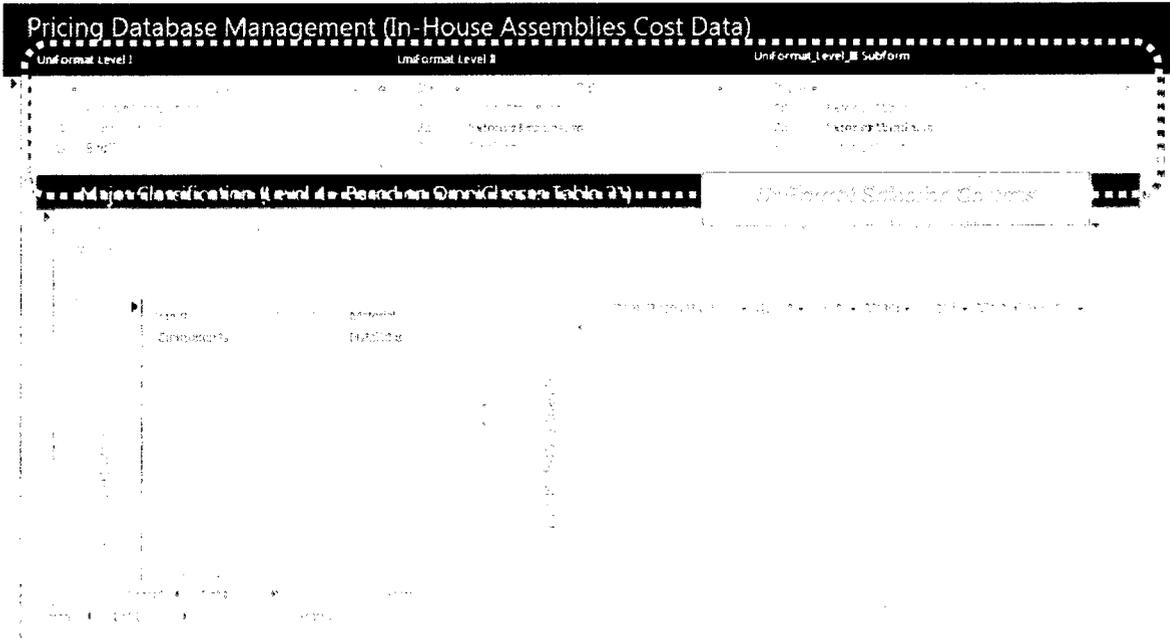


Figure 6.7: Selecting EWBS in Cost Database

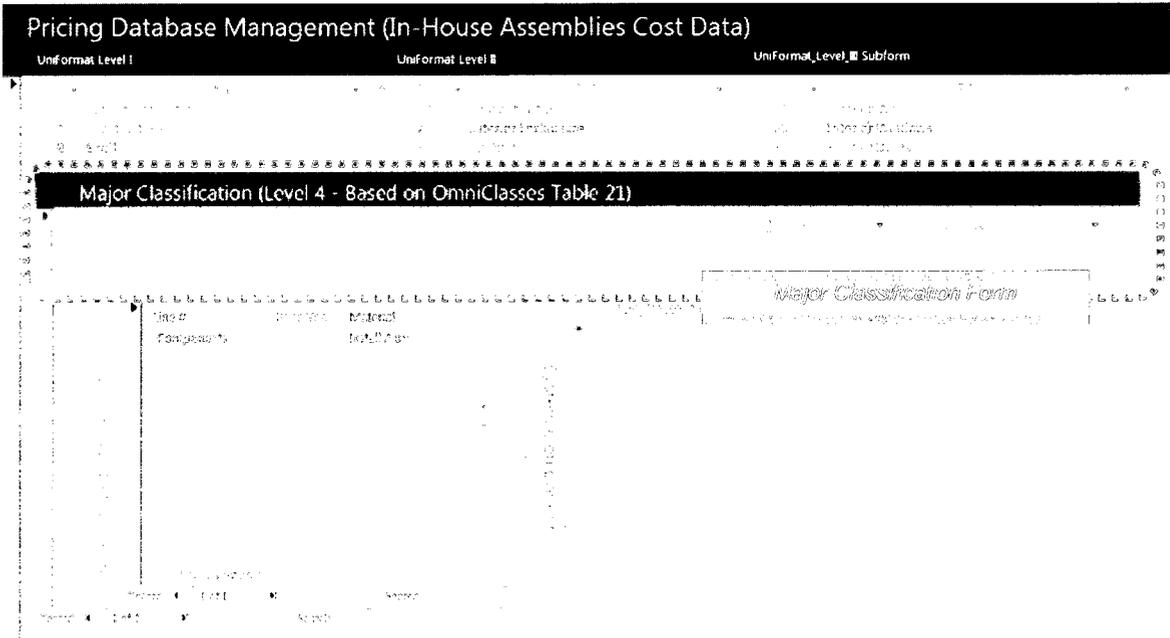


Figure 6.8: Data entry for major classification (level 4)

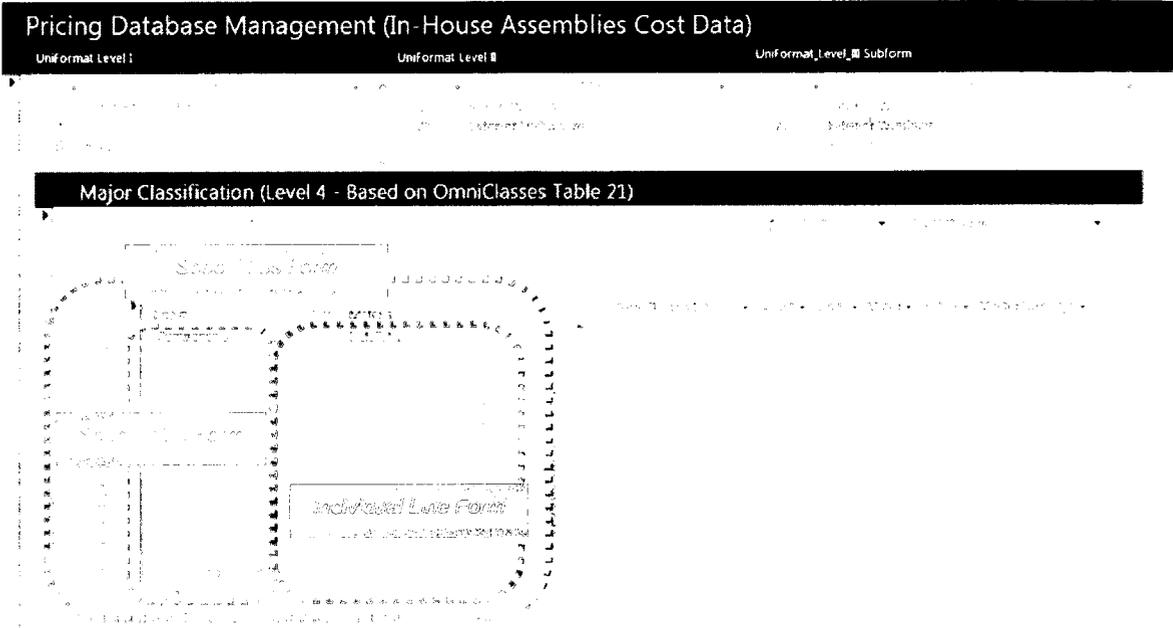


Figure 6.9: Data Entry for Individual Line Number (level 5)

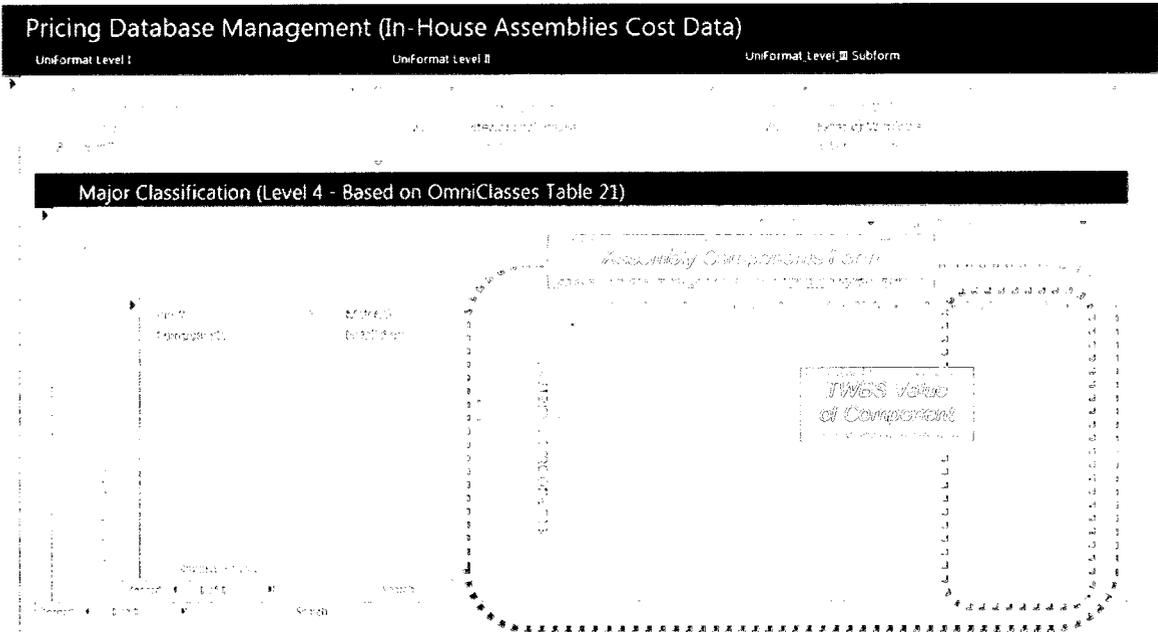


Figure 6.10: Data Entry for Assembly Components

Though datasheet view is available for the previous screens, it is not recommended due to the complexity of relations between the different tables. Errors will affect database integrity and might cause system malfunction.

6.4. Exporting CAG to Revit

As the system has accumulated some costs information from different sources, these will be aggregated into one table (query) of all the EWBS unit cost, and then exported to Revit.

The exporting process has been saved within the Main Module Access file. It can be accessed from “External Data” menu then clicking “Saved Export”. The user should select “Revit CAG” and click run. It should be noted that the export function must be run again whenever one of the cost databases modified or new one connected to the system (Figure 6.11). If the exported information already exists, a warning dialogue will let the user choose if he is willing to overwrite.

At this point the system is initialized and cost databases are all setup and exported to Revit. The system is ready to be utilized by the user.

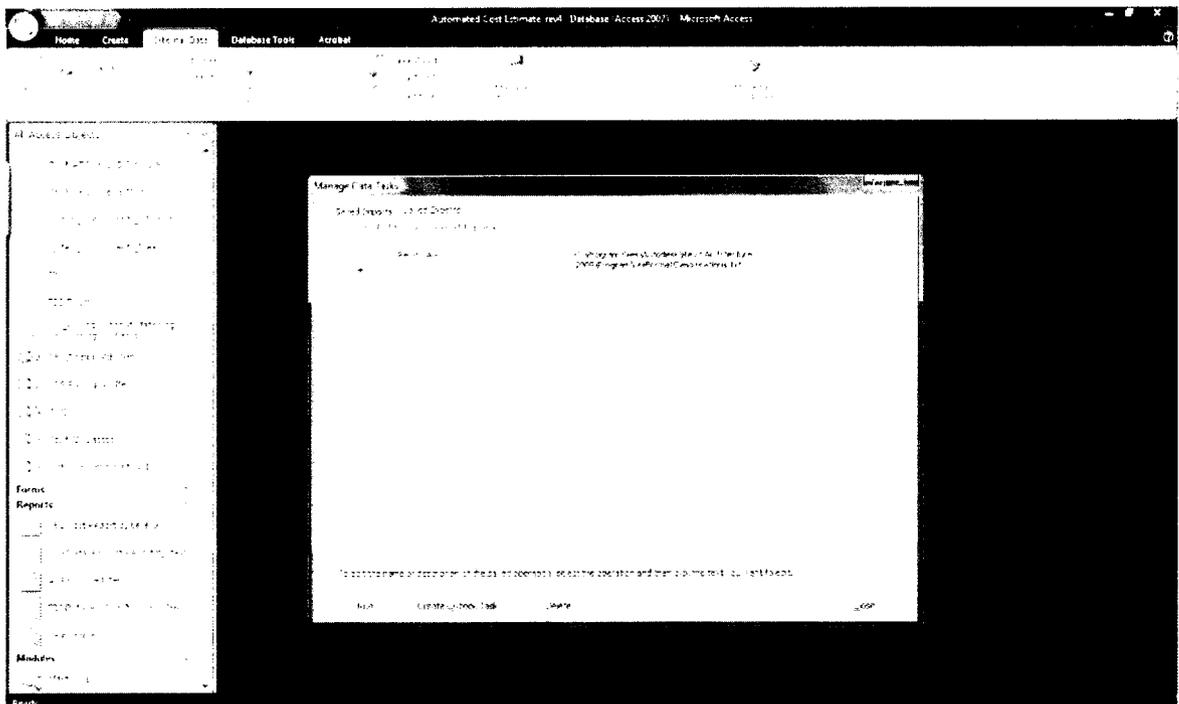


Figure 6.11: Exporting CAG to Revit

6.5. Inside Revit

As elements start to be added to the model inside Revit, it is possible to start calculating their cost right away to keep monitoring the project cost. There are two possibilities for linking Revit elements with cost data:

- Per Project; elements are linked to cost data for the current project only
- Globally; that is the link is saved in the element family file; hence whenever it is placed in new project the link will be already embedded.

Establishing the link between Revit element and the cost data is achieved in a simple way:

- Select any instance of the element then click the type properties button (Figure 6.12).

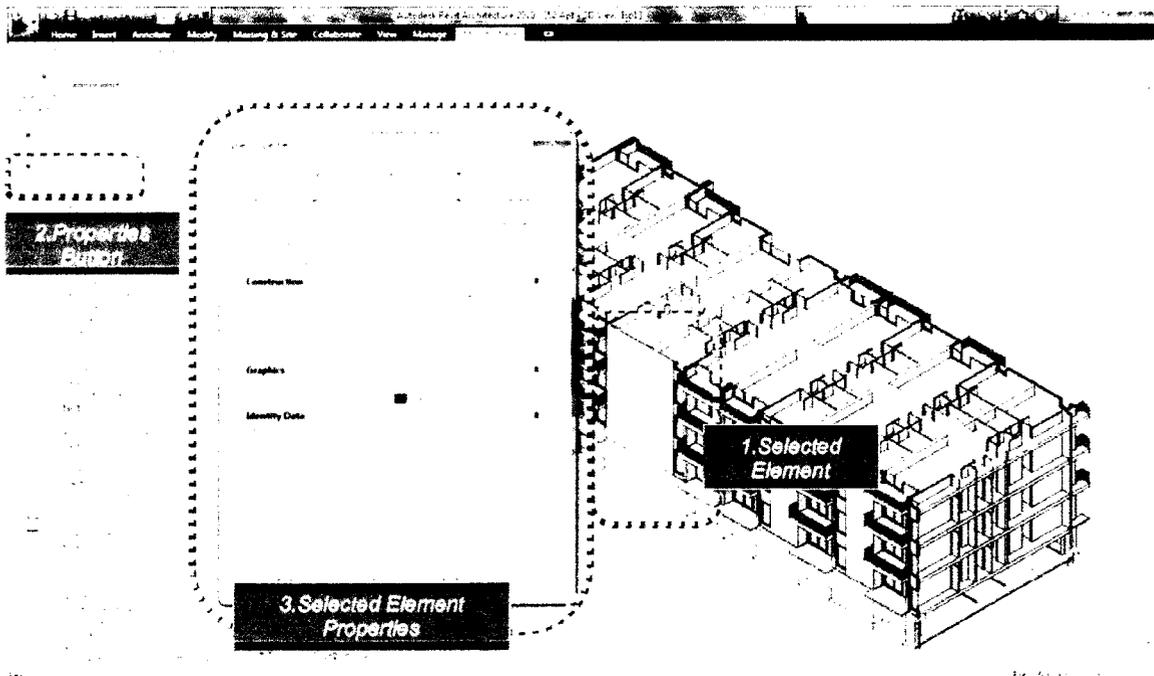


Figure 6.12: Linking Revit Element to Cost Data

- Select the corresponding assembly code, two choices are available; type in the assembly code or click the “...” button, which appears after clicking inside “Assembly Code” Field to invoke the “Choose Assembly Code” dialogue then browse the tree to select the corresponding cost data (Figure 6.13). It should be noted that due to Revit Interface Limitations, the user must hover over the item in the Assembly tree to get more information about its specs in a Tool Tip format (Figure 5.12)
- Close all dialogue boxes by clicking ok. That is all what is needed to link all the elements of the same type.

Those steps should be repeated for all the different elements that are in the model.

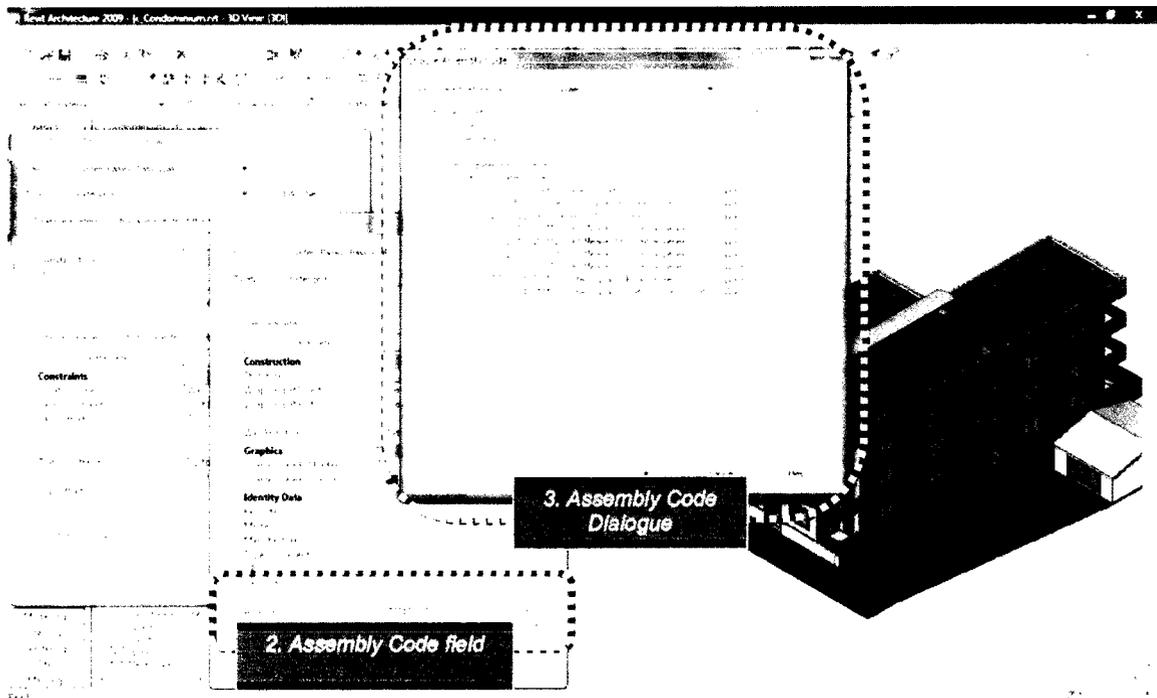


Figure 6.13: Linking Revit Element to Cost Data

After completing the linking process, the model is ready for cost estimate calculation. It will be exported through ODBC by choosing “ODBC Database...” from the “File/Export” menu, then choosing the saved DSN file that was generated in 6.2.3

6.6. Generating the Cost Estimate Reports

The last step in generating the cost estimate for the project is presenting the calculated data in useful format. The proposed model implementation with MS Access 2007 features allow the user to choose between two presentation methods, which will be covered herein after.

6.6.1. Generating Datasheets Reports

To generate the required report, the process does not exceed merely selecting the required one from the left pane in MS Access (Figure 6.14). The system includes nine reports and they are listed hereinafter, full samples of these reports are provided in appendixes.



Figure 6.14: Selecting Report in MS Access

6.6.1.1. EWBS Cost Report - Level V

This report will list all the assemblies in the project grouped by Individual Line Number (Level V) and summarized upward until Level I. This report is useful to study selected assemblies and their summary quantities and cost data (Figure 6.15).

B Shell (111 detail records)		Materials:	\$288,866.85
		Installation:	\$220,002.27
		Total:	\$508,869.12
10 Super Structure (12 detail records)		Material:	\$184,973.43
		Installation:	\$66,169.12
		Total:	\$251,142.55
10 Floor Construction (10 detail records)		Material:	\$176,298.71
Revit Family Name: Floor		Installation:	\$62,974.82
Revit Type Name:		Total:	\$239,273.53
Class	264	Title	Wood Beam & Joist
Line Number	2050	Material	\$11.45
Record Source	RSMeans	Installation	\$4.09
Price Year	2008	Unit Price	\$15.54
Summary for Line: 2050 (10 detail records)		Quantity	Material
		15,397.27 S.F.	\$176,298.71
			Installation
			\$62,974.82
			Total Price
			\$239,273.53
Summary for 264 Wood Beam & Joist (10 detail records)			
		15,397.27 S.F.	\$176,298.71
			Installation
			\$62,974.82
			Total Price
			\$239,273.53
20 Roof Construction (2 detail records)		Material:	\$8,674.72
Revit Family Name: Basic Roof		Installation:	\$3,194.30
Revit Type Name:		Total:	\$11,869.02
Class	108	Title	Steel Joists, Beams & Deck on Columns & Walls
Line Number	1200	Material	\$2.77
Record Source	RSMeans	Installation	\$1.02
Price Year	2008	Unit Price	\$3.79
Summary for Line: 1200 (2 detail records)		Quantity	Material
		3,131.67 S.F.	\$8,674.72
			Installation
			\$3,194.30
			Total Price
			\$11,869.02
Summary for 108 Steel Joists, Beams & Deck on Columns & Walls (2 detail records)			
		3,131.67 S.F.	\$8,674.72
			Installation
			\$3,194.30
			Total Price
			\$11,869.02

Figure 6.15: Snapshot of EWBS Cost Report by Level 5

6.6.1.2. EWBS Detailed Cost Report

This report will list every single object in Revit with its materials cost, installation cost and the total cost along with any comments associated with it that might be

of help to the cost estimator in order to apply cost adjustments. The data is summarized from Level V and upward until Level I (Figure 6.16).

The object Id is Revit internal Id for that object. This can be used by the user to find the object inside Revit for verification or to apply any required modifications.

B Shell		Materials:	\$502,488.03	\$913,493.11
		Installation:	\$411,005.09	(126 records)
10 Super Structure		Material:	\$341,272.72	\$490,768.05
		Installation:	\$149,495.33	(55 records)
10 Floor Construction		Material:	\$332,153.37	\$470,581.54
Revit Family: Floor		Installation:	\$138,428.17	(54 records)

Class	264	Title	Wood Beam & Joist
Line Number	2000	Material	\$8.95
Record Source	RSMean	Installation	\$3.73
Price Year	2008	Unit Price	\$12.68
		Keynote	
		Remarks	

Object ID	Comments:	Quantity	Material	Installation	Total Price
257174		8,559.78 S.F.	\$76,610.00	\$31,927.97	\$108,537.96
257358		8,559.78 S.F.	\$76,610.00	\$31,927.97	\$108,537.96
257542		8,559.78 S.F.	\$76,610.00	\$31,927.97	\$108,537.96
270247		61.08 S.F.	\$546.64	\$227.82	\$774.46
270466		60.47 S.F.	\$541.20	\$225.55	\$766.74
270483		61.08 S.F.	\$546.64	\$227.82	\$774.46

Figure 6.16: Snapshot of EWBS Detailed Cost Report

6.6.1.3. Objects without Cost Data

This report lists all the assemblies that are present in Revit model but are not linked to cost data. It lists with the item its geometrical measurements and identification data (Figure 6.17).

The data presented in this report helps the user to track the objects that are present in the project and do not have cost data associated with them. Also the cost estimator can apply cost to those object using non-automated methods to adjust the project total cost or add the missing cost data to the database.

FamilyName	Floor	id	987	Length	150.19
AssemblyCode	B1010.265	TypeName	Generic - 12" - Filled	Area	299.95
Description		TypeMark		Volume	91.43
Keynote		Type Comments		Count:	1

Figure 6.17: Snapshot of Objects without Cost Data Report

6.6.1.4. Value Engineering Report

This report is an extremely simplified illustration of how the proposed model can be expanded into value engineering. It presents to the user the possible minimum and maximum along with the specified cost of each Line Number to provide an idea about the possible minimum and maximum estimated cost for the project. This information can be used by the project management and the client to alter the specifications to match the allocated budget (Figure 6.18).

VE Analysis		Material	\$605,320.29	\$640,624.52	\$841,303.45
		Installation	\$633,313.94	\$684,103.27	\$869,054.98
		Total	\$1,238,634.23	\$1,324,727.80	\$1,710,358.42

ABS Level 4 ID:	A1010.110	Title:	Strip Footing
Number of prices in class:	4	Number of Items:	64
	Minimum	Specified	Maximum
Material	\$4,814.85	\$5,964.20	\$9,511.66
Installation	\$7,331.00	\$8,045.46	\$12,288.74
Total:	\$12,145.85	\$14,009.66	\$21,800.39

ABS Level 4 ID:	A1030.120	Title:	Plain & Reinforced
Number of prices in class:	2	Number of Items:	15
	Minimum	Specified	Maximum
Material	\$18,326.43	\$19,780.90	\$19,780.90
Installation	\$21,914.14	\$25,113.99	\$25,113.99
Total	\$40,240.56	\$44,894.90	\$44,894.90

ABS Level 4 ID:	A2020.110	Title:	Walls, Cast in Place
------------------------	------------------	---------------	-----------------------------

Figure 6.18: Snapshot of VE Report

6.6.1.5. TWBS Detailed Cost Report

This report uses TWBS to list products and activities and with which Revit objects they are associated (Figure 6.19). It is useful to analyse the distribution of products and activities over various objects in the project. Also it can be used in conjunction with scheduling information to generate cash flow or payments schedules, as well as for bidding purposes.

04 00 00. Masonry			\$105,544.21	\$193,468.93	\$299,013.13
04 01 00. Maintenance of Masonry			\$690.96	\$14,682.91	\$15,373.87
04 01 20. Maintenance of Unit Masonry					
Source: RSMeans Price Year: 2008			\$690.96	\$14,682.91	\$15,373.87
04 01 20.52 Unit Masonry Cleaning					
Wash smooth brick					
Object ID	Item Comments	Quantity	Material	Unit Price	Total Price
233319		351.86	\$14.07	\$299.08	\$313.16
245552		114.31	\$4.57	\$97.17	\$101.74
238673		87.97	\$3.52	\$74.77	\$78.29
245561		32.36	\$1.29	\$27.51	\$28.80
235780		32.36	\$1.29	\$27.51	\$28.80
245572		336.09	\$13.44	\$285.68	\$299.12
262897		247.28	\$9.89	\$210.18	\$220.06
262781		247.28	\$9.89	\$210.18	\$220.08
233569		114.31	\$4.57	\$97.17	\$101.74

Figure 6.19: TWBS Detailed Cost Report by Item

6.6.1.6. TWBS Detailed Cost Report - Level IV

This report is similar to the previous report but it summarizes the cost data by the TWBS highest level. It can be used for bidding or bidding benchmarking. It represents a typical MasterFormat cost estimate report used in the construction industry in North America (Figure 6.20).

04 05 00 Common Work Results for Masonry		\$2,070.00	\$2,773.00	\$8,980.00
04 05 01 Masonry, Arrangement and Refinishing				
04 05 01 01 RS Masonry	1000	\$848.48	\$2,428.98	\$2,766.84
04 05 01 02 Masonry, Arranging	1000			
04 05 01 03 Wall, Ven. corrugated, 7 3/4" x 7 1/2" gauge		\$848.48	\$2,428.98	\$2,766.84
04 05 25 Masonry Accessories				
04 05 25 01 RS Masonry	1000	\$1,727.40	\$5,894.94	\$7,022.84
04 05 25 02 Masonry Embedded Flashing	1000			
04 05 25 03 Flashing, copper, paperbacked		\$1,727.40	\$5,894.94	\$7,022.84
04 21 00 Clay Unit Masonry		\$102,780.37	\$171,012.71	\$273,793.08
04 21 01 Brick Masonry				
04 21 01 01 RS Masonry	1000	\$102,780.37	\$171,012.71	\$273,793.08
04 21 01 02 Bricklayer Masonry	1000			
04 21 01 03 Standard brick wall, 4" thick running bond		\$102,780.37	\$171,012.71	\$273,793.08
05 00 00 Metals		\$16,064.83	\$15,028.39	\$31,093.22
05 12 00 Structural Steel Framing		\$16,064.83	\$15,028.39	\$31,093.22
05 12 23 Structural Steel for Buildings				

Figure 6.20: Snapshot of TWBS Cost Report - Level IV

6.6.1.7. TWBS Detailed Cost Report by EWBS and TWBS Detailed Cost Report by EWBS - Level IV

These two reports are similar to previous TWBS reports except that they distribute the products and activities by assemblies. If used in conjunction with actual cost to track assemblies' costs to build historical data for future projects.

6.6.2. Generating Graph Reports

Graphs are very useful to analyse the project cost estimate for value engineering. They can provide the design teams quick understanding of cost distribution whether by EWBS or TWBS.

MS Access 2007 can generate graphs (Pivot Chart View) from any table or query. The process is described hereinafter.

- First step is to open the desired query or table, and then select PivotChart View from the View button on the top left of MS Access 2007 window. The user will be presented with an empty chart (Figure 6.21).
- Second Step is to select the desired chart type, for the following examples a 3D accumulative columns chart is selected (Figure 6.21).
- Third step is to select data fields and category fields from the Chart fields list. The selection process is achieved by dragging the desired field and dropping it over the designated area (Figure 6.21). After dropping a field over the data area, MS Access will automatically create total of that field. A filter field can be used to filter the result or focus on certain information by dropping it in the Filter Fields area.

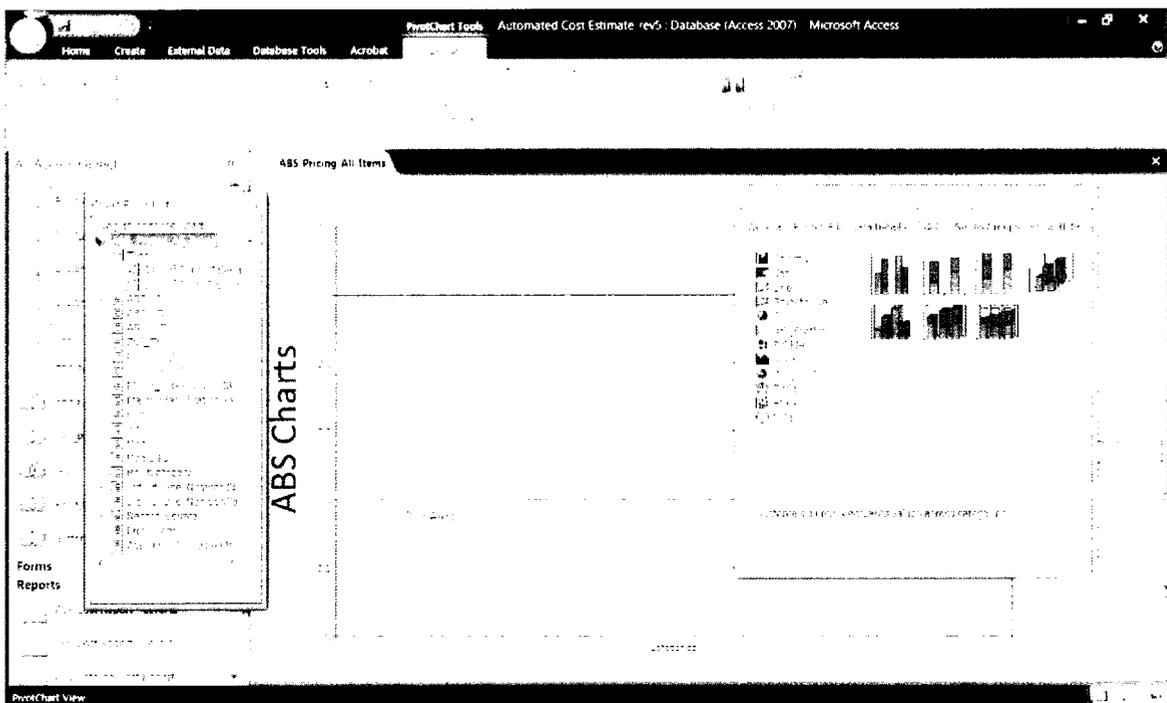


Figure 6.21: Choosing Chart Type and Fields

6.6.2.1. Cost Estimate EWBS Level I, II and III

The first chart that to be generated is the EWBS level I chart. It will present the cost estimate distributed over the EWBS main division; in the case of UniFormat they are nine, where seven of them are associated with the building assemblies. It is based on the Cost_EWBS_All_Objects query and accomplished by dropping the EWBS_LI field in the Category Fields drop area, Material and Installation fields in the Data Fields drop area as well as Title in the Filter Fields area (Figure 6.22).

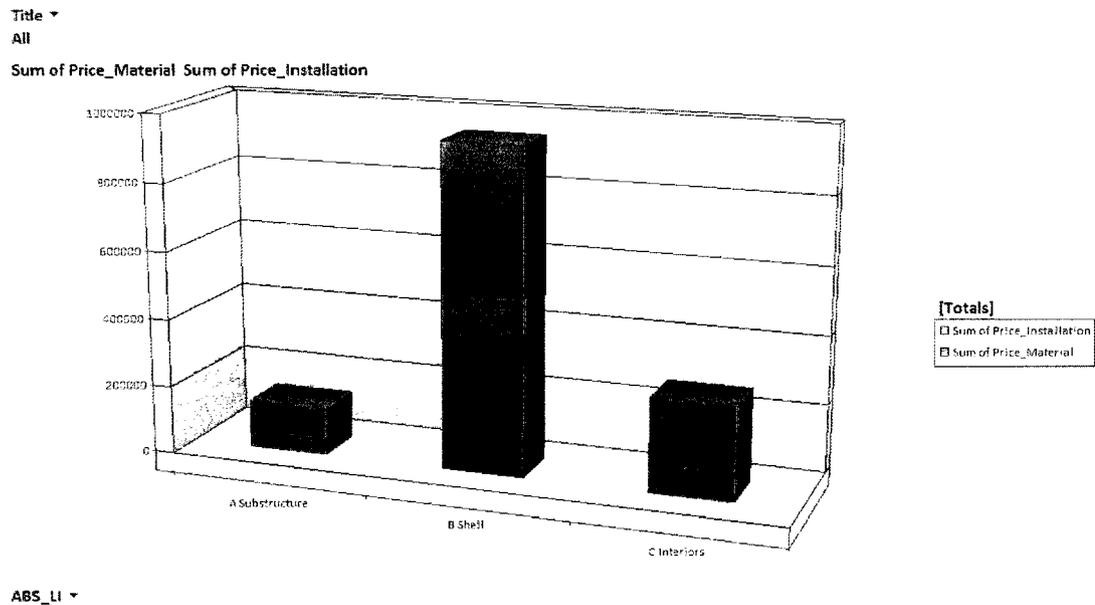


Figure 6.22: Cost Estimate EWBS Level I

If desired this chart can be detailed more by adding EWBS_LII to the Category Fields area, this will split each item in EWBS level I into its sub items (Figure 6.23). Now the chart displays 10-foundations and 20-basement construction under A-substructure, 10-super structure and 20-enclosure under B-shell in

addition to 10-interior construction under C-interiors. The same can be done with EWBS level III to display the sub-items of EWBS level 2.

These charts provide valuable information during the design stage. They can be used by the design team, the client and decision makers to fine tune the project specifications to make the project cost estimate match the project budget.

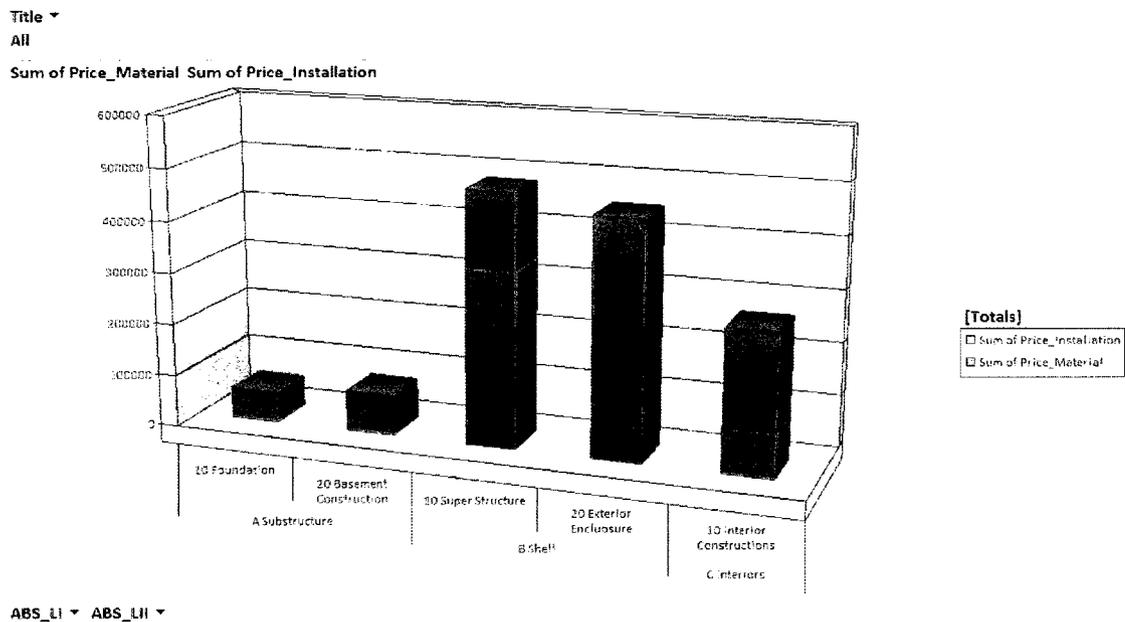
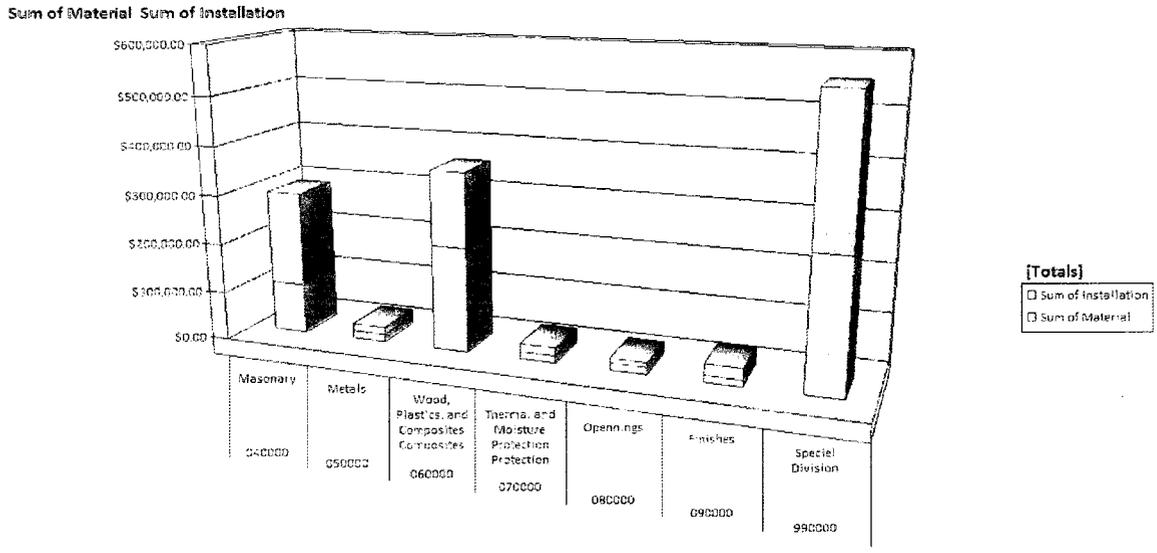


Figure 6.23: Cost Estimate EWBS Level II

6.6.2.2. Cost Estimate TWBS Level I and II

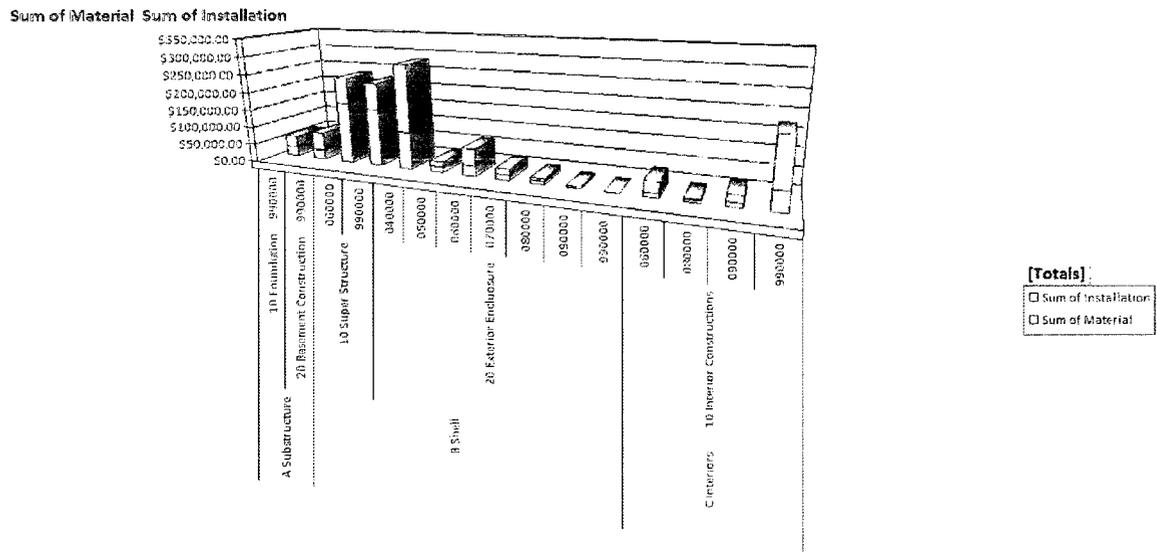
Similar to the EWBS charts, TWBS charts can be generated based on the Cost_TWBS query. It will visualize the cost estimate distribution by the TWBS main divisions (Figure 6.24) or subdivision, if TWBS level_II is added to the Category Fields drop area.



TBS_I | MF_Level_I.Description

Figure 6.24: Cost Estimate TWBS Level I Chart

6.6.2.3. Cost Estimate by Combined EWBS and TWBS



ABS_LI | ABS_LII | TBS_I

Figure 6.25: Combined EWBS and TWBS Chart

An interesting approach for deeper understanding of cost distribution can be achieved by combining the EWBS and TWBS in the charts. For example adding EWBS LI to the previous chart will show how are the different materials and

trades are distributed over the projects assemblies (Figure 6.27) or visa-versa (Figure 6.25).

6.7. Performance Benchmarking

The case study project was conducted with a Laptop PC with the specifications mentioned hereinafter. Although the system is quite modest from the hardware point of view the implemented model performed peculiarly fast; none of the reports mentioned before took more than 30 seconds to be generated. Although the project and the cost queries are designed to cost only architectural elements as well as that the cost database contains only handful set of records, in a full scale implementation the system is expected to be able to generate the reports and charts in a matter of minutes.

6.7.1. Testing System Specifications

- Operating System: Windows Vista professional 32bit
- Database engine & environment: MS Access 2007, SQL queries, ODBC connection with MS Access 2007 driver.
- Construction Design platform: AutoDesk Revit 2009 (BIM type)
- Hardware: CPU; Intel Centrino 1.6GHz, RAM; 4GB DDR2, GPU; Intel 945GM Express (Open GL 1.4, Max 256MB), Vista hardware rating 3.1

6.8. Summary

This chapter presented a walk through the developed system that generates cost estimate reports and charts based on EWBS or TWBS in an automated manner. The system proved to be; user friendly, efficient and flexible. It has the capacity of

generating professional reports and charts that can be used for cost budgeting or cost estimation during design and bidding stages as well as value engineering. It also gives the user the freedom of following the project cost estimate build up in matter of few clicks to generating cost estimate reports for value engineering proposes. The system in itself will help in reducing the project overheads by reducing the amount of time allocated for the 3D modeling and the cost estimation processes.

The simplicity of the user interface implies that the learning curve should be very steep and requires no more than couple of hours of training.

On the other hand, maintaining the cost database(s) is a time demanding process, which itself can be the subject of future research, unless it is imported from cost data providers or manufacturers.

Finally the versatile reports and charts that can be furnished by the system at a blazing speed make it a vital tool in the construction industry.

CHAPTER 7

Conclusion and Future Expansion

7.1. Conclusion

Preparing cost estimate for building projects is a significant task that traditionally requires a lot of resources and it is part of the project cost overheads. The absence of real-time cost monitoring tools combined with the complexity and inefficiency of the available cost estimation automation systems necessitated the development of an efficient model that alleviates the burden of this task. The main benefits of this model are its flexibility, simplicity and swift calculation to generate the required reports while maintaining a sufficient amount of details.

The proposed model uses the elemental cost approach, and then develops a systematic method for mapping EWBS to TWBS that renders the system beneficial during design phases and at bidding.

The system is flexible to accommodate any EWBS, TWBS or even multiple EWBSs and TWBSs. The cost databases can be home brewed, obtained from cost data providers like RS Means or even manufacturers. The system as well can handle quantity take-off and cost data in any quantifying system (e.g. imperial or metric) simultaneously without imposing any limitation as the conversion process is performed transparently.

7.2. Research contribution

- Till the date of this research the trends are focusing on generating detailed cost estimates by depending heavily on detailed 3D models of the project. While in theory this seems logical, practically it imposes serious implications and limitations, as building those extremely detailed models is challenging for; the available technologies, the tremendous man-hours required to build them as well as the wealth of information required that usually won't be available until the last minute of project design phase. In best cases that will virtually render such a system more of a burden than a solution that can be applied into real environment. In worst cases the system will be completely useless as the cost of automating the estimation process will be much higher than performing it in the traditional methods. In fact the later assertion was the major factor behind the failure of many available commercial packages. This research establishes a frame work that addresses these issues and offers a method to overcome using the available technologies.
- As well, the research proposes a method of generating detailed quantity take-off by mapping the assemblies' quantities, which in itself can be used to save tedious man-hour labour to bring the project design cost and contractor bidding price down by reducing the overheads.
- The established framework offers a continuous cost monitoring to make sure that project will not exceed the allocated budget.

7.3. Research Limitation

7.3.1. Limitations of Unit-Cost Method

The proposed model depends on Unit-Cost method to derive the project cost estimate; however this method has its limitations. The dollar-per-unit figure masks the actual man-hours and the achieved productivity. Consequently, this figure must be treated with care since each project is has his own uniqueness that applies as well to the crew composition, costs and production achieved (Halpin 1985).

7.3.2. Other limitations

In addition to the forth-mentioned limitations, the proposed model as well does not perform any optimization nor consider the project schedule.

7.4. Future Research and Expansion

7.4.1. Implementing IFC

Adding an IFC parser to the proposed model, will enable generating cost reports from various CAD/BIM packages. This parser should be located between the System Core Functions (set 1) and the exported model.

As well adding support to export cost data in IFC format will enable the system to attach cost data to 3D model for integration with other systems.

7.4.2. Implementing Cost Adjustments

EWBS cost data obtained from data providers are usually national averages that need to be adjusted to the project location. As well, consideration for inflation and

interest rates should be added to increase the accuracy of the generated cost estimate.

7.4.3. Integrating the 5thD

Adapting the alternative proposed model will provide the ground to integrate the 5thD in order to generate automated scheduling for the project, which in its turn will provide the ground for optimization.

It is worth mentioning as well that assemblies contain the labour data that will provides the possibility of expanding the proposed model to perform automated scheduling to serve as an outlook for the architects, engineers, owners and decision makers

This will allow building much more comprehensive system based on integration between 3D modeling cost and scheduling.

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APPENDIX A

MasterFormat 2004 Division Numbers and Titles

**PROCUREMENT AND CONTRACTING
REQUIREMENTS GROUP**

Division 00 Procurement and Contracting
Requirements

SPECIFICATIONS GROUP

GENERAL REQUIREMENTS SUBGROUP

Division 01 General Requirements

FACILITY CONSTRUCTION SUBGROUP

Division 02 Existing Conditions
Division 03 Concrete
Division 04 Masonry
Division 05 Metals
Division 06 Wood, Plastics, and Composites
Division 07 Thermal and Moisture Protection
Division 08 Openings
Division 09 Finishes
Division 10 Specialties
Division 11 Equipment
Division 12 Furnishings
Division 13 Special Construction
Division 14 Conveying Equipment
Division 15 Reserved
Division 16 Reserved
Division 17 Reserved
Division 18 Reserved
Division 19 Reserved

FACILITY SERVICES SUBGROUP

Division 20 Reserved
Division 21 Fire Suppression
Division 22 Plumbing
Division 23 Heating, Ventilating, and Air
Conditioning

Division 24 Reserved
Division 25 Integrated Automation
Division 26 Electrical
Division 27 Communications
Division 28 Electronic Safety and Security
Division 29 Reserved

SITE AND INFRASTRUCTURE SUBGROUP

Division 30 Reserved
Division 31 Earthwork
Division 32 Exterior Improvements
Division 33 Utilities
Division 34 Transportation
Division 35 Waterway and Marine
Construction
Division 36 Reserved
Division 37 Reserved
Division 38 Reserved
Division 39 Reserved

PROCESS EQUIPMENT SUBGROUP

Division 40 Process Integration
Division 41 Material Processing and Handling
Equipment
Division 42 Process Heating, Cooling, and
Drying Equipment
Division 43 Process Gas and Liquid
Handling, Purification, and
Storage Equipment
Division 44 Pollution Control Equipment
Division 45 Industry-Specific Manufacturing
Equipment
Division 46 Reserved
Division 47 Reserved
Division 48 Electrical Power Generation
Division 49 Reserved

APPENDIX B

UniFormat Levels

A SUBSTRUCTURE

A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls

B SHELL

B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
B20 Exterior Enclosure	B2010 Exterior Walls B2020 Exterior Windows B2030 Exterior Doors
B30 Roofing	B3010 Roof Coverings B3020 Roof Openings

C INTERIORS

C10 Interior Construction	C1010 Partitions C1020 Interior Doors C1030 Fittings
C20 Stairs	C2010 Stair Construction C2020 Stair Finishes
C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes

D SERVICES

D10 Conveying	D1010 Elevators & Lifts D1020 Escalators & Moving Walks D1090 Other Conveying Systems
D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2090 Other Plumbing Systems
D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems D3030 Cooling Generating Systems D3040 Distribution Systems D3050 Terminal & Package Units

	D3060 Controls & Instrumentation D3070 Systems Testing & Balancing D3090 Other HVAC Systems & Equipment
D40 Fire Protection	D4010 Sprinklers D4020 Standpipes D4030 Fire Protection Specialties D4090 Other Fire Protection Systems
D50 Electrical	D5010 Electrical Service & Distribution D5020 Lighting and Branch Wiring D5030 Communications & Security D5090 Other Electrical Systems

E EQUIPMENT & FURNISHINGS

E10 Equipment	E1010 Commercial Equipment E1020 Institutional Equipment E1030 Vehicular Equipment E1090 Other Equipment
E20 Furnishings	E2010 Fixed Furnishings E2020 Movable Furnishings

F SPECIAL CONSTRUCTION & DEMOLITION

F10 Special Construction	F1010 Special Structures F1020 Integrated Construction F1030 Special Construction Systems F1040 Special Facilities F1050 Special Controls and Instrumentation
F20 Selective Building Demolition	F2010 Building Elements Demolition F2020 Hazardous Components Abatement

APPENDIX C

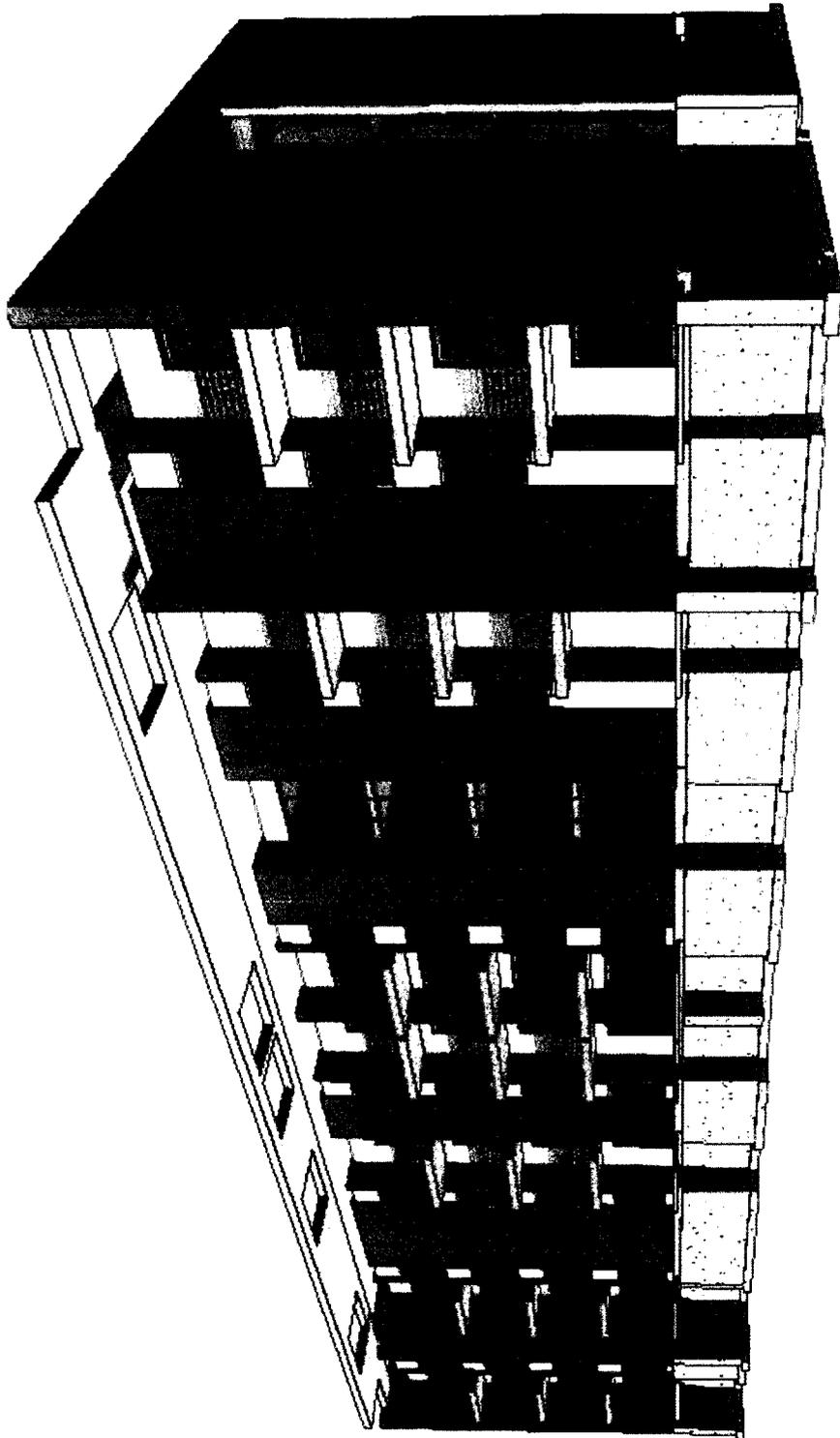
Mapping UniFormat to MasterFormat 2004

(McClain 2007)

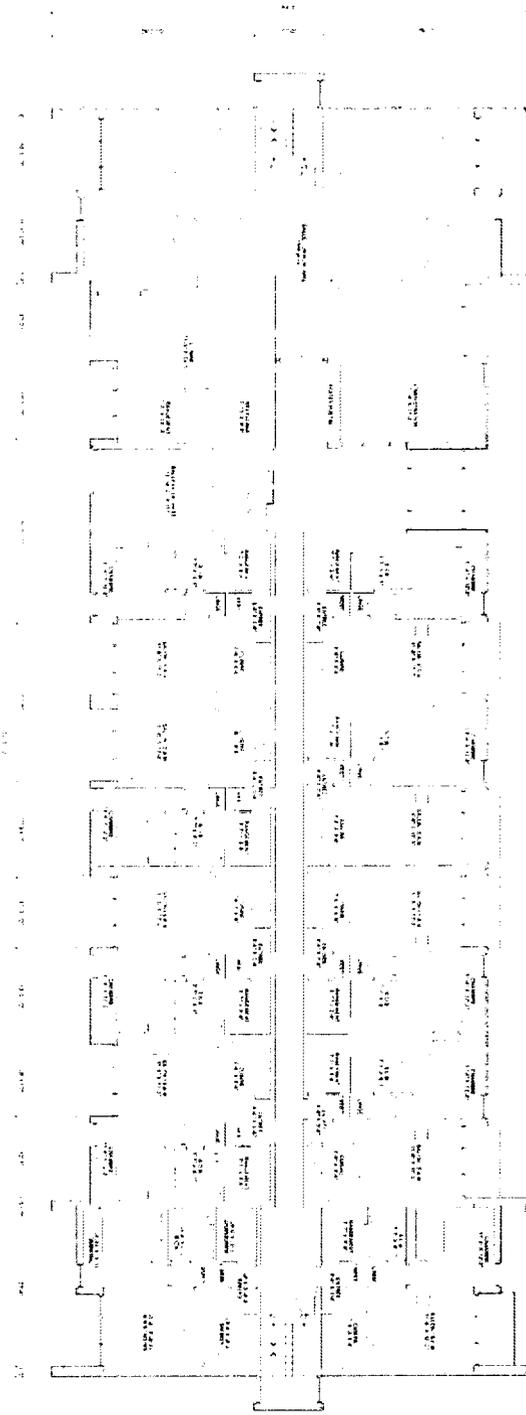
Uniformat II		MasterFormat 95		MasterFormat 2004	
Level One	G Building Sitework	G Building Sitework	D5010 Electrical Service & Distribution	02 Sitework	02 Existing Conditions
			D5020 Lighting and Branch Wiring	03 Concrete	03 Concrete
			D5030 Communications & Security	04 Masonry	04 Masonry
			D5090 Other Electrical Systems	05 Metals	05 Metals
			E1010 Commercial Equipment	06 Wood / Plastic	06 Wood, Plastics, and Composites
			E1020 Institutional Equipment	07 Thermal and Moisture Protection	07 Thermal and Moisture Protection
			E1030 Vehicular Equipment	08 Doors and Windows	08 Openings
			E1090 Other Equipment	09 Finishes	09 Finishes
			E2010 Fixed Furnishings	10 Specialties	10 Specialties
			E2020 Movable Furnishings	11 Equipment	11 Equipment
F Special Construction and Demolition	F20 Selective Building Demolition	F1010 Special Structures	12 Furnishings	12 Furnishings	
		F1020 Integrated Construction	13 Special Construction	13 Special Construction	
		F1030 Special Construction Systems	14 Conveying Systems	14 Conveying Equipment	
		F1040 Special Facilities	15 Mechanical	15 Mechanical	
		F1050 Special Controls and Instruments	16 Electrical	16 Electrical	
		F2010 Building Elements Demolition			
		F2020 Hazardous Components Abatement			
		G1010 Site Clearing			
		G1020 Site Demolition and Relocations			
		G1030 Site Earthwork			
G20 Site Improvements	G2040 Site Development	G1040 Hazardous Waste Remediation			
		G2010 Roadways			
		G2020 Parking Lots			
		G2030 Pedestrian Paving			
		G2040 Site Development			
		G2050 Landscaping			
		G3010 Water Supply			
		G3020 Sanitary Sewer			
		G3030 Storm Sewer			
		G3040 Heating Distribution			
G40 Site Electrical Utilities	G90 Other Site Construction	G3050 Cooling Distribution			
		G3060 Fuel Distribution			
		G3090 Other Site Mechanical Utilities			
		G4010 Electrical Distribution			
		G4020 Site Lighting			
		G4030 Site Communications & Security			
		G4090 Other Site Electrical Utilities			
		G9010 Service and Pedestrian Tunnels			
		G9090 Other Site Systems & Equipment			
		Level Two	Level Two		
Level Three	Level Three				
Level One	Level One				

APPENDIX D

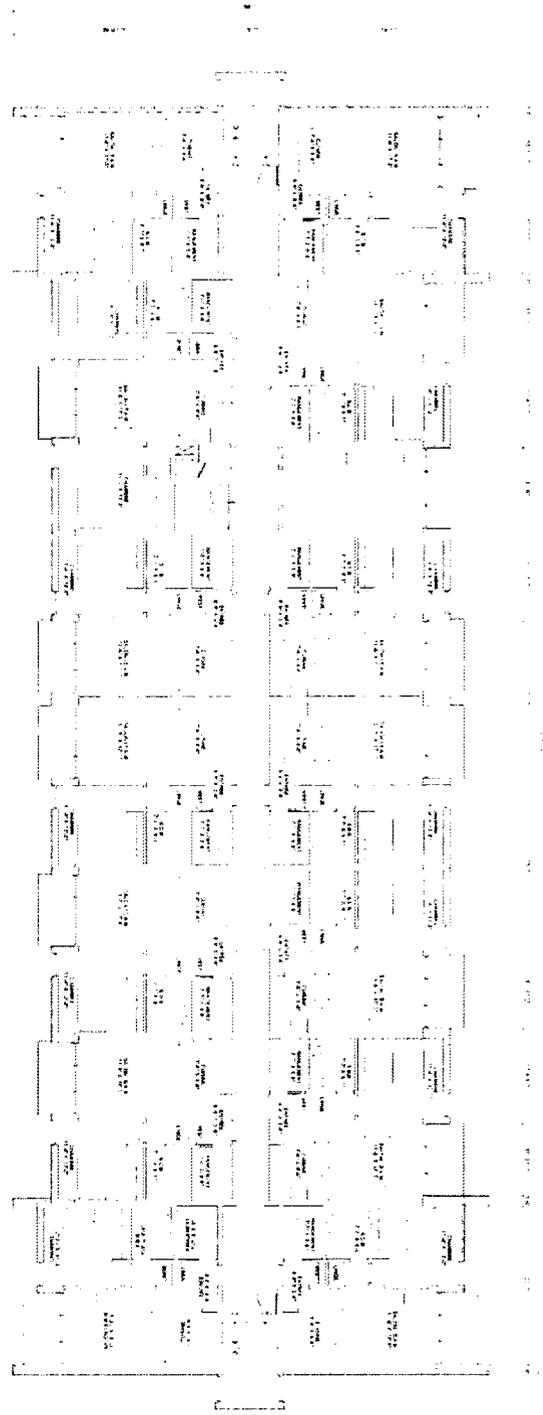
Case Study Project Drawings



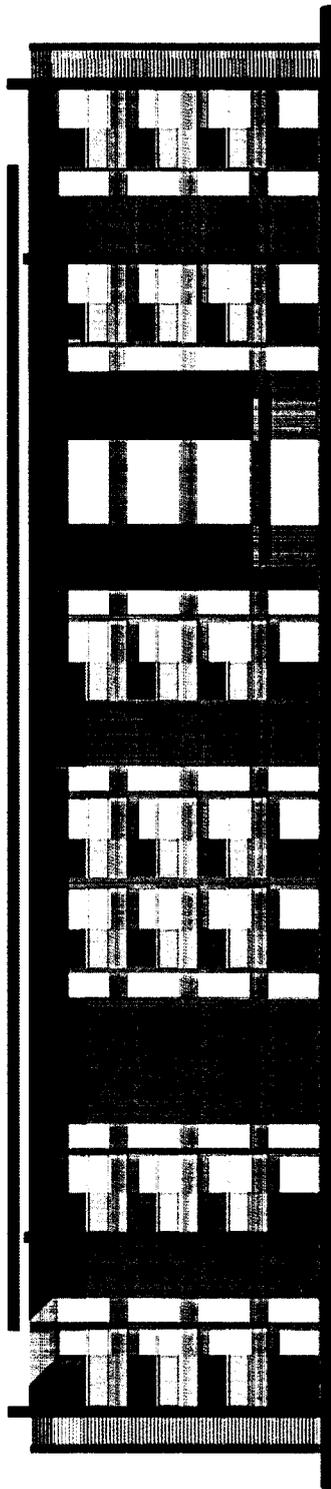
Perspective



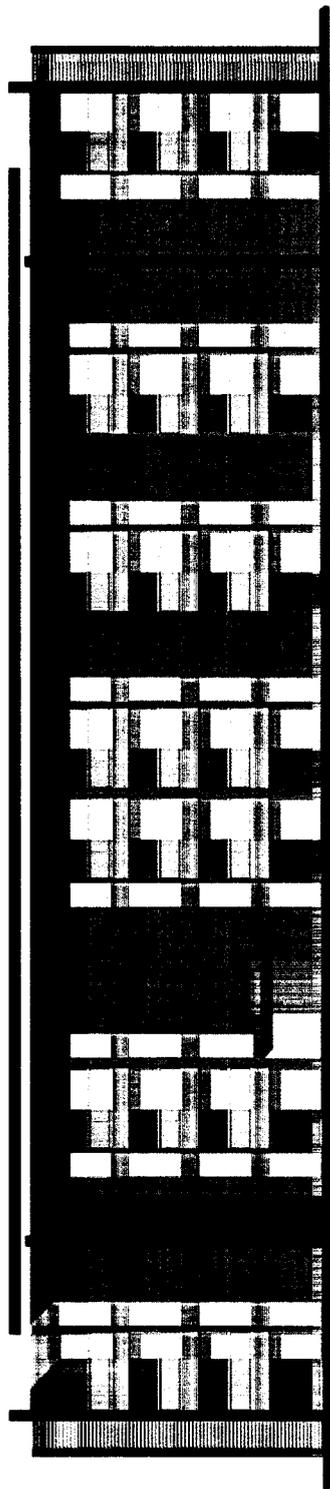
Ground Floor Plan



Typical Floor Plan



Front Elevation



Back Elevation

APPENDIX E

Case Study Project

Cost Estimation Reports

EWBS Cost Estimate - Level III

(959 records)

Material	\$640,028.96
Installation	\$673,579.62
Total	\$1,313,608.59

A Substructure

(144 records)

10 Foundation

(79 records)

10 Standard Foundation

Revit Family: Basic Wall

30 Slab on Grade

Revit Family: Floor

20 Basement Construction

(65 records)

20 Basement Walls

Revit Family: Basic Wall

B Shell

(216 records)

10 Super Structure

(55 records)

10 Floor Construction

Revit Family: Floor

20 Roof Construction

Revit Family: Basic Roof

20 Exterior Encluosure

(161 records)

10 Exterior Walls

Revit Family: Basic Wall

20 Exterior Windows

Revit Family: Fixed with Trim Type: 36" x 72"

Materials:	\$41,149.45	Total:	\$105,340.83
Installation:	\$64,191.39		
Material:	\$25,745.10	Total:	\$58,904.55
Installation:	\$33,159.45		
Material:	\$5,964.20	Total:	\$14,009.66
Installation:	\$8,045.46		(64 records)
Material:	\$19,780.90	Total:	\$44,894.90
Installation:	\$25,113.99		(15 records)
Material:	\$15,404.34	Total:	\$46,436.28
Installation:	\$31,031.94		
Material:	\$15,404.34	Total:	\$46,436.28
Installation:	\$31,031.94		(65 records)
Materials:	\$516,936.79	Total:	\$950,787.81
Installation:	\$433,851.02		
Material:	\$341,272.72	Total:	\$490,768.05
Installation:	\$149,495.33		
Material:	\$332,153.37	Total:	\$470,581.54
Installation:	\$138,428.17		(54 records)
Material:	\$9,119.35	Total:	\$20,186.51
Installation:	\$11,067.17		(1 record)
Material:	\$175,664.07	Total:	\$460,019.76
Installation:	\$284,355.69		
Material:	\$164,732.66	Total:	\$438,915.46
Installation:	\$274,182.80		(112 records)
Material:	\$10,931.41	Total:	\$21,104.30
Installation:	\$10,172.89		(49 records)

C Interiors

(599 records)

Materials: \$81,942.73 Total: \$257,479.95
Installation: \$175,537.22

10 Interior Constructions

(599 records)

Material: \$81,942.73 Total: \$257,479.95
Installation: \$175,537.22

10 Partitions

Revit Family: Basic Wall

Material: \$53,607.73 Total: \$187,169.95
Installation: \$133,562.22 (432 records)

20 Interior Doors

Revit Family: Single-Flush

Material: \$28,335.00 Total: \$70,310.00
Installation: \$41,975.00 (167 records)

Grand Total

\$640,028.96

\$673,579.62

\$1,313,608.59

EWBS Cost Estimate - Level V

Material	\$640,028.96
Installation	\$673,579.62
Total	\$1,313,608.59

A Substructure

Materials:	\$41,149.45	\$105,340.83
Installation:	\$64,191.39	(144 records)

10 Foundation

Material:	\$25,745.10	\$58,904.55
Installation:	\$33,159.45	(79 records)

10 Standard Foundation

Material:	\$5,964.20	\$14,009.66
Installation:	\$8,045.46	(64 records)

Revit Family: Base Wall

110 Strip Footing

2300 \$9.60

RSMean \$12.95

2008 \$22.55

The Strip Footing System Includes: excavation; hand trim; all forms needed for footing placement; forms for 2" x 6" keyway (four uses); dowels; and 3,000 p.s.i. Concret. The Footing size required varies for different soils. Soil bearing capacities are listed for 3 KSF and 6 KSF. Depths of the system range from 9" to 24". Widths range from 16" to 96". Smaller strip footings may not require reinforcement.

Please see the reference section for further design and cost information

Summary for: Line 2300	Quantity	Material	Installation	Total Price
(64 detail records)	621.27 L.F.	\$5,964.20	\$8,045.46	\$14,009.66

Summary for 110 Strip Footing (64 detail records)	621.27 L.F.	\$5,964.20	\$8,045.46	\$14,009.66
--	--------------------	-------------------	-------------------	--------------------

30 Slab on Grade

Revit Family: Slab

Material:	\$19,780.90	\$44,894.90
Installation:	\$25,113.99	(15 records)

120 Plain & Reinforced

2240 \$2.04

RSMean \$2.59

2008 \$4.63

Summary for: Line 2240	Quantity	Material	Installation	Total Price
(15 detail records)	9,696.52 S.F.	\$19,780.90	\$25,113.99	\$44,894.90

Summary for 120 Plain & Reinforced (15 detail records)	9,696.52 S.F.	\$19,780.90	\$25,113.99	\$44,894.90
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20 Basement Construction

Material: \$15,404.34 \$46,436.28
 Installation: \$31,031.94 (65 records)

20 Basement Walls

Revit Family: Basic Wall

Material: \$15,404.34 \$46,436.28
 Installation: \$31,031.94 (65 records)

Code	Description	Quantity	Unit	Material	Installation	Total Price
110	Walls, Cast in Place					
3060	Concrete	446.50	L.F.	\$34.50		\$15,404.34
RSMeans	Formwork	446.50	L.F.	\$69.50		\$31,031.94
2008	Formwork			\$104.00		
Summary for: Line 3060		Quantity		Material	Installation	Total Price
(65 detail records)		446.50	L.F.	\$15,404.34	\$31,031.94	\$46,436.28
Summary for 110 Walls, Cast in Place (65 detail records)						
		446.50	L.F.	\$15,404.34	\$31,031.94	\$46,436.28

B Shell

Materials: \$516,936.79 \$950,787.81
 Installation: \$433,851.02 (216 records)

10 Super Structure

Materials: \$341,272.72 \$490,768.05
 Installation: \$149,495.33 (55 records)

10 Floor Construction

Revit Family: Floor

Materials: \$332,153.37 \$470,581.54
 Installation: \$138,428.17 (54 records)

264 Wood Beam & Joist

2000 \$8.95

RSMean \$3.73

2008 \$12.68

Summary for: Line 2000	Quantity	Material	Installation	Total Price
(54 detail records)	37,112.11 S.F.	\$332,153.37	\$138,428.17	\$470,581.54

Summary for 264 Wood Beam & Joist (54 detail records)				
	37,112.11 S.F.	\$332,153.37	\$138,428.17	\$470,581.54

20 Roof Construction

Revit Family: Basic Roof

Materials: \$9,119.35 \$20,186.51
 Installation: \$11,067.17 (1 record)

102 Wood/Flat or Pitched

2550 \$1.03

RSMean \$1.25

2800 \$2.28

The Table below lists prices per S.F. for roof rafters and sheathing by nominal size and spacing. Sheathing is 15/16" CDX for 12" and 16" spacing and 3/8" CDX for 24 spacing.

Summary for: Line 2550	Quantity	Material	Installation	Total Price
(1 detail record)	8,853.73 S.F.	\$9,119.35	\$11,067.17	\$20,186.51

Summary for 102 Wood/Flat or Pitched (1 detail record)				
	8,853.73 S.F.	\$9,119.35	\$11,067.17	\$20,186.51

20 Exterior Enclousure

Materials: \$175,664.07 \$460,019.76
 Installation: \$284,355.69 (161 records)

10 Exterior Walls

Revit Family: Basic Wall

Materials: \$164,732.66 \$438,915.46
 Installation: \$274,182.80 (112 records)

129 Brick Veneer / Wood Stud Backup

1100				\$8.70		
RSMMeans				\$14.55		Exterior brick veneer / stud backup walls are defined in the following terms: types of brick and studs, stud spacing and bond. All Systems include a backup-wall, a control joint every 20', a brick shelf every 12' of height, ties to the backup and the necessary dampproofing, flushing and insulation
2008				\$23.25		
Summary for: Line 1100		Quantity	Material	Installation	Total Price	
(82 detail records)		17,274.01 S.F.	\$150,283.90	\$251,336.86	\$401,620.76	
Summary for 129 Brick Veneer / Wood Stud Backup (82 detail records)						
		17,274.01 S.F.	\$150,283.90	\$251,336.86	\$401,620.76	
148						Panel, Shingle & Lap Siding
1400				\$3.08		
RSMMeans				\$4.87		
2008				\$7.95		
Summary for: Line 1400		Quantity	Material	Installation	Total Price	
(30 detail records)		4,691.16 S.F.	\$14,448.76	\$22,845.93	\$37,294.70	
Summary for 148 Panel, Shingle & Lap Siding (30 detail records)						
		4,691.16 S.F.	\$14,448.76	\$22,845.93	\$37,294.70	
20 Exterior Windows			Material	\$10,931.41	\$21,104.30	
Kovot Family Fixed with 20' x 16" x 20"			Installation	\$10,172.89	(49 records)	
102						Wood Windows
3000				\$223.09		
RSMMeans				\$207.61		
2008				\$430.70		
Summary for: Line 3000		Quantity	Material	Installation	Total Price	
(49 detail records)		49.00 Ea.	\$10,931.41	\$10,172.89	\$21,104.30	
Summary for 102 Wood Windows (49 detail records)						
		49.00 Ea.	\$10,931.41	\$10,172.89	\$21,104.30	

C Interiors

Material: \$81,942.73
 Installation: \$175,537.22
\$257,479.95
 (599 records)

10 Interior Constructions

Material: \$81,942.73
 Installation: \$175,537.22
\$257,479.95
 (599 records)

10 Partitions

Revit Family: Basic Wall

Material: \$53,607.73
 Installation: \$133,562.22
\$187,169.95
 (432 records)

Line Item	Description	Quantity	Material	Installation	Total Price
124	Drywall Partitions / Wood Stud Framing				
1250			\$1.15		
RSMeans			\$2.83		
2008			\$3.98		
Summary for: Line 1250 (379 detail records)		29,832.21 S.F.	\$34,307.04	\$84,425.15	\$118,732.18
1600			\$2.18		
RSMeans			\$5.55		
2008			\$7.73		
Summary for: Line 1600 (53 detail records)		8,853.53 S.F.	\$19,300.69	\$49,137.07	\$68,437.76
Summary for 124 Drywall Partitions / Wood Stud Framing (432 detail records)					
		38,685.73 S.F.	\$53,607.73	\$133,562.22	\$187,169.95

20 Interior Doors

Revit Family: 2008 door opening

Material: \$28,335.00
 Installation: \$41,975.00
\$70,310.00
 (167 records)

Line Item	Description	Quantity	Material	Installation	Total Price
102	Special Doors				
5000			\$1,050.00		
RSMeans			\$775.00		
2008			\$1,825.00		
Summary for: Line 5000 (2 detail records)		2.00 Ea.	\$2,100.00	\$1,550.00	\$3,650.00
Summary for 102 Special Doors (2 detail records)					
		2.00 Ea.	\$2,100.00	\$1,550.00	\$3,650.00

Line Item	Description	Quantity	Material	Installation	Total Price
120	Wood Door/Wood Frame				
1600			\$159.00		
RSMeans			\$245.00		
2008			\$404.00		

	Quantity		Material	Installation	Total Price
Summary for: Line 1600 (165 detail records)	165.00	Ea.	\$26,235.00	\$40,425.00	\$66,660.00
Summary for 120 Wood Door/Wood Frame (165 detail records)	165.00	Ea.	\$26,235.00	\$40,425.00	\$66,660.00
Grand Total	\$640,028.96		\$673,579.62	\$1,313,608.59	

259485	4.81	L.F.	\$46.20	\$62.32	\$108.52
259166	20.82	L.F.	\$199.88	\$269.63	\$469.51
259204	11.75	L.F.	\$112.80	\$152.16	\$264.96
259250	8.29	L.F.	\$79.62	\$107.41	\$187.03
259292	11.75	L.F.	\$112.80	\$152.16	\$264.96
259328	20.70	L.F.	\$198.70	\$268.04	\$466.74
259407	12.27	L.F.	\$117.80	\$158.91	\$276.71
259752	23.54	L.F.	\$226.00	\$304.86	\$530.86
259461	12.81	L.F.	\$123.00	\$165.92	\$288.92
260219	20.78	L.F.	\$199.50	\$269.12	\$468.62
259523	11.27	L.F.	\$108.20	\$145.96	\$254.16
259543	2.79	L.F.	\$26.75	\$36.08	\$62.83
259572	12.42	L.F.	\$119.20	\$160.80	\$280.00
259599	2.75	L.F.	\$26.40	\$35.61	\$62.01
259629	12.50	L.F.	\$120.00	\$161.88	\$281.88
259653	2.83	L.F.	\$27.20	\$36.69	\$63.89
259432	2.81	L.F.	\$27.00	\$36.42	\$63.42
261530	12.81	L.F.	\$123.00	\$165.92	\$288.92
261142	2.81	L.F.	\$27.00	\$36.42	\$63.42
261190	23.54	L.F.	\$226.00	\$304.86	\$530.86
260399	20.78	L.F.	\$199.50	\$269.12	\$468.62
261253	25.46	L.F.	\$244.40	\$329.69	\$574.09
260052	2.81	L.F.	\$27.00	\$36.42	\$63.42
261317	11.29	L.F.	\$108.40	\$146.23	\$254.63
261119	12.40	L.F.	\$119.00	\$160.53	\$279.53
261374	11.81	L.F.	\$113.40	\$152.97	\$266.37
261213	2.79	L.F.	\$26.75	\$36.08	\$62.83
261556	2.80	L.F.	\$26.90	\$36.29	\$63.19
261621	12.27	L.F.	\$117.80	\$158.91	\$276.71
261765	12.69	L.F.	\$121.80	\$164.30	\$286.10
261785	7.56	L.F.	\$72.55	\$97.87	\$170.42
261808	12.69	L.F.	\$121.80	\$164.30	\$286.10
261856	7.56	L.F.	\$72.55	\$97.87	\$170.42
261340	2.81	L.F.	\$27.00	\$36.42	\$63.42
260902	11.69	L.F.	\$112.20	\$151.35	\$263.55
260533	12.18	L.F.	\$116.90	\$157.69	\$274.59
260560	2.81	L.F.	\$27.00	\$36.42	\$63.42
260797	12.81	L.F.	\$123.00	\$165.92	\$288.92
260820	1.54	L.F.	\$14.75	\$19.90	\$34.65
261282	2.79	L.F.	\$26.75	\$36.08	\$62.83
260874	3.28	L.F.	\$31.45	\$42.42	\$73.87
261075	2.81	L.F.	\$27.00	\$36.42	\$63.42

260921	2.81	L.F.	\$27.00	\$36.42	\$63.42
261054	11.69	L.F.	\$112.20	\$151.35	\$263.55
260992	12.40	L.F.	\$119.00	\$160.53	\$279.53
261021	2.81	L.F.	\$27.00	\$36.42	\$63.42
260851	11.81	L.F.	\$113.40	\$152.97	\$266.37
Summary for: Line 2300	621.27	L.F.	\$5,964.20	\$8,045.46	\$14,009.66

(64 detail records)

Summary for 110 Strip Footing (64 detail records)					
	621.27	L.F.	\$5,964.20	\$8,045.46	\$14,009.66

30 Slab on Grade

Revit Family: Floor

Material:	\$19,780.90	\$44,894.90
Installation:	\$25,113.99	(15 records)

120 Plain & Reinforced

2240	\$2.04
RSMeans	\$2.59
2008	\$4.63

Object ID	Comments	Quantity		Material	Installation	Total Price
256696		8,829.01	S.F.	\$18,011.18	\$22,867.13	\$40,878.31
271990		61.08	S.F.	\$124.60	\$158.19	\$282.79
272000		60.47	S.F.	\$123.36	\$156.61	\$279.97
272013		61.08	S.F.	\$124.60	\$158.19	\$282.79
272022		60.47	S.F.	\$123.36	\$156.61	\$279.97
272160		60.47	S.F.	\$123.36	\$156.61	\$279.97
272173		60.47	S.F.	\$123.36	\$156.61	\$279.97
273188		61.67	S.F.	\$125.81	\$159.73	\$285.55
273199		61.67	S.F.	\$125.81	\$159.73	\$285.55
273210		63.88	S.F.	\$130.31	\$165.45	\$295.76
286934		62.31	S.F.	\$127.11	\$161.38	\$288.49
286957		62.31	S.F.	\$127.11	\$161.38	\$288.49
287145		63.88	S.F.	\$130.31	\$165.45	\$295.76
287181		63.88	S.F.	\$130.31	\$165.45	\$295.76
287205		63.88	S.F.	\$130.31	\$165.45	\$295.76

Summary for: Line 2240	9,696.52	S.F.	\$19,780.90	\$25,113.99	\$44,894.90
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(15 detail records)

Summary for 120 Plain & Reinforced (15 detail records)					
	9,696.52	S.F.	\$19,780.90	\$25,113.99	\$44,894.90

20 Basement Construction

Material:	\$15,404.34	\$46,436.28
Installation:	\$31,031.94	(65 records)

20 Basement Walls

Revit Family: Basic Wall

Material:	\$15,404.34	\$46,436.28
Installation:	\$31,031.94	(65 records)

110 Walls, Cast in Place

3060	\$34.50
RSMeans	\$69.50
2008	\$104.00

QTY	Comments	Quantity	Material	Installation	Total Price
253752		12.42 L.F.	\$428.38	\$862.96	\$1,291.33
253783		2.92 L.F.	\$100.63	\$202.71	\$303.33
253964		3.01 L.F.	\$103.86	\$209.22	\$313.08
254013		12.38 L.F.	\$426.94	\$860.06	\$1,287.00
254116		2.76 L.F.	\$95.05	\$191.49	\$286.54
253671		2.80 L.F.	\$96.67	\$194.74	\$291.42
284107		8.33 L.F.	\$287.50	\$579.17	\$866.67
254211		12.40 L.F.	\$427.66	\$861.51	\$1,289.17
254064		2.90 L.F.	\$99.91	\$201.26	\$301.17
278362		2.90 L.F.	\$99.91	\$201.26	\$301.17
278526		2.90 L.F.	\$99.91	\$201.26	\$301.17
253623		7.68 L.F.	\$264.94	\$533.71	\$798.65
279760		26.60 L.F.	\$917.56	\$1,848.42	\$2,765.98
279944		26.46 L.F.	\$912.89	\$1,839.01	\$2,751.90
283880		8.33 L.F.	\$287.50	\$579.17	\$866.67
253569		2.81 L.F.	\$97.03	\$195.47	\$292.50
253516		5.68 L.F.	\$195.94	\$394.71	\$590.65
262958		1.00 L.F.	\$34.50	\$69.50	\$104.00
253599		12.81 L.F.	\$442.03	\$890.47	\$1,332.50
255165		2.81 L.F.	\$97.03	\$195.47	\$292.50
255561		2.79 L.F.	\$96.13	\$193.66	\$289.79
255531		25.46 L.F.	\$878.31	\$1,769.35	\$2,647.67
255470		2.79 L.F.	\$96.13	\$193.66	\$289.79
255380		2.81 L.F.	\$97.03	\$195.47	\$292.50
255355		12.40 L.F.	\$427.66	\$861.51	\$1,289.17
254466		7.68 L.F.	\$264.94	\$533.71	\$798.65
255287		2.81 L.F.	\$97.03	\$195.47	\$292.50
254564		12.81 L.F.	\$442.03	\$890.47	\$1,332.50
265216		26.58 L.F.	\$916.84	\$1,846.97	\$2,763.82
255203		12.40 L.F.	\$427.66	\$861.51	\$1,289.17
255663		11.81 L.F.	\$407.53	\$820.97	\$1,228.50
255102		3.28 L.F.	\$113.02	\$227.68	\$340.71
255074		11.81 L.F.	\$407.53	\$820.97	\$1,228.50
254999		4.40 L.F.	\$151.91	\$306.03	\$457.94
254673		2.78 L.F.	\$96.03	\$193.45	\$289.48
254971		2.87 L.F.	\$98.91	\$199.24	\$298.15
254947		12.81 L.F.	\$442.03	\$890.47	\$1,332.50

254905	2.81	L.F.	\$97.03	\$195.47	\$292.50
254825	5.68	L.F.	\$195.94	\$394.71	\$590.65
254797	26.60	L.F.	\$917.56	\$1,848.42	\$2,765.98
255228	2.81	L.F.	\$97.03	\$195.47	\$292.50
256044	2.79	L.F.	\$96.31	\$194.02	\$290.33
254754	5.68	L.F.	\$195.94	\$394.71	\$590.65
254334	2.90	L.F.	\$99.91	\$201.26	\$301.17
256653	1.00	L.F.	\$34.50	\$69.50	\$104.00
256608	1.00	L.F.	\$34.50	\$69.50	\$104.00
256564	1.00	L.F.	\$34.50	\$69.50	\$104.00
256525	0.80	L.F.	\$27.64	\$55.68	\$83.32
256474	0.80	L.F.	\$27.64	\$55.68	\$83.32
256422	1.00	L.F.	\$34.50	\$69.50	\$104.00
256373	1.00	L.F.	\$34.50	\$69.50	\$104.00
255607	2.81	L.F.	\$97.03	\$195.47	\$292.50
256216	1.00	L.F.	\$34.50	\$69.50	\$104.00
254379	24.63	L.F.	\$849.56	\$1,711.44	\$2,561.00
256016	2.79	L.F.	\$96.31	\$194.02	\$290.33
255963	2.79	L.F.	\$96.31	\$194.02	\$290.33
255937	2.79	L.F.	\$96.31	\$194.02	\$290.33
255894	5.68	L.F.	\$195.94	\$394.71	\$590.65
255805	2.81	L.F.	\$97.03	\$195.47	\$292.50
255778	12.81	L.F.	\$442.03	\$890.47	\$1,332.50
255732	2.87	L.F.	\$98.91	\$199.24	\$298.15
255698	4.87	L.F.	\$167.91	\$338.24	\$506.15
254241	2.76	L.F.	\$95.05	\$191.49	\$286.54
256290	1.00	L.F.	\$34.50	\$69.50	\$104.00
262957	2.87	L.F.	\$98.91	\$199.24	\$298.15
Summary for: Line 3060 (65 detail records)	446.50	L.F.	\$15,404.34	\$31,031.94	\$46,436.28
Summary for 110 Walls, Cast in Place (65 detail records)					
	446.50	L.F.	\$15,404.34	\$31,031.94	\$46,436.28

B Shell

Materials: \$516,936.79 **\$950,787.81**

Installation: \$433,851.02 (216 records)

10 Super Structure

Material: \$341,272.72 **\$490,768.05**

Installation: \$149,495.33 (55 records)

10 Floor Construction

Material: \$332,153.37 **\$470,581.54**

Installation: \$138,428.17 (54 records)

Revit Family: Floor

264 Wood Beam & Joist

2000 \$8.95

RSMeans \$3.73

2008 \$12.68

Object ID	Comments:	Quantity		Material	Installation	Total Price
257174		8,559.78	S.F.	\$76,610.00	\$31,927.97	\$108,537.96
257358		8,559.78	S.F.	\$76,610.00	\$31,927.97	\$108,537.96
257542		8,559.78	S.F.	\$76,610.00	\$31,927.97	\$108,537.96
270247		61.08	S.F.	\$546.64	\$227.82	\$774.46
270466		60.47	S.F.	\$541.20	\$225.55	\$766.74
270483		61.08	S.F.	\$546.64	\$227.82	\$774.46
270493		60.47	S.F.	\$541.20	\$225.55	\$766.74
270518		61.67	S.F.	\$551.98	\$230.04	\$782.02
270971		63.65	S.F.	\$569.64	\$237.40	\$807.04
270996		61.65	S.F.	\$551.75	\$229.95	\$781.70
271012		62.31	S.F.	\$557.67	\$232.41	\$790.08
271232		63.88	S.F.	\$571.72	\$238.27	\$809.99
271274		60.47	S.F.	\$541.20	\$225.55	\$766.74
271293		60.47	S.F.	\$541.20	\$225.55	\$766.74
273304		61.67	S.F.	\$551.98	\$230.04	\$782.02
273315		61.67	S.F.	\$551.98	\$230.04	\$782.02
273326		63.88	S.F.	\$571.72	\$238.27	\$809.99
275431		61.08	S.F.	\$546.64	\$227.82	\$774.46
275441		60.47	S.F.	\$541.20	\$225.55	\$766.74
275454		61.08	S.F.	\$546.64	\$227.82	\$774.46
275463		60.47	S.F.	\$541.20	\$225.55	\$766.74
275479		61.67	S.F.	\$551.98	\$230.04	\$782.02
275490		63.65	S.F.	\$569.64	\$237.40	\$807.04
275501		61.65	S.F.	\$551.75	\$229.95	\$781.70
275512		62.31	S.F.	\$557.67	\$232.41	\$790.08
275523		63.88	S.F.	\$571.72	\$238.27	\$809.99
275534		60.47	S.F.	\$541.20	\$225.55	\$766.74
275572		61.67	S.F.	\$551.98	\$230.04	\$782.02
275583		61.67	S.F.	\$551.98	\$230.04	\$782.02

275594	63.88	S.F.	\$571.72	\$238.27	\$809.99
275987	61.08	S.F.	\$546.64	\$227.82	\$774.46
275996	60.47	S.F.	\$541.20	\$225.55	\$766.74
276012	61.67	S.F.	\$551.98	\$230.04	\$782.02
276023	63.65	S.F.	\$569.64	\$237.40	\$807.04
276105	61.67	S.F.	\$551.98	\$230.04	\$782.02
276116	61.67	S.F.	\$551.98	\$230.04	\$782.02
276127	63.88	S.F.	\$571.72	\$238.27	\$809.99
277289	60.47	S.F.	\$541.20	\$225.55	\$766.74
277351	61.08	S.F.	\$546.64	\$227.82	\$774.46
277360	60.47	S.F.	\$541.20	\$225.55	\$766.74
277378	61.65	S.F.	\$551.75	\$229.95	\$781.70
277389	62.31	S.F.	\$557.67	\$232.41	\$790.08
277400	63.88	S.F.	\$571.72	\$238.27	\$809.99
277411	60.47	S.F.	\$541.20	\$225.55	\$766.74
277493	60.47	S.F.	\$541.20	\$225.55	\$766.74
280649	35.48	S.F.	\$317.51	\$132.33	\$449.84
280975	35.48	S.F.	\$317.51	\$132.33	\$449.84
282150	35.48	S.F.	\$317.51	\$132.33	\$449.84
282172	35.48	S.F.	\$317.51	\$132.33	\$449.84
282194	35.48	S.F.	\$317.51	\$132.33	\$449.84
282224	35.48	S.F.	\$317.51	\$132.33	\$449.84
282246	35.48	S.F.	\$317.51	\$132.33	\$449.84
282268	35.48	S.F.	\$317.51	\$132.33	\$449.84
286744	8,555.73	S.F.	\$76,573.78	\$31,912.87	\$108,486.65
Summary for: Line 2000	37,112.11	S.F.	\$332,153.37	\$138,428.17	\$470,581.54
(54 detail records)					

Summary for 264 Wood Beam & Joist (54 detail records)

37,112.11 S.F. \$332,153.37 \$138,428.17 \$470,581.54

20 Roof Construction

Material: \$9,119.35 \$20,186.51

Revit Family: Basic Roof

Installation: \$11,067.17 (1 record)

102 Wood/Flat or Pitched

2550	\$1.03
RSMMeans	\$1.25
2800	\$2.28

The Table below lists prices per S.F. for roof rafters and sheathing by nominal size and spacing. Sheathing is 15/16" CDX for 12" and 16" spacing and 3/8" CDX for 24" spacing.

Object ID	Comments	Quantity	Material	Installation	Total Price
262208		8,853.73 S.F.	\$9,119.35	\$11,067.17	\$20,186.51
Summary for: Line 2550		8,853.73 S.F.	\$9,119.35	\$11,067.17	\$20,186.51
(1 detail record)					

Summary for 102 Wood/Flat or Pitched (1 detail record)

8,853.73 S.F. \$9,119.35 \$11,067.17 \$20,186.51

20 Exterior Enclousure

Material: \$175,664.07 \$460,019.76

Installation: \$284,355.69 (161 records)

10 Exterior Walls

Material: \$164,732.66 \$438,915.46

Rev# Family: Basic Wall

Installation: \$274,182.80 (112 records)

245573 129 Brick Veneer / Wood Stud Backup

245572 1100 \$8.70

245561 RSMMeans \$14.55

245577 2008 \$23.25

Exterior brick veneer / stud backup walls are defined in the following terms: types of brick and studs, stud spacing and bond. All Systems include a backup-wall, a control joint every 20', a brick shelf every 12' of height, ties to the backup and the necessary dampproofing, flushing and insulation

QTY	UNIT	PRICE	AMOUNT	QTY	UNIT	PRICE	AMOUNT	TOTAL PRICE
85.98	S.F.	\$748.03	\$64,281.24	1,251.01	S.F.	\$1,251.01	\$1,565,291.01	\$1,629,572.25
336.09	S.F.	\$2,924.02	\$980,715.08	4,890.17	S.F.	\$4,890.17	\$23,723,111.69	\$24,703,826.77
32.36	S.F.	\$281.57	\$9,111.24	470.90	S.F.	\$470.90	\$221,417.10	\$230,528.34
114.31	S.F.	\$994.53	\$113,771.17	1,663.26	S.F.	\$1,663.26	\$2,747,811.96	\$2,861,583.13
281.47	S.F.	\$2,448.80	\$690,100.16	4,095.40	S.F.	\$4,095.40	\$16,771,111.60	\$17,461,211.76
32.36	S.F.	\$281.57	\$9,111.24	470.90	S.F.	\$470.90	\$221,417.10	\$230,528.34
114.31	S.F.	\$994.53	\$113,771.17	1,663.26	S.F.	\$1,663.26	\$2,747,811.96	\$2,861,583.13
672.19	S.F.	\$5,848.03	\$3,931,111.17	9,780.33	S.F.	\$9,780.33	\$95,461,111.69	\$99,392,222.86
32.36	S.F.	\$281.57	\$9,111.24	470.90	S.F.	\$470.90	\$221,417.10	\$230,528.34
114.31	S.F.	\$994.53	\$113,771.17	1,663.26	S.F.	\$1,663.26	\$2,747,811.96	\$2,861,583.13
88.12	S.F.	\$766.61	\$67,441.17	1,282.09	S.F.	\$1,282.09	\$1,647,111.69	\$1,714,552.86
34.80	S.F.	\$302.78	\$10,536.74	506.37	S.F.	\$506.37	\$257,291.13	\$267,827.87
32.36	S.F.	\$281.57	\$9,111.24	470.90	S.F.	\$470.90	\$221,417.10	\$230,528.34
114.31	S.F.	\$994.53	\$113,771.17	1,663.26	S.F.	\$1,663.26	\$2,747,811.96	\$2,861,583.13
351.86	S.F.	\$3,061.19	\$1,077,111.69	5,119.58	S.F.	\$5,119.58	\$26,401,111.69	\$27,478,223.38
1,104.66	S.F.	\$9,610.56	\$10,621,111.69	16,072.84	S.F.	\$16,072.84	\$258,111.69	\$10,879,223.38
441.63	S.F.	\$3,842.18	\$1,697,111.69	6,425.72	S.F.	\$6,425.72	\$41,401,111.69	\$43,098,223.38
144.40	S.F.	\$1,256.24	\$181,411.69	2,100.96	S.F.	\$2,100.96	\$4,401,111.69	\$4,582,523.38
144.40	S.F.	\$1,256.24	\$181,411.69	2,100.96	S.F.	\$2,100.96	\$4,401,111.69	\$4,582,523.38
114.31	S.F.	\$994.53	\$113,771.17	1,663.26	S.F.	\$1,663.26	\$2,747,811.96	\$2,861,583.13
351.86	S.F.	\$3,061.19	\$1,077,111.69	5,119.58	S.F.	\$5,119.58	\$26,401,111.69	\$27,478,223.38
64.73	S.F.	\$563.14	\$36,461.17	941.81	S.F.	\$941.81	\$887,111.69	\$923,572.86
35.69	S.F.	\$310.54	\$11,081.17	519.35	S.F.	\$519.35	\$270,111.69	\$281,192.86
247.28	S.F.	\$2,151.30	\$531,111.69	3,597.87	S.F.	\$3,597.87	\$12,811,111.69	\$13,342,223.38
1,141.45	S.F.	\$9,930.61	\$11,321,111.69	16,608.08	S.F.	\$16,608.08	\$274,111.69	\$11,595,223.38

283572	372.28	S.F.	\$3,238.85	\$5,416.69	\$8,655.54
285360	85.40	S.F.	\$742.94	\$1,242.51	\$1,985.45
247303	319.50	S.F.	\$2,779.62	\$4,648.68	\$7,428.30
247152	137.83	S.F.	\$1,199.15	\$2,005.48	\$3,204.63
247103	137.83	S.F.	\$1,199.15	\$2,005.48	\$3,204.63
286496	372.28	S.F.	\$3,238.85	\$5,416.69	\$8,655.54
246611	32.36	S.F.	\$281.57	\$470.90	\$752.48
246601	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
262897	247.28	S.F.	\$2,151.30	\$3,597.87	\$5,749.17
245574	307.40	S.F.	\$2,674.37	\$4,472.66	\$7,147.03
246303	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
245575	64.73	S.F.	\$563.14	\$941.81	\$1,504.95
245621	64.73	S.F.	\$563.14	\$941.81	\$1,504.95
245620	285.98	S.F.	\$2,488.00	\$4,160.96	\$6,648.95
245619	85.98	S.F.	\$748.03	\$1,251.01	\$1,999.03
245618	336.09	S.F.	\$2,924.02	\$4,890.17	\$7,814.18
286589	1,105.35	S.F.	\$9,616.54	\$16,082.84	\$25,699.39
245607	32.36	S.F.	\$281.57	\$470.90	\$752.48
245598	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
245595	281.47	S.F.	\$2,448.80	\$4,095.40	\$6,544.20
286590	1,105.47	S.F.	\$9,617.63	\$16,084.66	\$25,702.29
286592	80.00	S.F.	\$696.00	\$1,164.00	\$1,860.00
245581	112.03	S.F.	\$974.67	\$1,630.06	\$2,604.73
245463	88.12	S.F.	\$766.61	\$1,282.09	\$2,048.71
246313	32.36	S.F.	\$281.57	\$470.90	\$752.48
240037	32.36	S.F.	\$281.57	\$470.90	\$752.48
243097	194.46	S.F.	\$1,691.77	\$2,829.34	\$4,521.11
243096	85.98	S.F.	\$748.03	\$1,251.01	\$1,999.03
243095	336.09	S.F.	\$2,924.02	\$4,890.17	\$7,814.18
240915	64.73	S.F.	\$563.14	\$941.81	\$1,504.95
243075	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
240548	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
242706	112.03	S.F.	\$974.67	\$1,630.06	\$2,604.73
240025	332.45	S.F.	\$2,892.30	\$4,837.12	\$7,729.42
243098	64.73	S.F.	\$563.14	\$941.81	\$1,504.95
240026	132.78	S.F.	\$1,155.17	\$1,931.92	\$3,087.08
243084	32.36	S.F.	\$281.57	\$470.90	\$752.48
241879	34.80	S.F.	\$302.78	\$506.37	\$809.15
239314	32.36	S.F.	\$281.57	\$470.90	\$752.48
245468	319.50	S.F.	\$2,779.62	\$4,648.68	\$7,428.30
240542	281.62	S.F.	\$2,450.11	\$4,097.60	\$6,547.72
240858	147.18	S.F.	\$1,280.49	\$2,141.50	\$3,421.99

240826	85.98	S.F.	\$748.03	\$1,251.01	\$1,999.03
240643	336.09	S.F.	\$2,924.02	\$4,890.17	\$7,814.18
240559	32.36	S.F.	\$281.57	\$470.90	\$752.48
242590	87.97	S.F.	\$765.30	\$1,279.90	\$2,045.19
239302	839.82	S.F.	\$7,306.43	\$12,219.38	\$19,525.81
243072	281.62	S.F.	\$2,450.11	\$4,097.60	\$6,547.72
235780	32.36	S.F.	\$281.57	\$470.90	\$752.48
233569	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
238673	87.97	S.F.	\$765.30	\$1,279.90	\$2,045.19
238886	64.73	S.F.	\$563.14	\$941.81	\$1,504.95
239977	32.36	S.F.	\$281.57	\$470.90	\$752.48
233319	351.86	S.F.	\$3,061.19	\$5,119.58	\$8,180.77
239303	114.31	S.F.	\$994.53	\$1,663.26	\$2,657.79
243101	34.80	S.F.	\$302.78	\$506.37	\$809.15
238722	87.97	S.F.	\$765.30	\$1,279.90	\$2,045.19
Summary for: Line 1100	17,274.01	S.F.	\$150,283.90	\$251,336.86	\$401,620.76
(82 detail records)					

Summary for 129 Brick Veneer / Wood Stud Backup (82 detail records)					
	17,274.01	S.F.	\$150,283.90	\$251,336.86	\$401,620.76

Item #	Description	Quantity	Material	Unit Price	Total Price	
148	Panel, Shingle & Lap Siding					
1400		\$3.08				
RSMean		\$4.87				
2008		\$7.95				
286195		5.25	S.F.	\$16.17	\$25.57	\$41.74
287254		5.25	S.F.	\$16.17	\$25.57	\$41.74
287253		5.25	S.F.	\$16.17	\$25.57	\$41.74
290150		29.69	S.F.	\$91.44	\$144.58	\$236.02
285927		5.25	S.F.	\$16.17	\$25.57	\$41.74
245624		249.92	S.F.	\$769.74	\$1,217.09	\$1,986.84
246624		282.69	S.F.	\$870.70	\$1,376.72	\$2,247.42
246329		254.20	S.F.	\$782.94	\$1,237.95	\$2,020.89
246323		60.75	S.F.	\$187.11	\$295.85	\$482.96
245615		78.75	S.F.	\$242.55	\$383.51	\$626.06
245583		565.39	S.F.	\$1,741.40	\$2,753.45	\$4,494.84
245582		267.13	S.F.	\$822.75	\$1,300.90	\$2,123.64
245578		250.74	S.F.	\$772.27	\$1,221.09	\$1,993.35
245569		60.75	S.F.	\$187.11	\$295.85	\$482.96
245516		60.75	S.F.	\$187.11	\$295.85	\$482.96
245488		60.75	S.F.	\$187.11	\$295.85	\$482.96
245458		60.75	S.F.	\$187.11	\$295.85	\$482.96

240569	62.44	S.F.	\$192.31	\$304.07	\$496.38
246621	78.75	S.F.	\$242.55	\$383.51	\$626.06
243878	255.89	S.F.	\$788.14	\$1,246.18	\$2,034.32
240047	62.44	S.F.	\$192.31	\$304.07	\$496.38
242429	255.06	S.F.	\$785.58	\$1,242.14	\$2,027.72
242512	304.02	S.F.	\$936.38	\$1,480.58	\$2,416.97
237629	62.44	S.F.	\$192.31	\$304.07	\$496.38
242834	574.85	S.F.	\$1,770.53	\$2,799.51	\$4,570.04
243092	80.44	S.F.	\$247.75	\$391.73	\$639.48
243102	255.06	S.F.	\$785.58	\$1,242.14	\$2,027.72
242757	271.66	S.F.	\$836.70	\$1,322.97	\$2,159.67
239324	62.44	S.F.	\$192.31	\$304.07	\$496.38
239987	62.44	S.F.	\$192.31	\$304.07	\$496.38
Summary for: Line 1400 (30 detail records)	4,691.16	S.F.	\$14,448.76	\$22,845.93	\$37,294.70

Summary for 148 Panel, Shingle & Lap Siding (30 detail records)

	4,691.16 S.F.	\$14,448.76	\$22,845.93	\$37,294.70
20 Exterior Windows			Material: \$10,931.41	\$21,104.30
Revit Family: Wood with Trim Type: 26" x 72"			Insulation: \$10,172.89	(49 records)

Quantity	Material	Insulation	Total Price
102	Wood Windows		
3000		\$223.09	
RSMeans		\$207.61	
2008		\$430.70	
237669	1.00 Ea.	\$223.09	\$430.70
239326	1.00 Ea.	\$223.09	\$430.70
239989	1.00 Ea.	\$223.09	\$430.70
240049	1.00 Ea.	\$223.09	\$430.70
240571	1.00 Ea.	\$223.09	\$430.70
243093	1.00 Ea.	\$223.09	\$430.70
245460	1.00 Ea.	\$223.09	\$430.70
245490	1.00 Ea.	\$223.09	\$430.70
245518	1.00 Ea.	\$223.09	\$430.70
245570	1.00 Ea.	\$223.09	\$430.70
245616	1.00 Ea.	\$223.09	\$430.70
246325	1.00 Ea.	\$223.09	\$430.70
246623	1.00 Ea.	\$223.09	\$430.70
251841	1.00 Ea.	\$223.09	\$430.70
251843	1.00 Ea.	\$223.09	\$430.70
251845	1.00 Ea.	\$223.09	\$430.70

251847	1.00	Ea.	\$223.09	\$207.61	\$430.70
251849	1.00	Ea.	\$223.09	\$207.61	\$430.70
251851	1.00	Ea.	\$223.09	\$207.61	\$430.70
251853	1.00	Ea.	\$223.09	\$207.61	\$430.70
251855	1.00	Ea.	\$223.09	\$207.61	\$430.70
251857	1.00	Ea.	\$223.09	\$207.61	\$430.70
251859	1.00	Ea.	\$223.09	\$207.61	\$430.70
251861	1.00	Ea.	\$223.09	\$207.61	\$430.70
251863	1.00	Ea.	\$223.09	\$207.61	\$430.70
251865	1.00	Ea.	\$223.09	\$207.61	\$430.70
251870	1.00	Ea.	\$223.09	\$207.61	\$430.70
251872	1.00	Ea.	\$223.09	\$207.61	\$430.70
251874	1.00	Ea.	\$223.09	\$207.61	\$430.70
251876	1.00	Ea.	\$223.09	\$207.61	\$430.70
251878	1.00	Ea.	\$223.09	\$207.61	\$430.70
251880	1.00	Ea.	\$223.09	\$207.61	\$430.70
251882	1.00	Ea.	\$223.09	\$207.61	\$430.70
251884	1.00	Ea.	\$223.09	\$207.61	\$430.70
251886	1.00	Ea.	\$223.09	\$207.61	\$430.70
251888	1.00	Ea.	\$223.09	\$207.61	\$430.70
251890	1.00	Ea.	\$223.09	\$207.61	\$430.70
251892	1.00	Ea.	\$223.09	\$207.61	\$430.70
251894	1.00	Ea.	\$223.09	\$207.61	\$430.70
264962	1.00	Ea.	\$223.09	\$207.61	\$430.70
264964	1.00	Ea.	\$223.09	\$207.61	\$430.70
264966	1.00	Ea.	\$223.09	\$207.61	\$430.70
264968	1.00	Ea.	\$223.09	\$207.61	\$430.70
264970	1.00	Ea.	\$223.09	\$207.61	\$430.70
264972	1.00	Ea.	\$223.09	\$207.61	\$430.70
264974	1.00	Ea.	\$223.09	\$207.61	\$430.70
264976	1.00	Ea.	\$223.09	\$207.61	\$430.70
264978	1.00	Ea.	\$223.09	\$207.61	\$430.70
264980	1.00	Ea.	\$223.09	\$207.61	\$430.70
Summary for: Line 3000	49.00	Ea.	\$10,931.41	\$10,172.89	\$21,104.30
(49 detail records)					
Summary for 102 Wood Windows (49 detail records)	49.00	Ea.	\$10,931.41	\$10,172.89	\$21,104.30

C Interiors

Materials: \$81,942.73 \$257,479.95

Installation: \$175,537.22 (599 records)

10 Interior Constructions

Material: \$81,942.73 \$257,479.95

Installation: \$175,537.22 (599 records)

10 Partitions

Material: \$53,607.73 \$187,169.95

Revit Family: Basic Wall

Installation: \$133,562.22 (432 records)

124

Drywall Partitions / Wood Stud Framing

1250

\$1.15

RSMean

\$2.83

2008

\$3.98

Object ID	Comments:	Quantity	Material	Installation	Total Price
290864		14.58 S.F.	\$16.77	\$41.27	\$58.04
291126		758.92 S.F.	\$872.75	\$2,147.74	\$3,020.49
290889		751.63 S.F.	\$864.37	\$2,127.10	\$2,991.47
290862		85.46 S.F.	\$98.28	\$241.85	\$340.12
290776		758.92 S.F.	\$872.75	\$2,147.74	\$3,020.49
291113		85.46 S.F.	\$98.28	\$241.85	\$340.12
245657		758.92 S.F.	\$872.75	\$2,147.74	\$3,020.49
290717		195.56 S.F.	\$224.90	\$553.44	\$778.34
240463		20.42 S.F.	\$23.48	\$57.78	\$81.26
290775		85.46 S.F.	\$98.28	\$241.85	\$340.12
269198		108.83 S.F.	\$125.15	\$307.98	\$433.13
268335		90.77 S.F.	\$104.38	\$256.87	\$361.25
268189		40.62 S.F.	\$46.71	\$114.95	\$161.67
267927		133.14 S.F.	\$153.11	\$376.80	\$529.91
268437		93.04 S.F.	\$107.00	\$263.31	\$370.31
290806		188.09 S.F.	\$216.30	\$532.29	\$748.59
290892		195.56 S.F.	\$224.90	\$553.44	\$778.34
291720		16.06 S.F.	\$18.46	\$45.44	\$63.90
290699		85.46 S.F.	\$98.28	\$241.85	\$340.12
278653		90.00 S.F.	\$103.50	\$254.70	\$358.20
290714		751.63 S.F.	\$864.37	\$2,127.10	\$2,991.47
291138		171.92 S.F.	\$197.71	\$486.53	\$684.24
291137		79.88 S.F.	\$91.86	\$226.06	\$317.92
268334		98.71 S.F.	\$113.51	\$279.34	\$392.85
290852		20.42 S.F.	\$23.48	\$57.78	\$81.26
267074		150.06 S.F.	\$172.57	\$424.67	\$597.24
291064		751.63 S.F.	\$864.37	\$2,127.10	\$2,991.47
290950		85.46 S.F.	\$98.28	\$241.85	\$340.12
245548		20.42 S.F.	\$23.48	\$57.78	\$81.26

290765	14.58	S.F.	\$16.77	\$41.27	\$58.04
243099	85.46	S.F.	\$98.28	\$241.85	\$340.12
290874	85.46	S.F.	\$98.28	\$241.85	\$340.12
290981	209.09	S.F.	\$240.45	\$591.72	\$832.17
231493	188.09	S.F.	\$216.30	\$532.29	\$748.59
243071	14.58	S.F.	\$16.77	\$41.27	\$58.04
245432	195.56	S.F.	\$224.90	\$553.44	\$778.34
244081	751.63	S.F.	\$864.37	\$2,127.10	\$2,991.47
291039	14.58	S.F.	\$16.77	\$41.27	\$58.04
290763	85.46	S.F.	\$98.28	\$241.85	\$340.12
291037	85.46	S.F.	\$98.28	\$241.85	\$340.12
291027	20.42	S.F.	\$23.48	\$57.78	\$81.26
290928	20.42	S.F.	\$23.48	\$57.78	\$81.26
290753	20.42	S.F.	\$23.48	\$57.78	\$81.26
245622	85.46	S.F.	\$98.28	\$241.85	\$340.12
290940	14.58	S.F.	\$16.77	\$41.27	\$58.04
290689	14.58	S.F.	\$16.77	\$41.27	\$58.04
291103	20.42	S.F.	\$23.48	\$57.78	\$81.26
290951	758.92	S.F.	\$872.75	\$2,147.74	\$3,020.49
241554	85.46	S.F.	\$98.28	\$241.85	\$340.12
290687	85.46	S.F.	\$98.28	\$241.85	\$340.12
290938	85.46	S.F.	\$98.28	\$241.85	\$340.12
245576	85.46	S.F.	\$98.28	\$241.85	\$340.12
290677	20.42	S.F.	\$23.48	\$57.78	\$81.26
290631	188.09	S.F.	\$216.30	\$532.29	\$748.59
245594	14.58	S.F.	\$16.77	\$41.27	\$58.04
290959	29.53	S.F.	\$33.96	\$83.57	\$117.53
290965	66.90	S.F.	\$76.94	\$189.33	\$266.27
290969	29.53	S.F.	\$33.96	\$83.57	\$117.53
245566	29.53	S.F.	\$33.96	\$83.57	\$117.53
245564	36.46	S.F.	\$41.93	\$103.18	\$145.10
290968	36.46	S.F.	\$41.93	\$103.18	\$145.10
290964	76.52	S.F.	\$87.99	\$216.54	\$304.54
245554	66.90	S.F.	\$76.94	\$189.33	\$266.27
290962	83.16	S.F.	\$95.64	\$235.35	\$330.98
290958	36.46	S.F.	\$41.93	\$103.18	\$145.10
290955	66.90	S.F.	\$76.94	\$189.33	\$266.27
290954	76.52	S.F.	\$87.99	\$216.54	\$304.54
290953	81.62	S.F.	\$93.86	\$230.99	\$324.85
245596	83.16	S.F.	\$95.64	\$235.35	\$330.98
245597	81.62	S.F.	\$93.86	\$230.99	\$324.85
290952	83.16	S.F.	\$95.64	\$235.35	\$330.98

245599	76.52	S.F.	\$87.99	\$216.54	\$304.54
245600	66.90	S.F.	\$76.94	\$189.33	\$266.27
290963	81.62	S.F.	\$93.86	\$230.99	\$324.85
290932	66.90	S.F.	\$76.94	\$189.33	\$266.27
245511	29.53	S.F.	\$33.96	\$83.57	\$117.53
290990	36.46	S.F.	\$41.93	\$103.18	\$145.10
290987	66.90	S.F.	\$76.94	\$189.33	\$266.27
290986	76.52	S.F.	\$87.99	\$216.54	\$304.54
290985	81.62	S.F.	\$93.86	\$230.99	\$324.85
245550	83.16	S.F.	\$95.64	\$235.35	\$330.98
245551	81.62	S.F.	\$93.86	\$230.99	\$324.85
245483	29.53	S.F.	\$33.96	\$83.57	\$117.53
245498	76.52	S.F.	\$87.99	\$216.54	\$304.54
245553	76.52	S.F.	\$87.99	\$216.54	\$304.54
290991	29.53	S.F.	\$33.96	\$83.57	\$117.53
290948	29.53	S.F.	\$33.96	\$83.57	\$117.53
245494	81.62	S.F.	\$93.86	\$230.99	\$324.85
245493	83.16	S.F.	\$95.64	\$235.35	\$330.98
245509	36.46	S.F.	\$41.93	\$103.18	\$145.10
290995	83.16	S.F.	\$95.64	\$235.35	\$330.98
245481	36.46	S.F.	\$41.93	\$103.18	\$145.10
290984	83.16	S.F.	\$95.64	\$235.35	\$330.98
245499	66.90	S.F.	\$76.94	\$189.33	\$266.27
290898	66.90	S.F.	\$76.94	\$189.33	\$266.27
290920	66.90	S.F.	\$76.94	\$189.33	\$266.27
290919	76.52	S.F.	\$87.99	\$216.54	\$304.54
290918	81.62	S.F.	\$93.86	\$230.99	\$324.85
290917	83.16	S.F.	\$95.64	\$235.35	\$330.98
290913	29.53	S.F.	\$33.96	\$83.57	\$117.53
290912	36.46	S.F.	\$41.93	\$103.18	\$145.10
290909	66.90	S.F.	\$76.94	\$189.33	\$266.27
290908	76.52	S.F.	\$87.99	\$216.54	\$304.54
290907	81.62	S.F.	\$93.86	\$230.99	\$324.85
290906	83.16	S.F.	\$95.64	\$235.35	\$330.98
290936	29.53	S.F.	\$33.96	\$83.57	\$117.53
290901	36.46	S.F.	\$41.93	\$103.18	\$145.10
290923	36.46	S.F.	\$41.93	\$103.18	\$145.10
290897	76.52	S.F.	\$87.99	\$216.54	\$304.54
290896	81.62	S.F.	\$93.86	\$230.99	\$324.85
290895	83.16	S.F.	\$95.64	\$235.35	\$330.98
290743	81.62	S.F.	\$93.86	\$230.99	\$324.85
290888	81.62	S.F.	\$93.86	\$230.99	\$324.85

290886	26.13	S.F.	\$30.05	\$73.95	\$104.00
290885	9.70	S.F.	\$11.15	\$27.45	\$38.60
290882	29.53	S.F.	\$33.96	\$83.57	\$117.53
290881	36.46	S.F.	\$41.93	\$103.18	\$145.10
290878	66.90	S.F.	\$76.94	\$189.33	\$266.27
290902	29.53	S.F.	\$33.96	\$83.57	\$117.53
246305	76.52	S.F.	\$87.99	\$216.54	\$304.54
245612	29.53	S.F.	\$33.96	\$83.57	\$117.53
290947	36.46	S.F.	\$41.93	\$103.18	\$145.10
290944	66.90	S.F.	\$76.94	\$189.33	\$266.27
290943	76.52	S.F.	\$87.99	\$216.54	\$304.54
290942	81.62	S.F.	\$93.86	\$230.99	\$324.85
290941	83.16	S.F.	\$95.64	\$235.35	\$330.98
290996	81.62	S.F.	\$93.86	\$230.99	\$324.85
290935	36.46	S.F.	\$41.93	\$103.18	\$145.10
291001	36.46	S.F.	\$41.93	\$103.18	\$145.10
246300	83.16	S.F.	\$95.64	\$235.35	\$330.98
246616	29.53	S.F.	\$33.96	\$83.57	\$117.53
290931	76.52	S.F.	\$87.99	\$216.54	\$304.54
246614	36.46	S.F.	\$41.93	\$103.18	\$145.10
246306	66.90	S.F.	\$76.94	\$189.33	\$266.27
290930	81.62	S.F.	\$93.86	\$230.99	\$324.85
246316	36.46	S.F.	\$41.93	\$103.18	\$145.10
246318	29.53	S.F.	\$33.96	\$83.57	\$117.53
290929	83.16	S.F.	\$95.64	\$235.35	\$330.98
246599	83.16	S.F.	\$95.64	\$235.35	\$330.98
246600	81.62	S.F.	\$93.86	\$230.99	\$324.85
290924	29.53	S.F.	\$33.96	\$83.57	\$117.53
246603	76.52	S.F.	\$87.99	\$216.54	\$304.54
246604	66.90	S.F.	\$76.94	\$189.33	\$266.27
245610	36.46	S.F.	\$41.93	\$103.18	\$145.10
246301	81.62	S.F.	\$93.86	\$230.99	\$324.85
243077	66.90	S.F.	\$76.94	\$189.33	\$266.27
243156	84.90	S.F.	\$97.64	\$240.27	\$337.91
291098	36.46	S.F.	\$41.93	\$103.18	\$145.10
291095	66.90	S.F.	\$76.94	\$189.33	\$266.27
291094	76.52	S.F.	\$87.99	\$216.54	\$304.54
291093	81.62	S.F.	\$93.86	\$230.99	\$324.85
291092	83.16	S.F.	\$95.64	\$235.35	\$330.98
291088	29.53	S.F.	\$33.96	\$83.57	\$117.53
291087	36.46	S.F.	\$41.93	\$103.18	\$145.10
291084	66.90	S.F.	\$76.94	\$189.33	\$266.27

243073	83.16	S.F.	\$95.64	\$235.35	\$330.98
243074	81.62	S.F.	\$93.86	\$230.99	\$324.85
291104	83.16	S.F.	\$95.64	\$235.35	\$330.98
243076	76.52	S.F.	\$87.99	\$216.54	\$304.54
291105	81.62	S.F.	\$93.86	\$230.99	\$324.85
291082	81.62	S.F.	\$93.86	\$230.99	\$324.85
243087	36.46	S.F.	\$41.93	\$103.18	\$145.10
243089	29.53	S.F.	\$33.96	\$83.57	\$117.53
291081	83.16	S.F.	\$95.64	\$235.35	\$330.98
291077	29.53	S.F.	\$33.96	\$83.57	\$117.53
291076	36.46	S.F.	\$41.93	\$103.18	\$145.10
291073	66.90	S.F.	\$76.94	\$189.33	\$266.27
291072	76.52	S.F.	\$87.99	\$216.54	\$304.54
291071	81.62	S.F.	\$93.86	\$230.99	\$324.85
291070	83.16	S.F.	\$95.64	\$235.35	\$330.98
245467	81.62	S.F.	\$93.86	\$230.99	\$324.85
291083	76.52	S.F.	\$87.99	\$216.54	\$304.54
291128	81.62	S.F.	\$93.86	\$230.99	\$324.85
239970	66.90	S.F.	\$76.94	\$189.33	\$266.27
239980	36.46	S.F.	\$41.93	\$103.18	\$145.10
239982	29.53	S.F.	\$33.96	\$83.57	\$117.53
240023	83.16	S.F.	\$95.64	\$235.35	\$330.98
240024	81.62	S.F.	\$93.86	\$230.99	\$324.85
291134	29.53	S.F.	\$33.96	\$83.57	\$117.53
291133	36.46	S.F.	\$41.93	\$103.18	\$145.10
240029	76.52	S.F.	\$87.99	\$216.54	\$304.54
240030	66.90	S.F.	\$76.94	\$189.33	\$266.27
291130	66.90	S.F.	\$76.94	\$189.33	\$266.27
240040	36.46	S.F.	\$41.93	\$103.18	\$145.10
291099	29.53	S.F.	\$33.96	\$83.57	\$117.53
291129	76.52	S.F.	\$87.99	\$216.54	\$304.54
243157	76.52	S.F.	\$87.99	\$216.54	\$304.54
291127	83.16	S.F.	\$95.64	\$235.35	\$330.98
240545	83.16	S.F.	\$95.64	\$235.35	\$330.98
240546	81.62	S.F.	\$93.86	\$230.99	\$324.85
291111	29.53	S.F.	\$33.96	\$83.57	\$117.53
240551	76.52	S.F.	\$87.99	\$216.54	\$304.54
240552	66.90	S.F.	\$76.94	\$189.33	\$266.27
291110	36.46	S.F.	\$41.93	\$103.18	\$145.10
240562	36.46	S.F.	\$41.93	\$103.18	\$145.10
240564	29.53	S.F.	\$33.96	\$83.57	\$117.53
291107	66.90	S.F.	\$76.94	\$189.33	\$266.27

291106	76.52	S.F.	\$87.99	\$216.54	\$304.54
240042	29.53	S.F.	\$33.96	\$83.57	\$117.53
291008	76.52	S.F.	\$87.99	\$216.54	\$304.54
243155	83.16	S.F.	\$95.64	\$235.35	\$330.98
243218	9.70	S.F.	\$11.15	\$27.45	\$38.60
243220	26.13	S.F.	\$30.05	\$73.95	\$104.00
243350	81.62	S.F.	\$93.86	\$230.99	\$324.85
291020	66.90	S.F.	\$76.94	\$189.33	\$266.27
291019	76.52	S.F.	\$87.99	\$216.54	\$304.54
291018	81.62	S.F.	\$93.86	\$230.99	\$324.85
291017	83.16	S.F.	\$95.64	\$235.35	\$330.98
291013	29.53	S.F.	\$33.96	\$83.57	\$117.53
291012	36.46	S.F.	\$41.93	\$103.18	\$145.10
245435	83.16	S.F.	\$95.64	\$235.35	\$330.98
291023	36.46	S.F.	\$41.93	\$103.18	\$145.10
291009	66.90	S.F.	\$76.94	\$189.33	\$266.27
291024	29.53	S.F.	\$33.96	\$83.57	\$117.53
245440	76.52	S.F.	\$87.99	\$216.54	\$304.54
245441	66.90	S.F.	\$76.94	\$189.33	\$266.27
291007	81.62	S.F.	\$93.86	\$230.99	\$324.85
245451	36.46	S.F.	\$41.93	\$103.18	\$145.10
245453	29.53	S.F.	\$33.96	\$83.57	\$117.53
291006	83.16	S.F.	\$95.64	\$235.35	\$330.98
291002	29.53	S.F.	\$33.96	\$83.57	\$117.53
245466	83.16	S.F.	\$95.64	\$235.35	\$330.98
290998	66.90	S.F.	\$76.94	\$189.33	\$266.27
290997	65.10	S.F.	\$74.86	\$184.23	\$259.10
245471	76.52	S.F.	\$87.99	\$216.54	\$304.54
245436	81.62	S.F.	\$93.86	\$230.99	\$324.85
239300	83.16	S.F.	\$95.64	\$235.35	\$330.98
243158	66.90	S.F.	\$76.94	\$189.33	\$266.27
243166	36.46	S.F.	\$41.93	\$103.18	\$145.10
233182	83.16	S.F.	\$95.64	\$235.35	\$330.98
233224	81.62	S.F.	\$93.86	\$230.99	\$324.85
291061	26.13	S.F.	\$30.05	\$73.95	\$104.00
235112	76.52	S.F.	\$87.99	\$216.54	\$304.54
235177	66.90	S.F.	\$76.94	\$189.33	\$266.27
291060	9.70	S.F.	\$11.15	\$27.45	\$38.60
236390	36.46	S.F.	\$41.93	\$103.18	\$145.10
237093	29.53	S.F.	\$33.96	\$83.57	\$117.53
291051	84.90	S.F.	\$97.64	\$240.27	\$337.91
243168	29.53	S.F.	\$33.96	\$83.57	\$117.53

291034	36.46	S.F.	\$41.93	\$103.18	\$145.10
245472	66.90	S.F.	\$76.94	\$189.33	\$266.27
239301	81.62	S.F.	\$93.86	\$230.99	\$324.85
291031	66.90	S.F.	\$76.94	\$189.33	\$266.27
291030	76.52	S.F.	\$87.99	\$216.54	\$304.54
239306	65.10	S.F.	\$74.86	\$184.23	\$259.10
239307	66.90	S.F.	\$76.94	\$189.33	\$266.27
291029	81.62	S.F.	\$93.86	\$230.99	\$324.85
239317	36.46	S.F.	\$41.93	\$103.18	\$145.10
239319	29.53	S.F.	\$33.96	\$83.57	\$117.53
291028	83.16	S.F.	\$95.64	\$235.35	\$330.98
239963	83.16	S.F.	\$95.64	\$235.35	\$330.98
239964	81.62	S.F.	\$93.86	\$230.99	\$324.85
291035	29.53	S.F.	\$33.96	\$83.57	\$117.53
290761	29.53	S.F.	\$33.96	\$83.57	\$117.53
290727	29.53	S.F.	\$33.96	\$83.57	\$117.53
290780	66.90	S.F.	\$76.94	\$189.33	\$266.27
290748	36.46	S.F.	\$41.93	\$103.18	\$145.10
290779	76.52	S.F.	\$87.99	\$216.54	\$304.54
290731	83.16	S.F.	\$95.64	\$235.35	\$330.98
290778	81.62	S.F.	\$93.86	\$230.99	\$324.85
290777	83.16	S.F.	\$95.64	\$235.35	\$330.98
290773	29.53	S.F.	\$33.96	\$83.57	\$117.53
290772	36.46	S.F.	\$41.93	\$103.18	\$145.10
290769	66.90	S.F.	\$76.94	\$189.33	\$266.27
290768	76.52	S.F.	\$87.99	\$216.54	\$304.54
290767	81.62	S.F.	\$93.86	\$230.99	\$324.85
290766	83.16	S.F.	\$95.64	\$235.35	\$330.98
290691	81.62	S.F.	\$93.86	\$230.99	\$324.85
290693	66.90	S.F.	\$76.94	\$189.33	\$266.27
290744	76.52	S.F.	\$87.99	\$216.54	\$304.54
290640	36.46	S.F.	\$41.93	\$103.18	\$145.10
290637	66.90	S.F.	\$76.94	\$189.33	\$266.27
290636	76.52	S.F.	\$87.99	\$216.54	\$304.54
290635	81.62	S.F.	\$93.86	\$230.99	\$324.85
290697	29.53	S.F.	\$33.96	\$83.57	\$117.53
290692	76.52	S.F.	\$87.99	\$216.54	\$304.54
290732	81.62	S.F.	\$93.86	\$230.99	\$324.85
290755	81.62	S.F.	\$93.86	\$230.99	\$324.85
290756	76.52	S.F.	\$87.99	\$216.54	\$304.54
290757	66.90	S.F.	\$76.94	\$189.33	\$266.27
290696	36.46	S.F.	\$41.93	\$103.18	\$145.10

290760	36.46	S.F.	\$41.93	\$103.18	\$145.10
290787	83.16	S.F.	\$95.64	\$235.35	\$330.98
290634	83.16	S.F.	\$95.64	\$235.35	\$330.98
290812	66.90	S.F.	\$76.94	\$189.33	\$266.27
290783	36.46	S.F.	\$41.93	\$103.18	\$145.10
290820	83.16	S.F.	\$95.64	\$235.35	\$330.98
239969	76.52	S.F.	\$87.99	\$216.54	\$304.54
290721	81.62	S.F.	\$93.86	\$230.99	\$324.85
290720	83.16	S.F.	\$95.64	\$235.35	\$330.98
290711	26.13	S.F.	\$30.05	\$73.95	\$104.00
290815	36.46	S.F.	\$41.93	\$103.18	\$145.10
290710	9.70	S.F.	\$11.15	\$27.45	\$38.60
290811	76.52	S.F.	\$87.99	\$216.54	\$304.54
290810	81.62	S.F.	\$93.86	\$230.99	\$324.85
290809	83.16	S.F.	\$95.64	\$235.35	\$330.98
290713	81.62	S.F.	\$93.86	\$230.99	\$324.85
290745	66.90	S.F.	\$76.94	\$189.33	\$266.27
290877	76.52	S.F.	\$87.99	\$216.54	\$304.54
290816	29.53	S.F.	\$33.96	\$83.57	\$117.53
290680	76.52	S.F.	\$87.99	\$216.54	\$304.54
290733	76.52	S.F.	\$87.99	\$216.54	\$304.54
290788	81.62	S.F.	\$93.86	\$230.99	\$324.85
290789	76.52	S.F.	\$87.99	\$216.54	\$304.54
290790	66.90	S.F.	\$76.94	\$189.33	\$266.27
290793	36.46	S.F.	\$41.93	\$103.18	\$145.10
290722	76.52	S.F.	\$87.99	\$216.54	\$304.54
290794	29.53	S.F.	\$33.96	\$83.57	\$117.53
290784	29.53	S.F.	\$33.96	\$83.57	\$117.53
290701	84.90	S.F.	\$97.64	\$240.27	\$337.91
290702	76.52	S.F.	\$87.99	\$216.54	\$304.54
290703	66.90	S.F.	\$76.94	\$189.33	\$266.27
290706	36.46	S.F.	\$41.93	\$103.18	\$145.10
290707	29.53	S.F.	\$33.96	\$83.57	\$117.53
290723	66.90	S.F.	\$76.94	\$189.33	\$266.27
290700	83.16	S.F.	\$95.64	\$235.35	\$330.98
290855	76.52	S.F.	\$87.99	\$216.54	\$304.54
290832	81.62	S.F.	\$93.86	\$230.99	\$324.85
290833	76.52	S.F.	\$87.99	\$216.54	\$304.54
290834	66.90	S.F.	\$76.94	\$189.33	\$266.27
290837	36.46	S.F.	\$41.93	\$103.18	\$145.10
290838	29.53	S.F.	\$33.96	\$83.57	\$117.53
290738	29.53	S.F.	\$33.96	\$83.57	\$117.53

290842	83.16	S.F.	\$95.64	\$235.35	\$330.98
290843	81.62	S.F.	\$93.86	\$230.99	\$324.85
290844	76.52	S.F.	\$87.99	\$216.54	\$304.54
290678	83.16	S.F.	\$95.64	\$235.35	\$330.98
290845	66.90	S.F.	\$76.94	\$189.33	\$266.27
290848	36.46	S.F.	\$41.93	\$103.18	\$145.10
290849	29.53	S.F.	\$33.96	\$83.57	\$117.53
290641	29.53	S.F.	\$33.96	\$83.57	\$117.53
290865	83.16	S.F.	\$95.64	\$235.35	\$330.98
290876	84.90	S.F.	\$97.64	\$240.27	\$337.91
290875	83.16	S.F.	\$95.64	\$235.35	\$330.98
290872	29.53	S.F.	\$33.96	\$83.57	\$117.53
290871	36.46	S.F.	\$41.93	\$103.18	\$145.10
290868	66.90	S.F.	\$76.94	\$189.33	\$266.27
290853	83.16	S.F.	\$95.64	\$235.35	\$330.98
290866	81.62	S.F.	\$93.86	\$230.99	\$324.85
290854	81.62	S.F.	\$93.86	\$230.99	\$324.85
290742	83.16	S.F.	\$95.64	\$235.35	\$330.98
290679	81.62	S.F.	\$93.86	\$230.99	\$324.85
290860	29.53	S.F.	\$33.96	\$83.57	\$117.53
290859	36.46	S.F.	\$41.93	\$103.18	\$145.10
290856	66.90	S.F.	\$76.94	\$189.33	\$266.27
290827	29.53	S.F.	\$33.96	\$83.57	\$117.53
290867	76.52	S.F.	\$87.99	\$216.54	\$304.54
290690	83.16	S.F.	\$95.64	\$235.35	\$330.98
290831	83.16	S.F.	\$95.64	\$235.35	\$330.98
290734	66.90	S.F.	\$76.94	\$189.33	\$266.27
290658	76.52	S.F.	\$87.99	\$216.54	\$304.54
290685	29.53	S.F.	\$33.96	\$83.57	\$117.53
290657	81.62	S.F.	\$93.86	\$230.99	\$324.85
290662	36.46	S.F.	\$41.93	\$103.18	\$145.10
290749	29.53	S.F.	\$33.96	\$83.57	\$117.53
290663	29.53	S.F.	\$33.96	\$83.57	\$117.53
290652	29.53	S.F.	\$33.96	\$83.57	\$117.53
290651	36.46	S.F.	\$41.93	\$103.18	\$145.10
290648	66.90	S.F.	\$76.94	\$189.33	\$266.27
290647	65.10	S.F.	\$74.86	\$184.23	\$259.10
290646	81.62	S.F.	\$93.86	\$230.99	\$324.85
290645	83.16	S.F.	\$95.64	\$235.35	\$330.98
290656	83.16	S.F.	\$95.64	\$235.35	\$330.98
290674	29.53	S.F.	\$33.96	\$83.57	\$117.53
290726	36.46	S.F.	\$41.93	\$103.18	\$145.10

290826	36.46	S.F.	\$41.93	\$103.18	\$145.10
290823	66.90	S.F.	\$76.94	\$189.33	\$266.27
290681	66.90	S.F.	\$76.94	\$189.33	\$266.27
290822	65.10	S.F.	\$74.86	\$184.23	\$259.10
290659	66.90	S.F.	\$76.94	\$189.33	\$266.27
290737	36.46	S.F.	\$41.93	\$103.18	\$145.10
290754	83.16	S.F.	\$95.64	\$235.35	\$330.98
290673	36.46	S.F.	\$41.93	\$103.18	\$145.10
290670	66.90	S.F.	\$76.94	\$189.33	\$266.27
290669	76.52	S.F.	\$87.99	\$216.54	\$304.54
290668	81.62	S.F.	\$93.86	\$230.99	\$324.85
290667	83.16	S.F.	\$95.64	\$235.35	\$330.98
290684	36.46	S.F.	\$41.93	\$103.18	\$145.10
290821	81.62	S.F.	\$93.86	\$230.99	\$324.85
Summary for: Line 1250 (379 detail records)	29,832.21	S.F.	\$34,307.04	\$84,425.15	\$118,732.18
1600			\$2.18		
RMeans			\$5.55		
2008			\$7.73		
291846	38.67	S.F.	\$84.29	\$214.60	\$298.89
290741	199.15	S.F.	\$434.16	\$1,105.30	\$1,539.46
291147	127.19	S.F.	\$277.28	\$705.93	\$983.21
240022	195.74	S.F.	\$426.70	\$1,086.33	\$1,513.04
290719	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290730	176.18	S.F.	\$384.08	\$977.83	\$1,361.91
243067	188.13	S.F.	\$410.11	\$1,044.09	\$1,454.21
290752	159.96	S.F.	\$348.72	\$887.78	\$1,236.50
291091	199.15	S.F.	\$434.16	\$1,105.30	\$1,539.46
290688	184.57	S.F.	\$402.36	\$1,024.37	\$1,426.73
291102	159.96	S.F.	\$348.72	\$887.78	\$1,236.50
290807	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290718	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290819	132.30	S.F.	\$288.41	\$734.26	\$1,022.67
290927	159.96	S.F.	\$348.72	\$887.78	\$1,236.50
290916	199.15	S.F.	\$434.16	\$1,105.30	\$1,539.46
291080	176.18	S.F.	\$384.08	\$977.83	\$1,361.91
246970	176.18	S.F.	\$384.08	\$977.83	\$1,361.91
290797	176.18	S.F.	\$384.08	\$977.83	\$1,361.91
291005	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290808	174.54	S.F.	\$380.51	\$968.72	\$1,349.23

290841	188.63	S.F.	\$411.21	\$1,046.88	\$1,458.08
291881	129.80	S.F.	\$282.95	\$720.36	\$1,003.32
290905	175.96	S.F.	\$383.59	\$976.57	\$1,360.16
245492	199.15	S.F.	\$434.16	\$1,105.30	\$1,539.46
290994	132.30	S.F.	\$288.41	\$734.26	\$1,022.67
245520	162.60	S.F.	\$354.48	\$902.45	\$1,256.93
290983	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290982	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290972	175.96	S.F.	\$383.59	\$976.57	\$1,360.16
245593	159.96	S.F.	\$348.72	\$887.78	\$1,236.50
290939	159.96	S.F.	\$348.72	\$887.78	\$1,236.50
245465	176.18	S.F.	\$384.08	\$977.83	\$1,361.91
290633	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290666	188.63	S.F.	\$411.21	\$1,046.88	\$1,458.08
291069	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
231936	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
231998	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
291068	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290655	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
291038	67.08	S.F.	\$146.24	\$372.31	\$518.55
290830	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
239299	132.30	S.F.	\$288.41	\$734.26	\$1,022.67
290894	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290632	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
239962	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290764	159.96	S.F.	\$348.72	\$887.78	\$1,236.50
291016	188.63	S.F.	\$411.21	\$1,046.88	\$1,458.08
245433	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
245434	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290893	174.54	S.F.	\$380.51	\$968.72	\$1,349.23
290863	184.57	S.F.	\$402.36	\$1,024.37	\$1,426.73
290644	132.30	S.F.	\$288.41	\$734.26	\$1,022.67
Summary for: Line 1600	8,853.53	S.F.	\$19,300.69	\$49,137.07	\$68,437.76
(53 detail records)					

Summary for 124 Drywall Partitions / Wood Stud Framing (432 detail records)

	38,685.73	S.F.	\$53,607.73	\$133,562.22	\$187,169.95
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20 Interior Doors

Revit Family: Overhead-Rolling

Material: \$28,335.00 \$70,310.00

Installation: \$41,975.00 (167 records)

Class: 102 Title: Special Doors



	5000		\$1,050.00		
	RMeans		\$775.00		
	2008		\$1,825.00		

Object ID	Comments:	Quantity	Material	Installation	Total Price
270136		1.00 Ea.	\$1,050.00	\$775.00	\$1,825.00
274522		1.00 Ea.	\$1,050.00	\$775.00	\$1,825.00
Summary for: Line 5000		2.00 Ea.	\$2,100.00	\$1,550.00	\$3,650.00

(2 detail records)

Summary for 102 Special Doors (2 detail records)					
		2.00 Ea.	\$2,100.00	\$1,550.00	\$3,650.00

	120		Wood Door/Wood Frame		
	1600		\$159.00		
	RMeans		\$245.00		
	2008		\$404.00		

Object ID	Comments:	Quantity	Material	Installation	Total Price
290712		1.00 Ea.	\$159.00	\$245.00	\$404.00
290716		1.00 Ea.	\$159.00	\$245.00	\$404.00
290724		1.00 Ea.	\$159.00	\$245.00	\$404.00
290735		1.00 Ea.	\$159.00	\$245.00	\$404.00
290746		1.00 Ea.	\$159.00	\$245.00	\$404.00
290758		1.00 Ea.	\$159.00	\$245.00	\$404.00
290770		1.00 Ea.	\$159.00	\$245.00	\$404.00
290781		1.00 Ea.	\$159.00	\$245.00	\$404.00
290791		1.00 Ea.	\$159.00	\$245.00	\$404.00
290813		1.00 Ea.	\$159.00	\$245.00	\$404.00
290824		1.00 Ea.	\$159.00	\$245.00	\$404.00
290835		1.00 Ea.	\$159.00	\$245.00	\$404.00
290846		1.00 Ea.	\$159.00	\$245.00	\$404.00
290857		1.00 Ea.	\$159.00	\$245.00	\$404.00
290869		1.00 Ea.	\$159.00	\$245.00	\$404.00
235306		1.00 Ea.	\$159.00	\$245.00	\$404.00
239309		1.00 Ea.	\$159.00	\$245.00	\$404.00
239972		1.00 Ea.	\$159.00	\$245.00	\$404.00
240032		1.00 Ea.	\$159.00	\$245.00	\$404.00
240554		1.00 Ea.	\$159.00	\$245.00	\$404.00
243079		1.00 Ea.	\$159.00	\$245.00	\$404.00
243160		1.00 Ea.	\$159.00	\$245.00	\$404.00
243221		1.00 Ea.	\$159.00	\$245.00	\$404.00
245035		1.00 Ea.	\$159.00	\$245.00	\$404.00
245443		1.00 Ea.	\$159.00	\$245.00	\$404.00

245474	1.00	Ea.	\$159.00	\$245.00	\$404.00
245501	1.00	Ea.	\$159.00	\$245.00	\$404.00
245556	1.00	Ea.	\$159.00	\$245.00	\$404.00
245602	1.00	Ea.	\$159.00	\$245.00	\$404.00
246308	1.00	Ea.	\$159.00	\$245.00	\$404.00
246606	1.00	Ea.	\$159.00	\$245.00	\$404.00
290638	1.00	Ea.	\$159.00	\$245.00	\$404.00
290649	1.00	Ea.	\$159.00	\$245.00	\$404.00
290660	1.00	Ea.	\$159.00	\$245.00	\$404.00
290671	1.00	Ea.	\$159.00	\$245.00	\$404.00
290682	1.00	Ea.	\$159.00	\$245.00	\$404.00
290694	1.00	Ea.	\$159.00	\$245.00	\$404.00
290704	1.00	Ea.	\$159.00	\$245.00	\$404.00
290879	1.00	Ea.	\$159.00	\$245.00	\$404.00
290887	1.00	Ea.	\$159.00	\$245.00	\$404.00
290891	1.00	Ea.	\$159.00	\$245.00	\$404.00
290899	1.00	Ea.	\$159.00	\$245.00	\$404.00
290910	1.00	Ea.	\$159.00	\$245.00	\$404.00
290921	1.00	Ea.	\$159.00	\$245.00	\$404.00
290933	1.00	Ea.	\$159.00	\$245.00	\$404.00
290945	1.00	Ea.	\$159.00	\$245.00	\$404.00
290956	1.00	Ea.	\$159.00	\$245.00	\$404.00
290966	1.00	Ea.	\$159.00	\$245.00	\$404.00
290988	1.00	Ea.	\$159.00	\$245.00	\$404.00
290999	1.00	Ea.	\$159.00	\$245.00	\$404.00
291010	1.00	Ea.	\$159.00	\$245.00	\$404.00
291021	1.00	Ea.	\$159.00	\$245.00	\$404.00
291032	1.00	Ea.	\$159.00	\$245.00	\$404.00
291062	1.00	Ea.	\$159.00	\$245.00	\$404.00
291066	1.00	Ea.	\$159.00	\$245.00	\$404.00
291074	1.00	Ea.	\$159.00	\$245.00	\$404.00
291085	1.00	Ea.	\$159.00	\$245.00	\$404.00
291096	1.00	Ea.	\$159.00	\$245.00	\$404.00
291108	1.00	Ea.	\$159.00	\$245.00	\$404.00
291131	1.00	Ea.	\$159.00	\$245.00	\$404.00
291141	1.00	Ea.	\$159.00	\$245.00	\$404.00
290709	1.00	Ea.	\$159.00	\$245.00	\$404.00
290725	1.00	Ea.	\$159.00	\$245.00	\$404.00
290729	1.00	Ea.	\$159.00	\$245.00	\$404.00
290736	1.00	Ea.	\$159.00	\$245.00	\$404.00
290740	1.00	Ea.	\$159.00	\$245.00	\$404.00
290747	1.00	Ea.	\$159.00	\$245.00	\$404.00

290751	1.00	Ea.	\$159.00	\$245.00	\$404.00
290759	1.00	Ea.	\$159.00	\$245.00	\$404.00
290762	1.00	Ea.	\$159.00	\$245.00	\$404.00
290771	1.00	Ea.	\$159.00	\$245.00	\$404.00
290774	1.00	Ea.	\$159.00	\$245.00	\$404.00
290782	1.00	Ea.	\$159.00	\$245.00	\$404.00
290786	1.00	Ea.	\$159.00	\$245.00	\$404.00
290792	1.00	Ea.	\$159.00	\$245.00	\$404.00
290796	1.00	Ea.	\$159.00	\$245.00	\$404.00
290814	1.00	Ea.	\$159.00	\$245.00	\$404.00
290818	1.00	Ea.	\$159.00	\$245.00	\$404.00
290825	1.00	Ea.	\$159.00	\$245.00	\$404.00
290829	1.00	Ea.	\$159.00	\$245.00	\$404.00
290836	1.00	Ea.	\$159.00	\$245.00	\$404.00
290840	1.00	Ea.	\$159.00	\$245.00	\$404.00
290847	1.00	Ea.	\$159.00	\$245.00	\$404.00
290851	1.00	Ea.	\$159.00	\$245.00	\$404.00
290858	1.00	Ea.	\$159.00	\$245.00	\$404.00
290861	1.00	Ea.	\$159.00	\$245.00	\$404.00
235345	1.00	Ea.	\$159.00	\$245.00	\$404.00
237545	1.00	Ea.	\$159.00	\$245.00	\$404.00
239311	1.00	Ea.	\$159.00	\$245.00	\$404.00
239322	1.00	Ea.	\$159.00	\$245.00	\$404.00
239974	1.00	Ea.	\$159.00	\$245.00	\$404.00
239985	1.00	Ea.	\$159.00	\$245.00	\$404.00
240034	1.00	Ea.	\$159.00	\$245.00	\$404.00
240045	1.00	Ea.	\$159.00	\$245.00	\$404.00
240556	1.00	Ea.	\$159.00	\$245.00	\$404.00
240567	1.00	Ea.	\$159.00	\$245.00	\$404.00
243081	1.00	Ea.	\$159.00	\$245.00	\$404.00
243090	1.00	Ea.	\$159.00	\$245.00	\$404.00
243162	1.00	Ea.	\$159.00	\$245.00	\$404.00
243171	1.00	Ea.	\$159.00	\$245.00	\$404.00
245445	1.00	Ea.	\$159.00	\$245.00	\$404.00
245456	1.00	Ea.	\$159.00	\$245.00	\$404.00
245476	1.00	Ea.	\$159.00	\$245.00	\$404.00
245486	1.00	Ea.	\$159.00	\$245.00	\$404.00
245503	1.00	Ea.	\$159.00	\$245.00	\$404.00
245514	1.00	Ea.	\$159.00	\$245.00	\$404.00
245558	1.00	Ea.	\$159.00	\$245.00	\$404.00
245567	1.00	Ea.	\$159.00	\$245.00	\$404.00
245604	1.00	Ea.	\$159.00	\$245.00	\$404.00

245613	1.00	Ea.	\$159.00	\$245.00	\$404.00
246310	1.00	Ea.	\$159.00	\$245.00	\$404.00
246321	1.00	Ea.	\$159.00	\$245.00	\$404.00
246608	1.00	Ea.	\$159.00	\$245.00	\$404.00
246619	1.00	Ea.	\$159.00	\$245.00	\$404.00
290639	1.00	Ea.	\$159.00	\$245.00	\$404.00
290643	1.00	Ea.	\$159.00	\$245.00	\$404.00
290650	1.00	Ea.	\$159.00	\$245.00	\$404.00
290654	1.00	Ea.	\$159.00	\$245.00	\$404.00
290661	1.00	Ea.	\$159.00	\$245.00	\$404.00
290665	1.00	Ea.	\$159.00	\$245.00	\$404.00
290672	1.00	Ea.	\$159.00	\$245.00	\$404.00
290676	1.00	Ea.	\$159.00	\$245.00	\$404.00
290683	1.00	Ea.	\$159.00	\$245.00	\$404.00
290686	1.00	Ea.	\$159.00	\$245.00	\$404.00
290695	1.00	Ea.	\$159.00	\$245.00	\$404.00
290698	1.00	Ea.	\$159.00	\$245.00	\$404.00
290705	1.00	Ea.	\$159.00	\$245.00	\$404.00
290870	1.00	Ea.	\$159.00	\$245.00	\$404.00
290873	1.00	Ea.	\$159.00	\$245.00	\$404.00
290880	1.00	Ea.	\$159.00	\$245.00	\$404.00
290884	1.00	Ea.	\$159.00	\$245.00	\$404.00
290900	1.00	Ea.	\$159.00	\$245.00	\$404.00
290904	1.00	Ea.	\$159.00	\$245.00	\$404.00
290911	1.00	Ea.	\$159.00	\$245.00	\$404.00
290915	1.00	Ea.	\$159.00	\$245.00	\$404.00
290922	1.00	Ea.	\$159.00	\$245.00	\$404.00
290926	1.00	Ea.	\$159.00	\$245.00	\$404.00
290934	1.00	Ea.	\$159.00	\$245.00	\$404.00
290937	1.00	Ea.	\$159.00	\$245.00	\$404.00
290946	1.00	Ea.	\$159.00	\$245.00	\$404.00
290949	1.00	Ea.	\$159.00	\$245.00	\$404.00
290957	1.00	Ea.	\$159.00	\$245.00	\$404.00
290961	1.00	Ea.	\$159.00	\$245.00	\$404.00
290967	1.00	Ea.	\$159.00	\$245.00	\$404.00
290971	1.00	Ea.	\$159.00	\$245.00	\$404.00
290989	1.00	Ea.	\$159.00	\$245.00	\$404.00
290993	1.00	Ea.	\$159.00	\$245.00	\$404.00
291000	1.00	Ea.	\$159.00	\$245.00	\$404.00
291004	1.00	Ea.	\$159.00	\$245.00	\$404.00
291011	1.00	Ea.	\$159.00	\$245.00	\$404.00
291015	1.00	Ea.	\$159.00	\$245.00	\$404.00

291022	1.00	Ea.	\$159.00	\$245.00	\$404.00
291026	1.00	Ea.	\$159.00	\$245.00	\$404.00
291033	1.00	Ea.	\$159.00	\$245.00	\$404.00
291036	1.00	Ea.	\$159.00	\$245.00	\$404.00
291075	1.00	Ea.	\$159.00	\$245.00	\$404.00
291079	1.00	Ea.	\$159.00	\$245.00	\$404.00
291086	1.00	Ea.	\$159.00	\$245.00	\$404.00
291090	1.00	Ea.	\$159.00	\$245.00	\$404.00
291097	1.00	Ea.	\$159.00	\$245.00	\$404.00
291101	1.00	Ea.	\$159.00	\$245.00	\$404.00
291109	1.00	Ea.	\$159.00	\$245.00	\$404.00
291112	1.00	Ea.	\$159.00	\$245.00	\$404.00
291132	1.00	Ea.	\$159.00	\$245.00	\$404.00
291136	1.00	Ea.	\$159.00	\$245.00	\$404.00
Summary for: Line 1600	165.00	Ea.	\$26,235.00	\$40,425.00	\$66,660.00
(165 detail records)					
Summary for 120 Wood Door/Wood Frame (165 detail records)					
	165.00	Ea.	\$26,235.00	\$40,425.00	\$66,660.00
Grand Total			\$640,028.96	\$673,579.62	\$1,313,608.59

TWBS Cost Estimate - Level IV

	Material	Installation	Total
	\$639,657.84	\$673,579.63	\$1,313,237.47
04 00 00. Masonry	\$105,544.21	\$193,468.93	\$299,013.13
04 01 00. Maintenance of Masonry	\$690.96	\$14,682.91	\$15,373.87
04 01 20. Maintenance of Unit Masonry			
Source: RSMMeans Price Year: 2008	\$690.96	\$14,682.91	\$15,373.87
04 01 20.52 Unit Masonry Cleaning	Material	Installation	Total
Wash smooth brick	\$690.96	\$14,682.91	\$15,373.87
04 05 00. Common Work Results for Masonry	\$2,072.88	\$7,773.31	\$9,846.19
04 05 19. Masonry Anchorage and Reinforcing			
Source: RSMMeans Price Year: 2008	\$345.48	\$2,418.36	\$2,763.84
04 05 19.16 Masonry Anchors	Material	Installation	Total
Wall ties, corrugated, 7/8" x 7", 22 guage	\$345.48	\$2,418.36	\$2,763.84
04 05 23. Masonry Accessories			
Source: RSMMeans Price Year: 2008	\$1,727.40	\$5,354.94	\$7,082.34
04 05 23.16 Masonry Embedded Flashing	Material	Installation	Total
Flashing, copper, paperbacked	\$1,727.40	\$5,354.94	\$7,082.34
04 21 00. Clay Unit Masonry	\$102,780.37	\$171,012.71	\$273,793.08
04 21 13. Brick Masonry			
Source: RSMMeans Price Year: 2008	\$102,780.37	\$171,012.71	\$273,793.08
04 21 13.13 Brick Veneer Masonry	Material	Installation	Total
Standard brick wall, 4" thick, running bond	\$102,780.37	\$171,012.71	\$273,793.08

05 00 00. Metals

\$16,064.83 \$15,028.39 \$31,093.22

05 12 00. Structural Steel Framing

\$16,064.83 \$15,028.39 \$31,093.22

05 12 23. Structural Steel for Buildings

Source: RSMeans Price Year: 2008 \$16,064.83 \$15,028.39 \$31,093.22

05 12 23.00 Material Installation Total

Shelf angle \$16,064.83 \$15,028.39 \$31,093.22

06 00 00. Wood, Plastics, and Composites			\$227,472.64	\$182,800.80	\$410,273.44
Composites					
06 10 00. ROUGH CARPENTRY			\$445.90	\$1,179.92	\$1,625.82
06 10 53. Miscellaneous Rough Carpentry					
Source: RSMMeans Price Year: 2008			\$445.90	\$1,179.92	\$1,625.82
06 10 53.00			Material	Installation	Total
Framing rough opening, header w/jacks			\$445.90	\$1,179.92	\$1,625.82
06 11 00. Wood Framing			\$159,805.82	\$94,496.79	\$254,302.62
06 11 16. Mechanically Graded Lumber					
Source: RSMMeans Price Year: 2008			\$159,805.82	\$94,496.79	\$254,302.62
06 11 16.00			Material	Installation	Total
Beams and girders, structural grade, 8x12"			\$74,966.46	\$7,422.42	\$82,388.88
Framing joists fir 4x12"			\$44,534.53	\$12,989.24	\$57,523.77
Framing joists, 2x6"			\$18,927.18	\$23,751.75	\$42,678.93
Framing, 2 x 4 wood studs @ 16 O.C., 10'high			\$12,231.21	\$28,340.60	\$40,571.80
Partitions, 2" x 4" stud 8' high 16" O.C.			\$2,064.11	\$5,582.48	\$7,646.59
Wood stud partion, backup, 2" x 4" @ 16" O.C.			\$7,082.34	\$16,410.31	\$23,492.66
06 16 00. Sheathing			\$50,003.38	\$45,376.59	\$95,379.96
06 16 23. Subflooring					
Source: RSMMeans Price Year: 2008			\$37,483.23	\$29,689.69	\$67,172.92
06 16 23.00			Material	Installation	Total
Subfloor plywood CDX 3/4"			\$37,483.23	\$29,689.69	\$67,172.92
06 16 53. Moisture-Resistant Sheathing Board					
Source: RSMMeans Price Year: 2008			\$12,520.15	\$15,686.90	\$28,207.04
06 16 53.00			Material	Installation	Total
Sheathing plywood on wall CDX 1/2"			\$2,673.96	\$3,940.57	\$6,614.53
Sheating, plywood, CDX, 1/2"			\$9,846.19	\$11,746.33	\$21,592.51
06 20 00. FINISH CARPENTRY			\$5,817.03	\$6,614.53	\$12,431.57
06 20 13. Exterior Finish Carpentry					
Source: RSMMeans Price Year: 2008			\$5,817.03	\$6,614.53	\$12,431.57
06 20 13.00			Material	Installation	Total
Siding plywood texture 1-11 fir 5/8", natural			\$5,817.03	\$6,614.53	\$12,431.57
06 46 00. Wood Trim			\$1,665.51	\$2,132.97	\$3,798.48



06 46 13. Wood Door and Window Casings

Source:	RSMeans	Price Year:	2008	\$1,089.76	\$1,552.32	\$2,642.08
06 46 13.00				Material	Installation	Total
Casing, stock pine 11/16"x 2-1/2"				\$1,089.76	\$1,552.32	\$2,642.08

06 46 33. "Wood Stops, Stools, and Sills"

Source:	RSMeans	Price Year:	2008	\$575.75	\$580.65	\$1,156.40
06 46 33.00				Material	Installation	Total
Stool cap, pine 11/16"x 2-1/2"				\$575.75	\$580.65	\$1,156.40

06 48 00. Wood Frames

06 48 16. Interior Wood Door Frames

Source:	RSMeans	Price Year:	2008	\$9,735.00	\$33,000.00	\$42,735.00
06 48 16.00				Material	Installation	Total
Wood frame, Pine, drywall, 4-7/8" deep, 2'-8"x6'-8" single				\$9,735.00	\$33,000.00	\$42,735.00

07 00 00. Thermal and Moisture Protection Protection	\$14,842.49	\$16,761.92	\$31,604.42
07 11 00. Dampproofing	\$1,098.26	\$2,855.47	\$3,953.73
07 11 19. Sheet Dampproofing			
Source: RSMeans Price Year: 2008	\$1,098.26	\$2,855.47	\$3,953.73
07 11 19.00	Material	Installation	Total
Building paper, asphalt felt sheathing paper 15 lb	\$234.56	\$609.85	\$844.41
Building paper, asphalt felt, 15 lb.	\$863.70	\$2,245.62	\$3,109.32
07 21 00. Thermal Insulation	\$13,398.75	\$7,687.81	\$21,086.56
07 21 13. Board Insulation			
Source: RSMeans Price Year: 2008	\$13,398.75	\$7,687.81	\$21,086.56
07 21 13.16 Fibrous Board Insulation	Material	Installation	Total
Fiberglass insulation batts, paper or foil back, 3-1/2", R11	\$2,861.61	\$1,641.90	\$4,503.51
Fiberglass insulation, batts, 3-1/2" thick paper backing	\$10,537.15	\$6,045.90	\$16,583.05
07 91 00. Preformed Joint Seals	\$0.00	\$1,727.40	\$1,727.40
07 91 23. Backer Rods			
Source: RSMeans Price Year: 2008	\$0.00	\$1,727.40	\$1,727.40
07 91 23.00	Material	Installation	Total
Joint backer rod	\$0.00	\$1,727.40	\$1,727.40
07 92 00. Joint Sealants	\$345.48	\$4,491.24	\$4,836.72
07 92 13. Elastomeric Joint Sealants			
Source: RSMeans Price Year: 2008	\$345.48	\$4,491.24	\$4,836.72
07 92 13.00	Material	Installation	Total
Sealant	\$345.48	\$4,491.24	\$4,836.72

08 00 00. Openings

\$25,320.00 \$14,285.00 \$39,605.00

08 14 00. Wood Doors

\$16,500.00 \$7,425.00 \$23,925.00

08 14 16. Flush Wood Doors

Source: RSMeans Price Year: 2008 \$16,500.00 \$7,425.00 \$23,925.00

08 14 16.00

Material Installation Total

Wood door, flush, luan face, hollow core, 3-5/8" thick, 2'-8"x6'-8" \$16,500.00 \$7,425.00 \$23,925.00

08 52 00. Wood Windows

\$8,820.00 \$6,860.00 \$15,680.00

08 52 69. Wood Storm Windows

Source: RSMeans Price Year: 2008 \$8,820.00 \$6,860.00 \$15,680.00

08 52 69.00

Material Installation Total

Residential wood window, double hung, 2'-8"x4'-6" standard glazed \$8,820.00 \$6,860.00 \$15,680.00

09 00 00. Finishes			\$19,890.11	\$32,498.87	\$52,388.98
09 21 00. Plaster and Gypsum Board Assemblies			\$19,092.61	\$28,042.28	\$47,134.89
09 21 16. Gypsum Board Assemblies					
Source: RSMMeans	Price Year: 2008		\$19,092.61	\$28,042.28	\$47,134.89
09 21 16.33 Gypsum Board Area Separation Wall A					
			Material	Installation	Total
Gypsum plasterboard, nailed/screwed to studs, 5/8" regular			\$9,247.98	\$14,021.14	\$23,269.12
Gypsum plasterboard, nailed/screwed to studs, 5/8" F.R. Fire resistant			\$9,844.63	\$14,021.14	\$23,865.77
09 93 00. Staining and Transparent Finishing			\$797.50	\$4,456.60	\$5,254.10
09 93 13. Exterior Staining and Finishing					
Source: RSMMeans	Price Year: 2008		\$797.50	\$4,456.60	\$5,254.10
09 93 13.13 Exterior Staining					
			Material	Installation	Total
Exterior wood satin on other than shingles, 2 coats & sealer			\$797.50	\$4,456.60	\$5,254.10

99 00 00. Special Division			\$230,523.56	\$218,735.71	\$449,259.27
99 99 00. Listing all assemblies components that has not been assigned MF number. However the associated Prices are calculated in the total.			\$230,523.56	\$218,735.71	\$449,259.27
99 99 10. Pricing Adjustments to Match assemblies prices.					
Source: RSMMeans	Price Year: 2008		\$0.00	\$172.74	\$172.74
99 99 10.00		Material		Installation	Total
Price Adjustment to match ABS price			\$0.00	\$172.74	\$172.74
99 99 20. System componenets with no MF2004 number					
Source: RSMMeans	Price Year: 2008		\$158,854.08	\$92,617.34	\$251,471.42
99 99 20.00		Material		Installation	Total
Beam to girder saddles			\$110,965.21	\$23,009.51	\$133,974.71
column caps			\$31,916.41	\$2,968.97	\$34,885.38
Driling, bolt holes			\$0.00	\$11,133.63	\$11,133.63
Joist hangars 18 ga.			\$8,535.79	\$22,638.39	\$31,174.17
Machine bolts			\$4,453.45	\$4,824.57	\$9,278.03
Taping and finishing joints			\$2,983.22	\$28,042.28	\$31,025.50
99 99 30. Assemblies with no System Components (Listed as whole assembly)					
Source: RSMMeans	Price Year: 2008		\$71,669.48	\$125,945.63	\$197,615.11
99 99 30.00		Material		Installation	Total
Drywall Partitions / Wood Stud Framing			\$19,300.69	\$49,137.07	\$68,437.76
Plain & Reinforced			\$19,780.90	\$25,113.99	\$44,894.89
Speciel Doors			\$2,100.00	\$1,550.00	\$3,650.00
Strip Footing			\$5,964.20	\$8,045.46	\$14,009.66
Walls, Cast in Place			\$15,404.34	\$31,031.94	\$46,436.28
Wood/Flat or Pitched			\$9,119.35	\$11,067.17	\$20,186.51
Grand Total			\$639,657.84	\$673,579.63	\$1,313,237.47

Objects without Cost Data

(10 records)

(4 records)

FamilyName	Double-Flush	Id	269115	Length	0.00
AssemblyCode		Type Name	72" x 84"	Area	3.90
Description		Type Mark	67	Volume	0.00
Keynote		Type Comments		Count:	1
FamilyName	Sliding-2 panel	Id	238304	Length	0.00
AssemblyCode	B2020	Type Name	72" x 84"	Area	245.82
Description		Type Mark	58	Volume	0.00
Keynote		Type Comments		Count:	63
FamilyName	Single-Flush	Id	50865	Length	0.00
AssemblyCode	C1020	Type Name	36" x 84"	Area	122.91
Description		Type Mark	34	Volume	0.00
Keynote		Type Comments		Count:	63
FamilyName	Double-Glass 1	Id	50269	Length	0.00
AssemblyCode		Type Name	72" x 84"	Area	7.80
Description		Type Mark	29	Volume	0.00
Keynote		Type Comments		Count:	2

(1 record)

FamilyName	Floor	Id	987	Length	150.19
AssemblyCode		Type Name	Generic - 12" - Filled	Area	299.95
Description		Type Mark		Volume	91.43
Keynote		Type Comments		Count:	1

(1 record)

FamilyName	Railing	Id	35471	Length	194.37
AssemblyCode		Type Name	Handrail - Pipe	Area	0.00
Description		Type Mark		Volume	0.00
Keynote		Type Comments		Count:	42

				(1 record)	
FamilyName	Basic Roof	Id	1389	Length	0.00
AssemblyCode		Type Name	Generic - 12"	Area	4.18
Description		Type Mark		Volume	1.06
Keynote		Type Comments		Count:	2

				(3 records)	
FamilyName	Basic Wall	Id	272967	Length	13.00
AssemblyCode		Type Name	36" Footing	Area	3.78
Description		Type Mark		Volume	3.45
Keynote		Type Comments		Count:	8

FamilyName	Basic Wall	Id	26553	Length	93.93
AssemblyCode		Type Name	Foundation - 10" Concrete	Area	594.61
Description		Type Mark		Volume	151.03
Keynote		Type Comments		Count:	29

FamilyName	Curtain Wall	Id	391	Length	8.55
AssemblyCode		Type Name	Curtain Wall	Area	78.80
Description		Type Mark		Volume	
Keynote		Type Comments		Count:	5

VE: Cost Variations

EWBS Level 4 ID: A1010.110

Title: Strip Footing

Number of prices in class: 4

Number of Items: 64

	Minimum	Specified	Maximum
Material	\$4,814.85	\$5,964.20	\$9,511.66
Installation	\$7,331.00	\$8,045.46	\$12,288.74
Total	\$12,145.85	\$14,009.66	\$21,800.40

EWBS Level 4 ID: A1030.120

Title: Plain & Reinforced

Number of prices in class: 2

Number of Items: 15

	Minimum	Specified	Maximum
Material	\$18,326.43	\$19,780.90	\$19,780.90
Installation	\$21,914.14	\$25,113.99	\$25,113.99
Total	\$40,240.56	\$44,894.90	\$44,894.90

EWBS Level 4 ID: A2020.110

Title: Walls, Cast in Place

Number of prices in class: 2

Number of Items: 65

	Minimum	Specified	Maximum
Material	\$8,751.45	\$15,404.34	\$15,404.34
Installation	\$29,022.68	\$31,031.94	\$31,031.94
Total	\$37,774.13	\$46,436.28	\$46,436.28

EWBS Level 4 ID: B1010.264

Title: Wood Beam & Joist

Number of prices in class: 2

Number of Items: 54

	Minimum	Specified	Maximum
Material	\$332,153.37	\$332,153.37	\$424,933.65
Installation	\$138,428.17	\$138,428.17	\$151,788.52
Total	\$470,581.54	\$470,581.54	\$576,722.17

EWBS Level 4 ID: B1020.102 Title: Wood/Flat or Pitched
Number of prices in class: 3 Number of Items: 1

	Minimum	Specified	Maximum
Material	\$6,640.30	\$9,119.35	\$10,004.72
Installation	\$9,562.03	\$11,067.17	\$12,926.45
Total	\$16,202.33	\$20,186.51	\$22,931.17

EWBS Level 4 ID: B2010.129 Title: Brick Veneer / Wood Stud Backup
Number of prices in class: 4 Number of Items: 82

	Minimum	Specified	Maximum
Material	\$150,283.90	\$150,283.90	\$209,015.54
Installation	\$251,336.86	\$251,336.86	\$345,480.22
Total	\$401,620.76	\$401,620.76	\$554,495.76

EWBS Level 4 ID: B2010.148 Title: Panel, Shingle & Lap Siding
Number of prices in class: 2 Number of Items: 30

	Minimum	Specified	Maximum
Material	\$14,448.76	\$14,448.76	\$21,297.85
Installation	\$22,095.35	\$22,845.93	\$22,845.93
Total	\$36,544.11	\$37,294.70	\$44,143.78

EWBS Level 4 ID: B2020.102 Title: Wood Windows
Number of prices in class: 2 Number of Items: 49

	Minimum	Specified	Maximum
Material	\$10,931.41	\$10,931.41	\$19,110.00
Installation	\$10,172.89	\$10,172.89	\$11,172.00
Total	\$21,104.30	\$21,104.30	\$30,282.00

EWBS Level 4 ID: C1010.124 Title: Drywall Partitions / Wood Stud Framing
Number of prices in class: 4 Number of Items: 432

	Minimum	Specified	Maximum
Material	\$44,488.59	\$53,607.73	\$86,656.04
Installation	\$109,480.63	\$133,562.22	\$214,705.82
Total	\$153,969.22	\$187,169.95	\$301,361.86

EWBS Level 4 ID: C1020.102

Title: Special Doors

Number of prices in class: 1

Number of Items: 2

	Minimum	Specified	Maximum
Material	\$2,100.00	\$2,100.00	\$2,100.00
Installation	\$1,550.00	\$1,550.00	\$1,550.00
Total	\$3,650.00	\$3,650.00	\$3,650.00

EWBS Level 4 ID: C1020.120

Title: Wood Door/Wood Frame

Number of prices in class: 4

Number of Items: 165

	Minimum	Specified	Maximum
Material	\$20,790.00	\$26,235.00	\$34,155.00
Installation	\$34,485.00	\$40,425.00	\$41,580.00
Total	\$55,275.00	\$66,660.00	\$75,735.00

Material	\$613,729.07	\$640,028.96	\$851,969.69
Installation	\$635,378.74	\$673,579.62	\$870,483.62
Total	\$1,249,107.80	\$1,313,608.59	\$1,722,453.32